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Population density, ecological data and carbon budget

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Svensk Naturförvaltning AB

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Abstract

The Swedish Nuclear Fuel and Waste Management Co (Svensk Kärnbränslehantering AB, SKB) is in the process of selecting a safe and environmentally acceptable location for the deep-level repository of radioactive waste. SKB has expressed the importance of monitoring mammal species that are of interest both in biodiversity issues and for local hunting and recreational purposes. Two of the major goals are to: 1) monitor dynamics of population density over several years; 2) obtain information that is essential for modelling of energy/carbon flows in the biosphere and ultimately calculations of the risks of exposure to radionuclides. This report contributes to the major goals by presenting:

- Results from surveys of mammal abundance in the study sites near Forsmark and Oskarshamn, and a comparison with data from other surveys.
- A summary of traits associated to demography, resource selection and spatial distribution.
- A model framework that can be used to model the future development of populations.
- A plausible future scenario for mammal species.
- Mammal contribution to fluxes of energy and material in the ecosystem.
- Estimated harvest rates of mammals in the study sites.

General conclusions that can be drawn from the survey are that population densities of the most common species are in the same range as many other populations. Lynx, wild boar, red deer and fallow deer are expanding in the areas. Marine mammals have not been surveyed but at least grey seals are important top consumers in the coastal ecosystem. Red listed species resident in the areas are Lynx, Otter, Whiskered bat, Natterer's bat, Nathusius' pipistrelle and Harbour seal. Annual production of the mammal species that were surveyed was 40–50 mg carbon/m^2 and year. Hunters harvest nearly half of the production each year. Future developments for the populations are briefly discussed and a model framework that can be used to make better quantitative predictions is presented.

Sammanfattning

Svensk Kärnbränslehantering AB, SKB, utreder olika områdens lämplighet för ett slutförvar av radioaktivt avfall. SKB har uttryckligen pekat på betydelsen av att undersöka däggdjurspopulationerna i dessa områden. Undersökningarna syftar till att beskriva naturvärden, inkluderat hur och i vilken omfattning de utnyttjas av människan. Ett underlag för beslut skapas bäst genom att beskriva populationernas numerära utveckling. Två viktiga mål är att: 1) i ett övervakningssystem kunna beskriva variationer i tätheten över tid; 2) erhålla information som är viktig för att modellera energi/kolflöden i biosfären samt skapa underlag för riskkalkyler av exponering av radionuklider vid eventuella läckage. Denna rapport bidrar till att uppfylla målen genom att presentera:

- Resultat från täthetsskattningar utförda i undersökningsområdena runt Forsmark och Oskarshamn, samt en jämförelse med tätheter från andra områden.
- En sammanfattande beskrivning av egenskaper kopplade till demografi, resursval och rumslig fördelning.
- Modeller som kan användas till att beskriva populationers framtida utveckling.
- En tänkbar utveckling av däggdjurspopulationerna i områdena.
- Däggdjurens bidrag till flöde av energi och materia i ekosystemet.
- En skattning av hur stor andel av däggdjurens produktion som utnyttjas av människan.

Resultaten från inventeringarna visar att tätheten av de vanligaste arterna ligger på samma nivå som i andra områden. Lodjur, vildsvin, kronvilt och dovvilt är arter som ökar i områdena. Marina däggdjur har inte inventerats, men särskilt gråsäl är en viktig toppkonsument i de kustnära ekosystemen. Av de rödlistade arterna finns lodjur, utter, mustaschfladdermus, fransfladdermus, trollfladdermus och knubbsäl i områdena. Den årliga produktionen hos de arter som täthetsskattats var 40–50 mg kol/m^2 och år. Varav nästan halva produktionen skördas av jägare. Populationernas kvalitativa utveckling diskuteras och modeller som kan ge kvantitativa förutsägelser presenteras.

Contents

1 Introduction

The Swedish Nuclear Fuel and Waste management Co (SKB) is currently conducting site investigations in Forsmark and Oskarshamn in order to test the suitability of the areas for deep repository of nuclear waste. In each area two sub-areas have been selected for surveys of mammal populations. One area is selected as reference area. The main areas will be referred to as Forsmark and Oskarshamn in the text. The sub-areas will be referred to as Forsmark and Hållnäs (reference area) in the Forsmark area and Simpevarp and Blankaholm (reference area) in the Oskarshamn area. This report is a complement to the surveys of mammal populations made by Svensk Naturförvaltning (SN) in the areas between the years 2001 and 2004 /Cederlund et al. 2003, 2004/.

The requirements from SKB were that the report should fit the following description:

- A general description of the mammals in the areas.
- A reference work for estimating parameters in models.
- A basis for Environmental Impact Assessment.

The requirements are fulfilled by presenting:

- A summary of traits associated to demography, resource selection and spatial distribution.
- Estimates of abundance of mammal species.
- A model framework that can be used to model the future development of populations.
- A plausible future scenario for mammal species.
- Mammal contribution to fluxes of energy and material in the ecosystem.

The methods that were used to estimate abundance are described in Appendix 8. They are also described together with the results from the surveys in 2002 and 2003 in two earlier reports /Cederlund et al. 2003, 2004/. The general traits of the mammals that were found in the areas as well as their status, history and future have also been briefly described /Lång et al. 2004/.

Data concerning some of the traits that are necessary for predicting the development of mammal populations in the areas, and analyzing the flow of energy and materials through mammals are more elaborately described in this report. A model framework that can be used to describe future scenarios of abundance and distribution of mammal populations is presented. The mammal contribution to the flux of energy and material in the ecosystem is analyzed with a conceptual model that quantifies the mammal carbon pool and carbon flow.

Estimating the abundance and distribution of mammals is a hard task, and predicting their future development is even more difficult. It is therefore wise to carefully consider why the survey is performed, and if possible identify if there are some mammals that are more important than others. In an earlier report the following groups and species were suggested as candidates to a more solid investigation /Cederlund et al. 2004/.

1. Large herbivores (moose, deer species and hares).
2. Small rodents and insectivores.
3. Large predators (fox and badgers, eventually including lynx and wolf).

We will focus on these species in this report, because of their importance, but also because density estimates are available from the surveys. However, wolf will be excluded since there are no observations from the areas, and wild boar will be added since populations are growing rapidly.

2 Study areas

2.1 Forsmark

The northern part of the Uppland County is strongly influenced by the Baltic Sea. The landscape is flat (< 100 m above sea level) and contains few lakes and streams. It is also characterised by a mosaic of habitats with different tree- and understory composition. Near the coast the vegetation is influenced by lime and considered to be more productive than the inland.

The climatic variation is larger than in other areas at the same latitude in the inland of Sweden. This means for example periods of stormy weather and deep snow in winter that might effect mobility as well as survival of mammals. The Baltic Sea keeps the temperature relatively high in the fall, and delays the onset of winter compared to the inland. The ground is covered with snow for, on average, 100–125 days each winter. Precipitation in the region is > 500 mm annually.

Most land is forested and can be classified as belonging to the hemi boreal zone. Near the coast temperate, broad-leaved tree species may occur. More patchily distributed is rowan and alder. In poor soils conifers are dominating (inland areas). Agricultural areas constitute less than 10% of the total land area.

There are no obvious differences between Forsmark and Hållnäs as concerns habitat structure and composition.

Figure 2-1. A map indicating the border of the selected study areas in Forsmark: Forsmark in the south and Hållnäs (reference area) in the north.

2.2 Oskarshamn

The landscape is flat with interspersed ridges (usually < 50 m above sea level) and numerous small lakes and streams. Open water constitutes approximately 10% in the two main study areas Simpevarp and Blankaholm. It is also characterised by a mosaic of habitats with different tree- and understory composition. The coast is considered to be more productive than the inland.

The climatic variation is larger than in other areas at the same latitude in the inland of Sweden. This means for example periods of stormy weather and short periods of deep snow in winter that might temporary effect mobility as well as survival of mammals. The Baltic Sea keeps the temperature relatively high in the fall, and delays the onset of winter compared to the inland. The ground might be covered with snow for short periods, in total less than 50 days each winter.

Most land is forested and can be classified as belonging to the hemi boreal zone. Near the coast temperate, broad-leaved tree species such as elm and oak may be frequent. More patchily distributed is rowan and alder. In poor soils conifers are dominating (inland areas). Agricultural areas constitute less than 10% of the total land area and forested areas approximately 80%

There are no obvious differences between Simpevarp and Blankaholm as concerns habitat structure and composition.

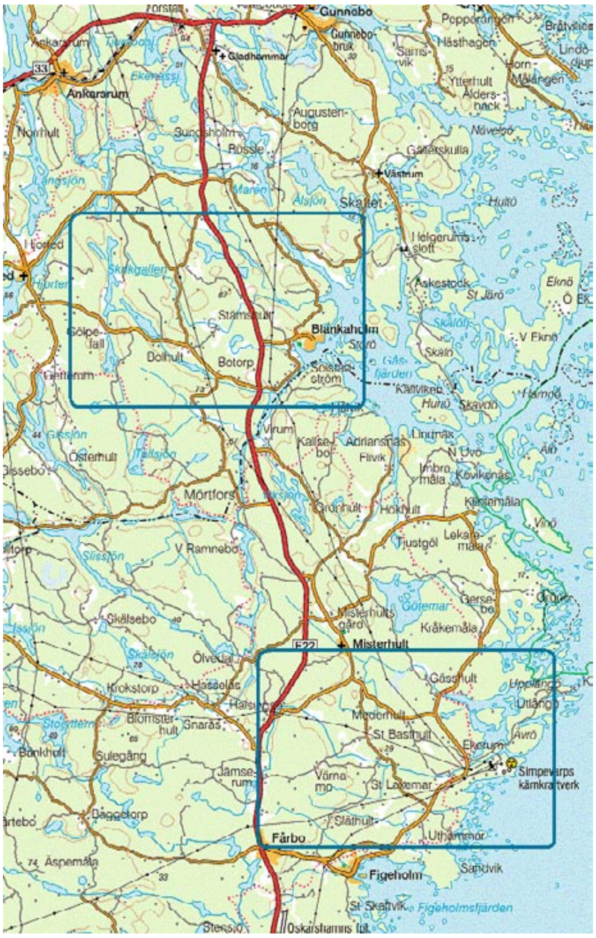

Figure 2-2. *A map indicating the border of the selected study areas in Oskarshamn: Simpevarp in the south and Blankaholm (reference area) in the north.*

3 Mammals in the study areas

3.1 Terrestrial mammals

Both study areas provide habitats for a major part of the mammal species found in the Swedish fauna, except for those, which only are found in the alpine region.

A complete list of the mammal species which have been found in the surveys are presented in Appendix 1. We also included species that most likely are resident in the areas although not found in the surveys. The species treated in this report are those which we have site specific density estimates on (Table 3-1).

Densities of fox and badger have not been estimated but they are included in this report since they were considered as important predators in these areas.

Some mammal species have not been surveyed by SN but are known to be present in the areas or are assumed to colonize habitats in the areas in the near future. Bats have been surveyed separately by other contractors and will be discussed in this report.

General traits of respective species have been collected from publications in order to present range and average values. Although there is a vast literature on mammals, many publications are difficult to access and many descriptive studies are of poor quality. Besides, some species are scarcely described because they are rare or difficult to study.

Table 3-1. Species from the study areas with estimated population density.

Lynx (Lo)	*Lynx lynx*
Red fox (Rödräv)	*Vulpes vulpes*
Badger (Grävling)	*Meles meles*
Wild boar (Vildsvin)	*Sus scrofa*
Red deer (Kronhjort)	*Cervus elaphus*
Fallow deer (Dovhjort)	*Dama dama*
Roe deer (Rådjur)	*Capreolus capreolus*
Moose (Älg)	*Alces alces*
European hare (Fälthare)	*Lepus europaeus*
Mountain hare (Skogshare)	*Lepus timidus*
Bank vole (Skogssork/Ängssork)	*Cletrionomus glareolus*
Field vole (Åkersork)	*Microtus agrestis*
Water vole (Vattensork)	*Arvicola terrestris*
Yellow necked mouse (Större skogsmus)	*Apodemus flavicollis*
Wood mouse (Mindre skogsmus)	*Apodemus sylvaticus*
Common shrew (Vanlig näbbmus)	*Sorex araneus*

An alternative method to describe general traits and their variation between species is to use scaling laws. Scaling laws are used in biology to show that size related variation can be described by allometric equations, which are power functions of the form $Y = Y_o M^b$ /Brown et al. 2004/. The dependent variable Y is related to body mass (M) through a normalization constant Y_0 and an allometric exponent b. Scaling laws have been used to describe how physiological traits e.g. metabolic rates are related to body mass. As well as how ecological properties e.g. home range area is related to body mass.

The results from the population survey, data from literature, and estimates from allometric models are summarized in this report. A complete list of the data used for the summaries and the cited papers are presented in appendices.

3.2 Marine mammals

Both study sites are coastal areas but no survey of the marine mammals has been undertaken. There are four species of marine mammals in the Baltic Sea (Table 3-2).

With exception of the grey seal the species are red listed. The Ringed seal and the Porpoise are rarely observed in the Baltic. Populations of Harbour seal are located in the south Baltic with about 400 individuals in Kalmarsund, not far from Oskarshamn.

Grey seal populations have increased in the Baltic with an average growth rate of 8.7% per year between 1990 and 2002 /Karlsson and Helander, 2003a/. The number of counted seals in 2002 was 13,300 in the whole Baltic and 5,500 along the Swedish coast. However, the observability is probably around 60–70% /Naturvårdsverket, 2002/ so the population size is most likely underestimated. The annual harvest in Sweden was limited to 170 animals in 2004, and 82 were reported shot. In addition, many seals drown when they are caught in fishing nets. In year 2000 approximately 500 animals died this way along the Swedish east coast /Naturvårdsverket, 2002/. The annual count is based on observations on traditional haul-out sites in May–June when seals moult. Grey seals use areas within a 50 km radius around the haul-out site for more than 75% of the time, and in these areas they select depths between 11 and 40 metres /Sjöberg and Ball, 2000/. Haul-out sites in the vicinity of Forsmark are Märket and Gräsö skärgård where 350 and 256 grey seals were counted respectively in 2002 /Karlsson and Helander, 2003b/. In the Oskarshamn area Örö sankor is the closest haul-out site where 18 grey seals were counted in 2002 /Karlsson and Helander, 2003b/. Population size and growth rate is lower in the south Baltic than in the north. The populations will probably continue to increase and although there is a national management plan for Grey seal /Naturvårdsverket, 2002/, no quantitative goals with respect to population size or density are set.

Table 3-2. Marine mammals in the Baltic Sea.

Grey seal (Gråsäl)	*Halichoerus grypus*
Ringed seal (Vikare)	*Phoca hispida*
Harbour seal (Knubbsäl)	*Phoca vitulina*
Porpoise (Tumlare)	*Phocoena phocoena*

Grey seals prey on fish and play an important role in the coastal top consumer trophic level. The species is also a nuisance to fishermen, as a competitor for the fish stock, and for its habit of plundering fishing gear. Since efforts are being taken to reduce by-catch of seals, population growth rate will eventually increase. The number of seals that will be subject to hunting will consequently increase and the attitude toward grey seal as a highly valued game-species will probably experience renaissance.

3.3 Red listed species

Red Lists are lists of threatened and rare species according to an international standard. The classification system for Sweden agrees with the international standards, the global classification system by the The World Conservation Union /IUCN, 2001/, with the application principles suggested for national level. Red List categories do not provide any form of priority for conservation actions. The purpose of these categories is to give a clear and objective view of the status for each individual species. It should also be pointed out that the system does not describe a linear degree of extinction risk. The red listed mammal species which have been found in the study sites are presented in Table 3-3.The species are grouped according to a system of six categories reflecting the risk of extinction in Sweden. For listing as Critically Endangered, Endangered or Vulnerable there is a range of quantitative criteria. The different criteria (A–E) are derived from a wide review aimed at detecting risk factors across the broad range of organisms and the diverse life histories they exhibit. The categories are briefly described below but for a description of the criteria we refer to the The World Conservation Union /IUCN, 2001/.

Table 3-3. Red listed species found in the study areas. The Location column shows the areas where species were either found during the survey or on previous occasions. F = Forsmark, H = Hållnäs, S = Simpevarp, B = Blankaholm.

Species		Red list status	Location
Lynx (Lo)	*Lynx lynx*	VU	F, H
Otter (Utter)	*Lutra lutra*	VU	F, H
Whiskered bat (Mustaschfladdermus)	*Myotis mystacinus*	VU	F, S
Natterer’s bat (Fransfladdermus)	*Myotis nattereri*	VU	F, S
Nathusius’ pipistrelle (Trollfladdermus)	*Pipistrellus nathusii*	NT	F, S
Harbour seal (Knubbsäl)	*Phoca vitulina*	EN (Baltic)	See text

Red list categories

RE – Regionally Extinct

A species is Regionally Extinct when there is no reasonable doubt that the last individual potentially capable of reproduction within the country (region) has died or disappeared from the country (region).

CR – Critically Endangered

A species is Critically Endangered when it is facing an extremely high risk of extinction in the wild in the immediate future, as defined by any of the criteria A to E for that category.

EN – Endangered

A species is Endangered when it is not Critically Endangered but yet facing a very high risk of extinction in the wild in the near future, as defined by any of the criteria A to E for that category.

VU – Vulnerable

A species is Vulnerable when it is not Critically Endangered or Endangered but yet facing a high risk of extinction in the wild in the medium-term future, as defined by any of the criteria A to D for that category.

NT – Near Threatened

A species is Near Threatened when it does not satisfy the criteria of any of the categories Critically Endangered, Endangered or Vulnerable, but is close to qualifying for Vulnerable.

DD – Data Deficient

A species is assigned to Data Deficient when there is inadequate information to make a direct, or indirect, assessment of its risk of extinction based on its distribution and/or population status. According to the guidelines adopted for this Red List no species should, however, be placed in this category unless there is some indication that it may be threatened or even regionally extinct.

Lynx

General description

With a body length of 0.7–1.2 m and weighing up to 30 kg the lynx is the largest European cat /Macdonald, 1996/. It is exterminated from much of Europe and scattered populations survive only in Scandinavia, the Baltic states, the Balkans, Russia, Spain and Portugal /Orr and Pope, 1983/. The different populations vary greatly in the spotting of the coat. In the south of Europe the lynxes are heavily spotted, whereas the spots on Scandinavian lynxes are very weak. It has been suggested that these forms should be treated as different species /Macdonald, 1996/. Roe deer is nowadays, after the roe deer expansion, the main prey of the lynx in Scandinavia but also hare, rodents, grouse and fox is found on the menu. The territories are very large, up to 1,000 km^2 in Scandinavia /Ahlén and Tjernberg, 1996/.

The lynx has been censused on 5 occasions since 1994, the latest in the spring 2000. The censuses were performed by searching for tracks on newly-fallen snow along a predetermined set of small roads. The results suggest that the national lynx population is growing both numerically and geographically out of its core areas. Dividing the census area from four years in a northern (highland boreal), middle (lowland boreal) and southern (lowland agricultural) area reveals that the lynx population in the northern area stopped growing and even decreased, whereas the population in the middle and southern areas is increasing /Liberg and Glöersen, 2000/. Migration from northern areas probably explains a part of this pattern.

The lynx is included in the Swedish Red List as Vulnerable and is noted as Resident in both counties /Gärdenfors, 2000/.

Local situation

In the county of Uppsala 50% of the area, more or less the northwestern parts, was surveyed in 2000. Tracks from 41 lynxes were found giving a density of 1.24 individuals per 100 km^2. Eight family groups were found in the whole county. The Östhammar hunting commune, containing the Forsmark site survey area, was not censused. However, in the two neighbouring hunting communes that were censused, tracks from a total of 6 lynxes were found. In Dannemora there were tracks from two adults and in Närdinghundra there was a family group with two adults and two cubs /Liberg and Glöersen, 2000/. The census did not encompass the county of Kalmar but there have been reports of lynx in the area of the Oskarshamn site survey. In the survey performed by SN snowtracks were found in Forsmark in 2002 and across water systems in 2002 and 2003. The density estimated from snowtracks in 2002 was 2 individuals per 100 km^2. In Hållnäs SN found tracks across water systems in 2003.

SN found no tracks of lynx in Simpevarp or in Blankaholm.

The future

The population is probably still spreading east and south from the present core areas. The numbers in Uppsala is a large increase compared to earlier surveys. An increase in the distribution and the size of the population is expected in all site survey areas.

Otter

General description

The European otter is distributed throughout most of Eurasia south of the tundra. It is one of the larger mustelids reaching 70 cm in body length excluding tail and weighing from 4 to 15 kg. Males are generally 30% heavier than females /Olsson and Sandegren, 1993; Macdonald, 1996/. The otter is adapted to life in water but cross over land when travelling between different waters. It feeds mainly on small fish, but also on crustaceans and amphibians /Ahlén and Tjernberg, 1996/.

The number of otters was steadily decreasing in Sweden from the 1950’s until the 1980’s when it was estimated that only 500–1,000 otters remained in Sweden. The probable main cause to this was the use of PCBs, a group of organic chemicals that has been shown to disturb the reproduction in e.g. mink /Sjöåsen et al. 1997/. Habitat destruction through water regulation, drainage of lakes and wetlands, and loss of suitable prey through acidification has also had a negative effect on the otter population /Ahlén and Tjernberg, 1996/. The otter was protected 1969, but no evident increase in population size have been shown to occur until recently.

The otter is included in the Swedish Red List as Vulnerable and noted as Resident in both counties of Uppsala and Kalmar /Gärdenfors, 2000/.

Local situation

In both Uppland, including most of the county of Uppsala, and Småland, including all of the county of Kalmar, inventories for otter traces have been carried out during the 1990's. Until 1995, the isolated otter population that were present in the eastern parts of Uppsala seemed to remain stable in geographical distribution /Hammar, 1996/. Only one coastal locality in the south of the Forsmark area showed traces of otter. However, at the end of the 1990's the otter has increased its geographical distribution and presumably also its numbers. Inventories in succeeding years have shown a continuous increase of the frequency and geographical distribution of otter traces. In 2001 Forsmarksån in the Forsmark area had certain presence of otter (Hammar, unpublished). SN found tracks along water systems in Forsmark in 2001, 2002 and 2003. Tracks were also found in forested areas in Forsmark in 2001. In Hållnäs tracks were found in 2003. Data sets are too small for density estimates.

In the inventory made in Småland 2000 there were no traces of otter within the boundaries of the Oskarshamn site survey area /Föreningen rädda uttern i Småland, 2001/. However, there are uncertain traces at the river mouth of the stream Virån in Figeholmsfjärden just south of the site survey area. There are also several localities about 20 km upstream in this river system that have certain occurrences of otter, but all of them are more than 10 km west from the site survey area.

In the overall comparison with earlier inventories, 1983 and 1991, there is a slight increase in the number of localities where markings are found and in the distribution area overall, but the frequency of otter markings on the localities has not increased significantly /Föreningen rädda uttern i Småland, 2001/. However, this can be a "dilution effect", since the number of localities that has been checked have decreased in the "known" otter areas and at the same time increased overall in order to get a better cover of the total examined area. No tracks were found in Simpevarp or Blankaholm in the surveys made by SN.

The future

For the next decade, we expect that the population size of otter will show a slight increase or be stable in Forsmark. And that the otter will spread into the Oskarshamn area as well.

Whiskered bat

General description

Mainly found in forests, both coniferous and deciduous. Prefer to hunt close to rich environments like nutrient-rich lakes and hardwood forests. Feed on butterflies, beetles and mosquitoes. Females meet in breeding colonies in June in houses or hollow trees where they normally produce one young each. They overwinter in caves, mines, and stone houses. The species is distributed up north to Hälsingland at the east coast but populations are probably declining due to habitat changes /de Jong, 2001/.

The Whiskered bat is included in the Swedish Red List as Vulnerable, noted as Resident in the county of Uppsala and as Uncertain in the county of Kalmar /Gärdenfors, 2000/.

Local situation

There are no previous records in any of the site survey areas, but little monitoring work has been done (Ahlén I, pers. comm.). Whiskered bat and Brandt's bat can not be separated when using ultrasound detector, but at least one of the species was detected on five locations in Simpevarp /Ignell, 2004/. In Forsmark bats were trapped with nets in addition to ultrasound detection. Whiskered bat and Brandt's bat were detected by ultrasound in nine sites and trapping was performed in three of them. One Whiskered bat was trapped in one of the sites (Johannisfors) while several Brandt's bats were trapped in all three /de Jong and Gylje, 2004/.

The future

Not possible to evaluate.

Natterer's bat

General description

Natterer's bat is present in many parts of southern Sweden in scattered populations. It is found in habitats rich in deciduous trees close to streams and recently also found in wet forests with spruce and birch. Breeding colonies is found in hollows of trees and buildings, nesting-boxes, cellars, bridge-arches and in attics. The species mainly feed on day-active flies, mosquitoes and night-flying insects. Distributed north up to Uppland on the east coast. The Swedish population size is unknown but supposed to be 1,000–10,000 individuals /Ahlén and Tjernberg, 1996/.

The Natterer's bat is included in the Swedish Red List as Vulnerable and noted as Resident both in the county of Uppsala and the county of Kalmar /Gärdenfors, 2000/.

Local situation

The species is previously observed in the Forsmark site survey area along Forsmarksån. There are no records for the other site survey areas, but little monitoring work has been done (Ahlén I, pers. comm.). In Simpevarp one individual was detected (Punktobjekt 4) /Ignell, 2004/ but there was no individual detected in Forsmark /de Jong and Gylje, 2004/.

The future

Not possible to evaluate.

Nathusius' pipistrelle

General description

The Nathusius' pipistrelle is reproducing yearly in at least two populations in the county of Skåne. Scattered distribution north up to Uppland on the east coast. The species roost in hollow trees, nesting-boxes, barns and houses. Foraging takes place in sparse forests, in glades and at edges of lakes. Migrating south in winter. The population size is unknown but supposed to be 100–1,000 individuals /Ahlén and Tjernberg, 1996/.

The Nathusius' bat is included in the Swedish Red List as Near Threatened and noted as Uncertain both in the county of Uppsala and the county of Kalmar /Gärdenfors, 2000/.

Local situation

It has been regularly breeding at two localities and observed in six more places in Uppland /Ahlén and Tjernberg, 1996/ but there are no previous records within any of the site survey areas (Ahlén I, pers. comm.). In Simpevarp one individual was detected (Båtstad) /Ignell, 2004/. In Forsmark individuals were found on three sites, in one of them > 10 individuals were detected /de Jong and Gylje, 2004/.

The future

Not possible to evaluate.

Harbour seal

General description

A male harbour seal weighs around 75 kg, the females around 65 kg. Body length is just over 1.5 m. It feeds in shallow waters on all kinds of fish /Ahlén and Tjernberg, 1996/. The Baltic sea populations are located in the south and the most northern one is found in Kalmarsund and consists of a total of 400 individuals after the epidemic virus-disease in 1988/89 /Ahlén and Tjernberg, 1996/.

The Harbour seal is included in the Swedish Red List as Endangered and noted as Regionally Extinct in the county of Kalmar /Gärdenfors, 2000/.

Local situation

Probably only passing through on longer foraging bouts. No known populations resident close to the area (Lunneryd S G, pers. comm.).

The future

Not likely to establish a population in any of the areas within the next decade.

4 Ecological and morphological data

4.1 Body mass

Body mass is used in this report to quantify carbon content in mammals and as a parameter in allometric equations. Body mass of mammals is reported in almost all encyclopedias of mammals but often as minimum and maximum values. Since body mass is a central parameter in many ecological and physiological models it is often measured in field studies of animals. However, average population value of body mass is not so often reported in publications. Values of body mass that has been used in this report are presented in Appendix 1. If average values of body mass have been reported, in any of the used publications for this survey, they were used. Other values have been collected from mammal encyclopedias or from previous reports. Since weights often are presented as maximum and minimum values we calculated the median value, and when there was a sexual dimorphism, we calculated the mean of the medians of the two sexes. The only animal which we have site-specific weight data from is moose.

4.2 Habitat and resource preferences

The spatial distribution of a population is determined by the availability of resources, interaction with other animals and plants, and also management actions.

Population density varies in space and individuals are seldom evenly distributed. Such variation can be caused by uneven distribution of resources necessary to fulfill animal metabolic demands, but also because of variation in birth, mortality and migration rates caused by other factors. Selection of a component is when an animal actually chooses a specific component. Usage is selective if components are used disproportionally to their availability. Preference is the likelihood of a resource being chosen if offered on an equal basis with others. Preference can be determined by comparing the proportional use of a resource to its proportional availability. A resource is said to be preferred if usage exceeds availability, and avoided if usage is lower than the availability. Depending on the scale of selection, resources are estimated on appropriate spatial levels and can span from specific prey items to habitat type on the landscape level. Resources are not necessarily biotic and can comprise physical features e.g. distance to water, aspect and slope. If the preferred resources of a species are plotted on a map it will give a crude estimate of the spatial distribution of the population. Critical assumptions are that all resources are equally available, and that the resources that are chosen for the study are the most relevant.

Several methods have been used to quantify the relationships between the distribution of species and their abiotic and biotic environment and they usually share three basic components /Rushton et al. 2004/:

1. A data set describing the incidence or abundance of species and a data set of putative explanatory variables.
2. A mathematical model that relates the species data to the explanatory variables.
3. An assessment of the utility of the model developed in terms of a validation exercise or an assessment of model robustness.

A resource selection function (RSF) is defined as any function that is proportional to the probability of resource use by an organism. The procedure for estimating a RSF for a specific species includes measuring the use and availability of resources. This can be done by dividing the proportional use with the proportional availability of each habitat (resource) and get a selection ratio:

$$w_i = \frac{o_i}{\pi_i} \qquad o_i = \frac{u_i}{a_i} \qquad \pi_i = \frac{a_i}{a_+} \tag{4-1}$$

Where u_i represent the used resource units in category i and a_i represents the total available resource units in category i. a_+ is the total population of resource units /Boyce and McDonald, 1999/. The selection ratio can be standardized so the values for all habitats sum to 1. RSF can be used to predict the location of individuals in a landscape since they assign probabilities of use to different habitats /Boyce et al. 2002/.

4.3 Home range

The home range concept is frequently used when quantifying the utilized area of an animal. A home range is usually defined as the area an individual normally traverse during its activities of food gathering, mating and caring for young /Burt, 1943/. Home ranges are usually quantified by sampling locations of individuals e.g. by telemetry and using statistical estimators to delimit the area where an animal can be found with some level of probability. However, home range boundaries and areas are imprecise not only because of difficulties in estimating them but to animals themselves. Home range estimators should therefore be chosen to be appropriate to the data and the hypotheses being tested /Powell, 2000/. One obstacle is that home range estimates from the same set of data can vary considerably between different estimators and between different programs using the same estimator /Lawson and Rodgers, 1997/. Therefore, variation in home range can be caused by factors associated to the methods used as well as variation in behavior, population density and resource distribution. For instance, fox home ranges varies considerably between rural and urban areas /Coman et al. 1991/, and for many species there is large seasonal variation in home range area /Mysterud et al. 2001/. Many species select different habitats during different seasons. Such a redistribution can occur within a small area but there are also examples of mammals migrating longer distances. For example in roe deer 19–31% of the females migrate /Wahlstrom and Liberg, 1995/.

An alternative approach to estimate home range area is by calculating it from body size with the formula

$$H = aW^k \tag{4-2}$$

where H is the area and W is the body mass /McNab, 1963/ (parameters in Table 4-1). The factor k may be altered depending on trophic level.

If a species is territorial, with nonoverlapping home ranges, it is tempting to estimate population density by dividing the total area of suitable habitat with average territory size. Unfortunately, both home range size and degree of overlap show considerable variation among populations within a species /McLoughlin et al. 2000/. Besides, the habitat of animals is often a matrix of different habitat types. For territorial mammals without overlapping home ranges a theoretical distribution can be applied to an area of suitable habitat. Mammals with overlapping home ranges can be treated in a similar way, applying different degrees of overlap.

Estimates of home range areas that are attributed to the mammals in the study are presented in Appendix 2 and summarized in Table 4-2. The studies have not used the same methods when sampling and analyzing data. Median values are presented, since median is not as drastically affected by extreme values, as is the mean.

Table 4-1. Parameters in allometric home range model 4-2 where H is the area in hectares and W is the body mass in kilograms.

Group	a	k	Reference
Herbivores	2.71	1.02	/Harestad and Bunnell, 1979/
Omnivores	3.4	0.92	/Harestad and Bunnell, 1979/
Carnivores (>v45° latitude)	339	1.08	/Lindstedt et al. 1986/

Table 4-2. Home range estimates for mammals. Allometric area is calculated from body weight. Range is the span between the smallest and largest area reported. Median is the median value of reported area sizes.

Species	Allometric data		Literature data (km^2)	
Large/medium sized mammals	**hectares**	**km^2**	**Range**	**Median**
Wolf	16,499.7	165.0		
Lynx	13,350.3	133.5	561–1,906	1,234
Red fox	2,347.5	23.5	0.6–7	3.07
Badger	33.4	0.3	3.9–13.6	7.9
Pine Marten	431.4	4.3	1.49–2.23	1.86
Wild boar	147.0	1.5	0.82–12.3	5.31
Red deer	510.5	5.1	0.31–11.8	3.07
Fallow deer	206.5	2.1	0.66–1.89	1.275
Roe deer	72.3	0.7	0.09–5.08	0.46
Moose	911.2	9.1	0.21–113	13.3
European hare	10.6	0.1	0.27–1.9	1.09
Mountain hare	8.3	0.1	0.1–0.13	0.55

Species	Allometric data (m^2)	Literature data (m^2)	
Small mammals		**Range**	**Median**
Bank vole	578		8,900
Field vole	758		8,900
Water vole	1,904		8,900
Yellow necked mouse	681	3,800–15,500	9,650
Wood mouse	476		5,000
Common shrew	423	360–1,058	779
Pygmy shrew	187		5,200
Eurasian water shrew	599		5,200

4.4 Diet selection

The food items an animal chose to eat depend on what is available. The food items animals select and the rate of consumption is relevant for several issues in this report; modeling population dynamics with resource-consumer models, describing the distribution of available resources, and quantifying carbon flow. Energy requirements can also be quantified using allometric models. Studies on the diet of animals use several sampling techniques, including direct observations on intake and analyses of feces and stomach content. The proportion of each food item is quantified using different methods including proportion of volume or weight, proportion of occurrence and weight or volume intake.

The mean proportion of each food item in the diet was calculated from studies on food selection. If several studies were available, the proportions were standardized by first calculating the mean proportion of each food item from different studies. Thereafter, the mean proportion of a specific food item was divided by the sum of mean proportions of all food items.

Lynx

Lynx mainly feed on hares and deer species /Pulliainen et al. 1995/ but also on rodents, grouse and fox /Lång et al. 2004/

Fox

Foxes mainly feed on rodents, hares and birds during summer but several other animals as well as plant material is found in the diet /Kauhala et al. 1998/ (Table 4-3).

A study from Poland reported a similar diet in winter with the exception that hares occurred less frequently while carrion from cervids was an important food item in winter /Jedrzejewski and Jedrzejewska, 1992/.

Table 4-3. Red fox summer diet in Finland presented as frequency of occurrence (FO).

Food item	FO (%)	
	min	max
Voles	13	63
Water voles	19	83
Muskrat	0	21
Mice	0	11
Shrews	0	14
Hares	35	91
Birds	18	96
Eggs	0	6
Fish	0	15
Carrion	0	9
Insects	5	60
Berries	0	7
Other plants	7	13

Marten

Food selection of Pine Martens have been studied in south Norway /Selas, 1992/. Birds were most frequent both in scats and stomachs, followed by berries and small mammals. Birds and mammals together made up more than 80% of the estimated food biomass (mammals alone 70% in summer, and 55% in winter). A review on diet selection on mustelids in Britain showed that the diet of Martens also can include several other food items /McDonald, 2002/ (Table 4-4).

Table 4-4. Diet of martens in Britain.

Food item	%
Small mammals	29
Medium mammals	4
Large mammals	11
Unindentified mammals	3
Birds	14
Eggs	1
Fish	< 1
Herpetofauna	4
Earthworms	1
Invertebrates	20
Fruit and vegetables	10
Other	4

Wild boar

Wild boar are opportunistic omnivores whose diet is largely determined by the relative availability of different food types /Schley and Roper, 2003/. Plants dominate and the general food categories are mast, roots, green plant matter and agricultural crops (Table 4-5).

Table 4-5. Percentage volume of food items in the diet of wild boar in Europe.

Species	Season	Animal food	Plant food	Indigestible
Wild boar	All year	7.8	91.3	1.0

Badger

Badgers are also opportunistic omnivores but their diet is generally more animal based than Wild boar diet /Roper, 1994/ (Table 4-6). Omnivore diet is however often habitat related and badgers living close to farmland have a higher proportion of vegetable material in their diet than forest living individuals /Goszczynski et al. 2000/ (Table 4-7).

Table 4-6. Diet of badgers in Europe %.

Species	Earthworms	Insects	Amphibs	Mammals/ birds	Fruit	Cereals	Other plants	Scavenged material
Badger	28.6	17.8	6.3	10.3	17.7	9.3	7.3	2.7

Table 4-7. Badger diet in relation to habitat in Poland %.

Habitat type	Earthworms	Vegetable material	Vertebrates	Insects
Forest	62	5	28	5
Forest-farmland	46	34	12	6
Farmland-pastures	34	34	18	13

Moose, roe deer, red deer and fallow deer

Diet of moose, roe deer and red deer are presented in Table 4-8 with data from a study on diet overlap in Fennoscandia /Mysterud, 2000/.

Table 4-8. Proportion of diets in moose, roe deer and red deer in Scandinavia. (Gra = graminoids, Her = Herbs, Shr = low shrubs, FLH = fems/lycopods/horsetails, Dec = deciduous browse, Con = coniferous trees, Lic = lichens, Mos = mosses, Oth = other).

Species	Season	Gra	Her	Shr	FLH	Dec	Con	Lic	Mos	Oth
moose	winter	0.8	0.1	6.5	0.0	49.7	36.6	0.5	0.0	5.9
moose	summer	5.0	25.8	12.9	1.6	42.6	4.4	0.0	0.0	7.7
roe deer	winter	6.2	1.3	25.8	0.8	37.1	10.4	12.4	0.0	6.0
roe deer	summer	5.9	65.3	6.6	2.7	12.1	0.1	0.0	0.0	7.2
red deer	winter	22.8	0.7	33.7	0.4	19.5	15.6	6.8	0.5	0.0
red deer	summer	62.0	18.3	18.1	0.0	1.0	0.5	0.0	0.0	0.0

Fallow deer mainly feed on graminoids, foliage of broadleaved deciduous trees and Scots pine and forbs /Borkowski and Obidzinski, 2003/. These four categories of food accounted for about 73% of the diet, which is similar to red deer diet.

Hares

Mountain hares mainly feed on grasses and forbs during summer but in winter they mainly browse on deciduous trees and occasionally on evergreen species /Rao et al. 2003a/. The European hare feeds to a large extent on agricultural crops and pasture vegetation all around the year, and do not browse to the same extent as mountain hares do /Lång et al. 2004/.

Voles

All voles are herbivorous generalists and they consume to a large extent green plants during the summer /Bjärvall and Ullström, 1985/. Seeds and fruits are also important food items, especially during the winter. Voles collect hoards of food in the summer which they consume during the winter.

Mice

Mice are omnivores and feed on insects and larvae but vegetable material is dominating the diet /Bjärvall and Ullström, 1985/. Similar to voles they also collect hoards of food when availability is high.

Shrews

Shrews mainly feed on small invertebrates like insects, spiders and earthworms but also on carrion /Bjärvall and Ullström, 1985/.

4.5 Intake rate (dry mass)

Intake rate, the amount of food that is consumed per time unit, is a function of food density (functional response). Few studies have reported the relationship between intake and body mass within species /Andersen and Saether, 1992/ (Table 4-9). In Table 4-9 body mass in the unit is raised to an exponent of 0.75 to make comparisons with animals of different size relevant /Andersen and Saether, 1992/. In section 7.4 intake rates are estimated from the metabolic rate from animals.

Table 4-9. Daily dry mass intake rate in relation to body mass. Body mass is raised to an exponent of 0.75 in the unit to.

Species	Season	Summer	Unit	Reference
Roe deer	winter	21–55	g/kg$^{0.75}$/day	/Duncan et al. 1998/
	summer	57–80		
Moose	winter	57	g/kg$^{0.75}$/day	/Andersen and Saether, 1992/

5 Population dynamics

5.1 Demography, dispersal and population growth rate

Demographic parameters; rates of survival, reproduction and movement, are the biological processes that influence population dynamics. Variation in observed abundance is consequently caused by changes in demographic rates. Information about demographic rates is therefore important when forecasting and managing population growth. Information about abundance alone provides limited information of why populations behave as they do. The surveys performed in the areas are not designed to study demography. In this section demographic traits of mammals in the study areas will be summarized by means of data from literature. They will be used in the discussion of how populations may develop in the future. Based on the demographic data in Appendix 3 we calculated the growth rate (λ) for some of the species using the Euler equation /Williams et al. 2002/

$$\sum \frac{l_x b_x}{\lambda^x} = 1 \qquad (5\text{-}1)$$

where l_x is the probability that an individual survives from birth to the beginning of age x, b_x is the number of female offspring born per female of age x (we ignore the males and assume a 50/50 sex ratio) and λ is the finite rate of increase. λ can also be calculated from time series since

$$N_{t+1} = \lambda \times N_t \qquad (5\text{-}2)$$

Because λ is a ratio of population sizes, it is a dimensionless number with no units. The calculated growth rates are presented together with dispersal rates from Appendix 4 in Table 5-1. Dispersal rate is the proportion of individuals that leaves their social group or home range per generation.

The data originate from several geographically, and temporally separated populations, exposed to different harvest rates, but they provide some information on relative growth and dispersal rates. Wild boar populations grow fast and expand rapidly because of high dispersal rates (proportion of females dispersing). Deer species have moderate growth rates but only roe deer have dispersal rates that can match wild boar. Moose populations grow slower, and the growth rate in this example is slightly negative. The high dispersal rate in moose is because females live solitary and separate from their calves before they give birth again. However, the calves behave as many other dispersing mammals and stay near their natal home range.

Table 5-1. Rate of growth and dispersal in large mammals.

Species	λ	Dispersal rate (%)
wild boar	1.57	43
Red deer	1.10	< 10
Fallow deer	1.18	–
Roe deer	1.10	44–54
Moose	0.98	100

5.2 Population density

There are several ways to value if a population in an area possesses some unique traits. Population density is the only quantitative measure that has been surveyed in the study sites. It can be used to make comparisons between the study sites as well as between study sites and other areas. We collected estimates of population density from the literature (Appendix 5) and compared them to the estimates obtained in the study areas. The methods that were used in the surveys are presented in Appendix 8.

Table 5-2. Density estimates from surveys of large mammals 2001–2004.

Species	Study site	Year	Method	Mean	Unit	SE	n
Lynx	Forsmark	2002	Snowtracking	0.2	Ind/10 km^2		
Marten	Forsmark	2002	Snow tracking	2.4	Ind/10 km^2		
	Hållnäs	2002	Snow tracking	4.2	Ind/10 km^2		
	Simpevarp	2003	Snow tracking	1.3	Ind/10 km^2		
	Blankaholm	2003	Snow tracking	0.5	Ind/10 km^2		
Wild boar	Simpevarp	2003	Snow tracking	0.4	Ind/10 km^2		
	Simpevarp	2003	Pellet	2.6	Ind/10 km^2	1.95	887
	Blankaholm	2003	Snow tracking	0.5	Ind/10 km^2		
	Blankaholm	2003	Pellet	1.2	Ind/10 km^2	0.80	746
Red deer	Simpevarp	2003	Pellet	0.3	Ind/10 km^2	0.18	887
	Blankaholm	2003	Pellet	1.5	Ind/10 km^2	0.58	746
Fallow deer	Blankaholm	2003	Pellet	0.4	Ind/10 km^2	0.34	746
Roe deer	Forsmark	2002	Pellet	59.3	Ind/10 km^2	11.86	656
	Forsmark	2003	Pellet	93.6	Ind/10 km^2	20.77	595
	Hållnäs	2002	Pellet	37.7	Ind/10 km^2	9.20	549
	Hållnäs	2003	Pellet	48.0	Ind/10 km^2	8.24	908
	Simpevarp	2003	Pellet	49.0	Ind/10 km^2	9.30	887
	Blankaholm	2003	Pellet	51.6	Ind/10 km^2	11.00	746
Moose	Forsmark	2002	Aerial	2.4	Ind/10 km^2	0.90	
	Forsmark	2002	Pellet	8.3	Ind/10 km^2	2.09	656
	Forsmark	2003	Pellet	12.3	Ind/10 km^2	2.77	595
	Forsmark	2004	Aerial	6.5*	Ind/10 km^2	0.69	
	Hållnäs	2002	Aerial	12	Ind/10 km^2	2.90	
	Hållnäs	2002	Pellet	6.3	Ind/10 km^2	1.65	549
	Hållnäs	2003	Pellet	6.7	Ind/10 km^2	1.62	908
	Hållnäs	2004	Aerial	6.5*	Ind/10 km^2	0.69	
	Simpevarp	2003	Aerial	7.8	Ind/10 km^2	1.80	
	Simpevarp	2003	Pellet	5.7	Ind/10 km^2	1.08	887
	Blankaholm	2003	Pellet	4	Ind/10 km^2	1.06	746
Hares – field	Forsmark	2002	Pellet	3.2	Ind/10 km^2	1.75	832
	Forsmark	2003	Pellet	3.2	Ind/10 km^2	1.90	883
	Hållnäs	2002	Pellet	2.5	Ind/10 km^2	0.40	2,402
	Hållnäs	2003	Pellet	22.8	Ind/10 km^2	8.50	658
	Simpevarp	2003	Pellet	35.1	Ind/10 km^2	13.11	1,113
	Blankaholm	2003	Pellet	19.1	Ind/10 km^2	7.37	1,257

Species	Study site	Year	Method	Mean	Unit	SE	n
Hares – forest	Forsmark	2002	Pellet	4.4	Ind/10 km^2	3.80	1,274
	Forsmark	2003	Pellet	2.3	Ind/10 km^2	2.08	595
	Hållnäs	2002	Pellet	2.3	Ind/10 km^2	1.97	1,048
	Hållnäs	2003	Pellet	1.5	Ind/10 km^2	2.23	908
	Simpevarp	2003	Pellet	5.2	Ind/10 km^2	2.83	887
	Blankaholm	2003	Pellet	3.2	Ind/10 km^2	1.86	746

* Density estimates for 2004 are for an area including both Forsmark and Hållnäs.

Table 5-3. Density estimates from surveys of small mammals 2001–2004.

Species	Study site	Year	Season	Method	Mean	Unit	SE	n
Mouse – forest	Forsmark	2003	spring	trapping	0.7	Ind/0.01 km^2	0.19	11
			autumn	trapping	2.8	Ind/0.01 km^2	0.38	11
		2004	–	–	–	–	–	–
			autumn	trapping	2.5	Ind/0.01 km^2	0.39	4
	Simpevarp	2003	spring	trapping	4.8	Ind/0.01 km^2	0.81	5
			autumn	trapping	8.9	Ind/0.01 km^2	0.74	10
		2004	–	–	–	–	–	–
			autumn	trapping	11.5	Ind/0.01 km^2	0.85	4
Mouse – field	Forsmark	2003	spring	trapping	0.4	Ind/0.01 km^2	0.30	4
			autumn	trapping	6.4	Ind/0.01 km^2	2.34	3
		2004	–	–	–	–	–	–
			autumn	trapping	0.2	Ind/0.01 km^2	0.15	4
	Simpevarp	2003	–	–	–	–	–	–
			autumn	trapping	6.4	Ind/0.01 km^2	2.34	3
		2004	–	–	–	–	–	–
			autumn	trapping	6.7	Ind/0.01 km^2	0.78	4
Bank vole – forest	Forsmark	2003	spring	trapping	2.3	Ind/0.01 km^2	0.36	11
			autumn	trapping	3.2	Ind/0.01 km^2	0.43	4
		2004	–	–	–	–	–	–
			autumn	trapping	7.4	Ind/0.01 km^2	0.82	4
	Simpevarp	2003	spring	trapping	4.1	Ind/0.01 km^2	0.83	5
			autumn	trapping	4.8	Ind/0.01 km^2	0.56	10
		2004	–	–	–	–	–	–
			autumn	trapping	3.7	Ind/0.01 km^2	0.59	4
Water vole	Forsmark	2003	spring	trapping	5.7	Ind/0.01 km^2	1.47	5
			autumn	trapping	4.8	Ind/0.01 km^2	1.35	5
		2004	spring	–	–	–	–	–
			autumn	trapping	7.9	Ind/0.01 km^2	1.28	4
	Simpevarp	2003	spring	trapping	5.7	Ind/0.01 km^2	1.47	5
			autumn	trapping	–	Ind/0.01 km^2	–	14
		2004	–	–	–	–	–	–
			autumn	trapping	4.5	Ind/0.01 km^2	0.96	4

Species	Study site	Year	Season	Method	Mean	Unit	SE	n
Field vole – forest	Forsmark	2003	spring	trapping	0.1	Ind/0.01 km^2	0.03	11
			autumn	trapping	0.1	Ind/0.01 km^2	0.04	11
		2004	–	–	–	–	–	–
			autumn	trapping	1.5	Ind/0.01 km^2	0.13	4
	Simpevarp	2003	–	–	–	–	–	–
			autumn	trapping	0.3	Ind/0.01 km^2	0.06	10
		2004	–	–	–	–	–	–
			autumn	trapping	0.9	Ind/0.01 km^2	0.11	4
Field vole – field	Forsmark	2003	spring	trapping	0.4	–	0.11	4
			autumn	trapping	0.1	Ind/0.01 km^2	0.06	4
		2004	spring	–	–	–	–	–
			autumn	trapping	10.2	Ind/0.01 km^2	0.35	4
	Simpevarp	2003	–	–	–	–	–	–
			autumn	trapping	4.2	Ind/0.01 km^2	0.18	3
		2004	–	–	–	–	–	–
			autumn	trapping	2.3	Ind/0.01 km^2	0.17	4
Common shrew	Forsmark	2003	spring	trapping	0.2	Ind/0.01 km^2	0.09	15
			autumn	trapping	2.7	Ind/0.01 km^2	0.30	15
		2004	spring	–	–	–	–	–
			autumn	trapping	2.7	Ind/0.01 km^2	0.30	8
	Simpevarp	2003	spring	trapping	0.5	Ind/0.01 km^2	0.29	5
			autumn	trapping	1.5	Ind/0.01 km^2	0.26	14
		2004	–	–	–	–	–	–
			autumn	trapping	4.4	Ind/0.01 km^2	0.38	8

Table 5-4. Density estimates from other surveys of large mammals.

	Population density (Ind/10km^2)	
Species	**Range**	**Median**
Lynx	0.3–3	0.4
Red fox	1.6–26.2	5.9
Badger	1.6–307	15.2
Pine Marten	3.6–7.6	5.6
Wild boar	6–400	32
Red deer	3–350	177
Fallow deer	99–222	120
Roe deer	20–310	110
Moose	0.8–45	4.4
European hare	20–280	55
Mountain hare		3

Table 5-5. Density estimates from other surveys of small mammals.

Species	Density range (ind/0.01 km^2)	Median density (ind/0.01 km^2)
Bank vole	0.6–99	20.2
Field vole	5–120	30
Water vole	0.01–116	61.5
Mouse	0.37–44.7	8.15
Shrew	1.8–18.5	12.8

Population density of Roe deer and European hare in Simpevarp was also estimated in 2004 using spotlight sampling /Tannerfeldt and Thiel, 2004/. There were 39 Roe deer and 28 Hares per 10 km^2, a figure that is comparable to the results from the fecal pellet count in 2003. Comparing the densities from the surveys with densities collected from literature show that many species in the study sites have relatively low densities. However, lynx, wild boar, red deer and fallow deer have recently established populations in the areas. Moose, roe deer, marten, hares and small rodents have densities that fall into the range of what is reported from many other areas.

Bats have mainly been surveyed by counting animals using ultrasound detectors in arbitrary selected areas. A line transect survey was performed in the Forsmark area but density estimates were not calculated. Since the report from the Forsmark area declares that bat populations can reach high densities with more than 10 individuals/ha, it could be worth considering an appropriate density survey. Since bats apparently can be detected using line transect surveys, but also seem to be aggregated, with some species in low abundance, perhaps an adaptive sampling method can be used.

SN has not surveyed marine mammals but data from the national monitoring program of grey seals is available. Populations of grey seals along the Swedish coast are growing rapidly. With a minor survey or monitoring program, perhaps based on data from seals caught in fishing gear, it would be possible to give a fairly accurate description of the local density and spatial distribution of seals in the coastal areas of the study sites.

5.3 Population models

Temporal population change can be expressed via a simple balance equation that incorporates gains and losses:

$$N(t+1) = N(t) + B(t) - D(t) + I(t) - E(t) \tag{5-3}$$

Where N denotes population size, B is the number of births, D is the number of individuals dying, I is the number of immigrants and E is the number of emigrants.

Rate of population change is often expressed with birth, death, immigration and emigration as factors proportional to population size. However, immigration rates are rarely proportional to the population they enter, they are proportional to the population they come from and are often excluded. Rate of population change is then expressed as:

$$\frac{dN}{dt} = N(b - d - e) \tag{5-4}$$

Populations are often assumed to be closed or to have equal rates of immigration and emigration and therefore is the rate of population change often expressed as:

$$\frac{dN}{dt} = N(b-d) \tag{5-5}$$

The variables can be further divided into different sub variables, e.g.

$$d = predation + harvest + traffic \tag{5-6}$$

The simplicity of this model is attractive. It can also be developed to include regulating factors e.g. density dependence

$$\frac{dN}{dt} = N(b-d)\left(1-\frac{N}{K}\right) \tag{5-7}$$

Where K, often called carrying capacity, is the maximum number of individuals that can be supported in a population. But since trophic interactions often determine the development of mammal populations one usually has to go one step further. There are several models that describe the interactions between vegetation, herbivores and predators. By analyzing long-term data Peter Turchin presented the "generic mammalian herbivore model" as a framework for investigating cervid population dynamics /Turchin, 2003/.

$$\frac{dV}{dt} = u_0\left(1-\frac{V}{m}\right) - \frac{aVN}{b+V} \tag{5-8}$$

$$\frac{dN}{dt} = \xi N\left(\frac{aV}{b+V} - \eta\right) \tag{5-9}$$

V denotes the vegetation biomass density, N is the population density of herbivores, u_0 is the (linear) regrowth rate of vegetation at V = 0, m is the maximum standing crop, a and b are the parameters of the herbivore's functional response, epsilon ξ is the conversion efficiency and η is the herbivore ZPG (zero population growth) consumption (the rate of consumption that an individual needs to survive and replace itself). The parameters are in the following units: forage in g of dry weight, area in km^2, time in year and density in ind/km^2.

If the herbivores are exposed to predation:

$$\frac{dN}{dt} = \xi N\left(\frac{aV}{b+V} - \eta\right) - \frac{cNP}{d+N} \tag{5-10}$$

$$\frac{dP}{dt} = \chi\left(\frac{cN}{d+N} - \eta\right)P - \frac{s_0}{\kappa}P^2 \tag{5-11}$$

P denotes the density of predators, χ the conversion rate of eaten prey into new predators, c and d are parameters of the predator's functional response (c = maximum killing rate, d = half saturation constant), s_0 is predator intrinsic rate of increase, κ is the carrying capacity due to territoriality.

The effect of predation for large herbivores in the areas, e.g. moose is very low because of absence of large carnivores. But on the other hand, harvest is the dominating cause of mortality, and predation should therefore be replaced with a harvest term in the model.

$$\frac{dN}{dt} = \xi N\left(\frac{aV}{b+V} - \eta\right) - hN \tag{5-12}$$

The presented models can be used to show how the mammal populations will develop given different scenarios, e.g. changes in vegetation, predation and harvest.

5.4 Future scenarios of mammal populations

Detailed predictions of population dynamics of a particular species in a particular place requires detailed studies of that species in the place of interest /Lawton, 1999/. However, “quick and dirty answers” are sometimes required, and they are preferably based on sound theory than on pure guesswork and better than no answers at all. There are after all some general laws in ecology /Lawton, 1999/, especially in population dynamics /Turchin, 2001/, and although the rules are contingent there are ways to make predictions in the face of uncertainty /Hilborn and Mangel, 1997/.

Many mammals have been and are highly valued for their meat, fur and fat (trainoil). Human actions have caused direct impact on many mammals in the two regions due to hunting. Indirect actions like forestry and farming also have a great impact on mammals. The way humans exploit natural resources frequently undergo extensive changes and mammal populations are also affected. For the last 100 years several mammals have been exterminated, or nearly become extinct. Several of these have recovered or been reintroduced. Also, species have been deliberately or accidentally introduced and established vital populations. Most species therefore has a history of great change in population density, since habitats developed and were colonized after the last ice age. Predicting the future for the populations is difficult, especially since management goals for the populations rarely occurs. If they occur they are usually vague and arbitrarily set. During the last decades there has been a growing concern for conservation of species. In addition, improvements of management and monitoring programs for several species are investigated, and high biodiversity is the guiding principle for several authorities dealing with management of natural resources. We therefore find it reasonable that all species included in the survey will withstand extinction in the foreseeable future. Densities will continue to fluctuate and stochastic events, like the storm that changed the habitat structure in many forests in southern Sweden in January 2005, will rapidly alter the conditions in favor for some species and with devastating effects for others.

Future predictions can be based on how populations have developed over the last few years, if such data exist, and that the development will continue with the same rate, at least into the near future. Also, a plausible scenario can be modeled for some of the species that are or most likely will be subject to management actions. However, in the following text we will only briefly describe a qualitative scenario for some of the mammal species in the study sites.

Lynx

An increase in the distribution and the size of the population is expected in all site survey areas.

Red fox

Populations of red fox are increasing nationwide, still recovering from the strike of sarcoptic mange in the 1980's. The rapid decrease of fox populations during the mange epidemic is an illustrative example of how several species can be affected by an incident that rapidly decreased the population of a single species.

Badger

Badger populations increased between 1970 and 1990, but growth rate has been slightly negative during the last decade.

Marten

Marten populations grew rapidly between 1980 and 1990, but after the peak in 1994 the populations declined back to the 1980-level in a few years. The variation in density during the period can most likely be attributed to the variation in fox density.

Wild boar

Population size will increase as the population expands and colonize a higher proportion of all survey areas. Dispersal rates and birth rates are often high and populations grow exponentially with annual growth rates between 10 and 100%, and expand with several km per year /Truvé, 2004/. Eventually the population will reach an equilibrium density were harvest rates balance birth rates. Wild boars do however have a high interannual variation in birth and death rates, which results in fluctuating population density and harvest rates. Annual harvest in established wild boar populations in Sweden ranges from a few up to 40 individuals per 10 km^2.

Red deer and Fallow deer

Abundance of both species is increasing in several areas in Sweden. Red deer is present in all areas except Hållnäs. The populations are probably expanding, although not with the same rate as wild boar populations since both dispersal rates and birth rates are lower.

Fallow deer was only present in Blankaholm with a low density. Dispersal rate seems to be very low /Nugent, 1994/, but the species will probably continue to expand.

Roe deer

Roe deer populations increased rapidly when predation from fox decreased during the sarcoptic mange epidemic. Populations have decreased during the last ten years and will most likely continue to do so since both fox and lynx populations are increasing. However, in Forsmark and Hållnäs population density increased from 2002 to 2003 so the populations are evidently not negatively affected by the presence of Lynx in the area.

Moose

Density in Swedish moose populations have declined since they peaked in 1980, but the negative growth rate seem to have leveled out in recent years. Both aerial- and pellet counts show an increase in density in Forsmark but the two methods gave different estimates. In Hållnäs pellet count estimates were equal between 2002 and 2004. The aerial count in 2004 gave the same estimates as the pellet counts but the 2002 aerial survey gave an estimate twice the pellet count estimate. Demographic data from moose in Hållnäs show that birth rates are high /Svensk Naturförvaltning, 2004a/ and we assume that moose densities will not go through any dramatic changes in the near future. Population density in Oskarshamn is nearly the same as in Forsmark but birth rates are lower /Svensk Naturförvaltning, 2004b/, perhaps because of a lower age distribution. Since we only have density data from one year in Simpevarp and Blankaholm it is difficult to make any predictions for the future. Densities will probably not change dramatically but the demographic data from the area show that the population can be sensitive to overexploitation.

Hares

Field hare and mountain hare live in separate habitats with a substantial overlap between populations. Hybridization between the species occurs and may possibly explain the decline of mountain hare in some areas. The species are not separated in the survey since fecal pellets are difficult to assign to the correct species. Densities are higher in fields than in forests and a future development is depending on the structure of the landscape and the density of predators e.g. fox.

Small rodents

The population cycles of small rodents are well known and they can largely be explained by predation, food and maternal effects /Turchin, 2003/. In addition to high interannual variation small rodent density can show high variation over the season. The species of small rodents that were found in the study sites are all widespread in Sweden. We do not believe that the populations will change dramatically in the future.

5.5 A modeling approach

A brief qualitative scenario can be described by simply discussing how the parameters in the model 5-3 may change in the future. A more quantitative approach can be applied for species, which have been thoroughly studied and parameters in more complex models can be, at least crudely estimated. As an example can a scenario for the moose population in Forsmark be modeled under the assumption that availability of food changes, e.g. maximum standing crop in model 5-8 increases with 1% per year (Figure 5-1). The starting value of moose density is based on pellet counts from Forsmark in 2003, and other parameters in the model are taken from /Turchin, 2003/. The model can also be applied to other herbivores, and carnivores.

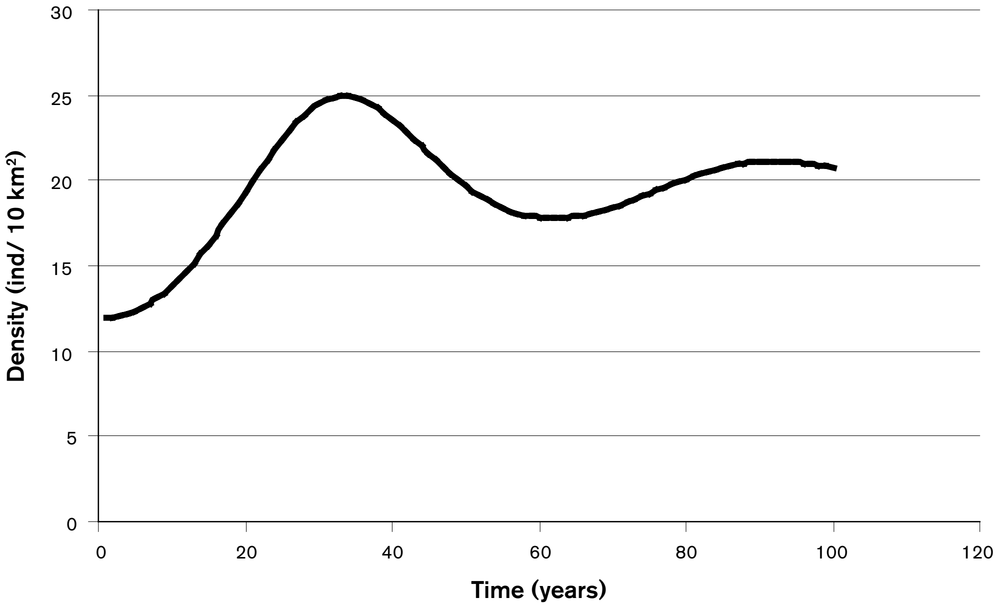

Figure 5-1. *Future moose density when maximum standing crop increases with 1% per year.*

6 Wildlife utilization and management

Human interaction with wildlife is a complex issue. Species are valued differently depending on if they are utilized as a resource or considered a pest. Whether a species is considered a pest or a resource differs between humans and also changes over time. For instance, large predators were not long ago considered as a general pest, but nowadays they are highly valued by some people, while others do what they can to keep them locally extinct. Many game species are highly valued but are also causing damage to agriculture, forestry and fishery, and are a substantial cause of traffic accidents. Wildlife management seeks to manipulate populations so that densities are kept at levels that satisfy concerned parties. In this section, we arbitrarily divide the human population into five categories; hunters, farmers, fishermen, foresters and conservationists. Each category should preferably be thought of as a collection of interests that values different mammals in a similar way. Often these values overlap several categories, e.g. people living on the countryside often take interest in farming, forestry and hunting. We describe how these different categories qualitatively affect the dynamics of different groups of mammals.

Hunters

Hunters actively exploit mammal populations through harvest. Hunting is the main mortality cause for large mammals in Sweden. Hunters often have a desire of sustainable harvest, with equal or increased quantities harvested from year to year. Notwithstanding, management plans are rare and if they occur at all they are vague and the objectives are impossible to evaluate quantitatively /Wallin et al. 2004/. Harvest rates from the populations are not available but we have made some assumptions and calculated the annual harvest in section 7.5.

Farmers

Farmers dislike the damage some mammals cause to their crops. Especially ungulates can cause trouble by damaging fields through rooting, trampling and foraging. Rodents and farmers also have a long-established relation, without mutual benefits. The main effect farmers have on the dynamics of mammal populations is by forming the landscape and setting the limits for the access of food for many herbivores.

Fishermen

Marine mammals, especially seals, interact with fishermen by competition for resources and by destroying fishing gear. Fishermen reduce the growth rate of marine mammal populations by resource competition and increased mortality caused by accidental by-catch of seals and porpoise. They are also propagating for an increased harvest of those species they consider as major competitors.

Foresters

Together with farmers, foresters have a great impact on wildlife by affecting the availability of different habitats. Browsing mammals cause damage mainly on plants and small trees, but occasionally also on larger trees. Due to the damage browsers cause on vegetation, foresters require that populations should be kept at densities where the level of browsing is acceptable. Management actions where highly preferred vegetation is supplied in order to prevent wildlife from browsing on plants of high commercial value are rare. Setting plants that are avoided by herbivores, e.g. spruce instead of pine, often solve the problem.

Conservationists

This category values the sole existence of mammals. Conservationists mainly focus their efforts on conservation of endangered species. Management actions are sometimes accomplished to reduce mortality or increase reproduction, e.g. by improving habitats or releasing individuals, which have been bred in captivity.

7 Elemental composition and carbon budget

Ecosystem ecology studies the pools and fluxes of energy and material through the system /Chapin et al. 2002/. Carbon is often used to describe the flow of both energy and matter since it is one of the major elements in organisms and easily measured simultaneously with other key elements in organic tissue /Hessen et al. 2004/. Terrestrial and aquatic ecosystems are usually treated separately. Some of the mammals in the study areas are semi aquatic and act as links between terrestrial and aquatic ecosystems e.g. Otter, Mink, Beaver and seals. Only the Porpoise can be attributed as strictly aquatic. However, seals, although they spend a lot of time on dry solid ground, lack the ability to move smoothly on land. Since this report only considers the carbon pool and flow in mammals, they are not separated in aquatic and terrestrial. However, when carbon flow in the entire ecosystem is treated, and if terrestrial and aquatic systems are separated, it will also be necessary to separate the mammals into their appropriate element.

Animals and plants can be divided into several classes depending on what trait the members of a specific class share. This report only considers mammals, which have in common that they feed their offspring with milk from mammary glands. From an ecological point of view mammals are often divided into functional groups, often with respect to their feeding habits. They can then easily be lumped together with animals from other systematic groups who share traits that are of more concern for their role in the ecosystem than the way they feed their offspring. Traditionally the members of an ecosystem are divided into primary producers (plants) and consumers. All mammals are consumers but they are divided into different trophic levels depending on their diet. Herbivores consume < 10% animal matter, carnivores including insectivores consume > 90% animal matter and omnivores consume 10–90% animal matter /Schoener, 1968/.

7.1 Elemental composition of mammals

The human body is composed of approximately 59 elements but eleven of them comprise more than 99% of body weight /Heymsfield et al. 1991/. The elemental composition of other mammals can be assumed to be approximately the same as for humans /Hendriks et al. 1997/. Oxygen, carbon, hydrogen and nitrogen are the main constituents of organic matter and make up 96% of the total body weight of a living mammal (Table 7-1). A complete list of elements in mammals is presented in Appendix 7.

Table 7-1. Elemental composition of mammals.

Element	% of live weight /Emsley, 1998/	% of dry weight /Sterner and Elser, 2002/	% of total number of atoms /Eckert et al. 1988/
Oxygen	61.4		25.5
Carbon	22.9	57.0	9.5
Hydrogen	10.0		63.0
Nitrogen	2.57	6.4	1.4

7.2 Carbon budget

The mammal contribution to terrestrial carbon pool and carbon flow can be described with a simple conceptual model (Figure 7-1). Sources of carbon are the material ingested by the mammals. Carbon is transported between mammals since carnivores and omnivores predate on herbivores and also consume each other. Carbon sinks comprises the respiration of CO_2, excretion, mortality leading to consumption by predators, parasites, scavengers and microbial decomposers, and also migration. For species that are subject to harvest, humans constitute a carbon sink of variable magnitude.

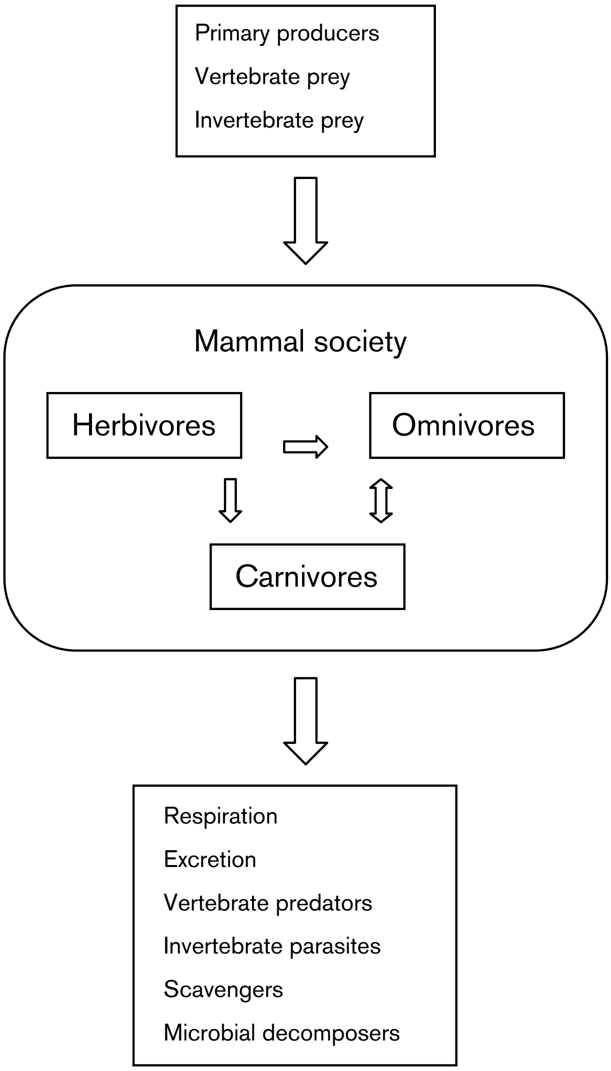

Figure 7-1. *Conceptual model of carbon flow in the society of terrestrial mammals.*

There are three relevant concepts that can be distinguished when analyzing the amount and flow of matter in animal populations. These are standing crop (or standing stock), production and turnover /Petrusewicz, 1975/. Standing crop is the quantitative state at any moment of the population, often expressed as animal numbers or biomass per unit of space. Standing crop provides little or no information on the amount of energy, which passes through the population. Production is the total amount of organic matter or energy that is produced in a population through reproduction and body growth over a given time period, including matter that is eliminated through migration, mortality and other losses of biomass. The total energy budget for an organism is often expressed as:

$$C = P + R + E \tag{7-1}$$

Where C = consumption or total intake, P = production, R = respiration or metabolic heat loss, and E = egestion, that portion of the ingested material not assimilated but released back into the environment as fecal material /Baird and Ulanowicz, 1989/. Turnover represents a relationship between standing crop and production, expressing the rate of biomass change during a definite time period (T):

$$\theta_{(T)} = \frac{P_{(T)}}{\bar{B}_{(T)}} \tag{7-2}$$

The total amount of carbon in the standing crop of a mammal population can be calculated if estimates of population density for mammal species in the area are available.

A number of ecological parameters have to be estimated in order to quantify the production of a population in an area /Petrusewicz and Hansson, 1975/; density, age structure, birth rates, mortality, time of presence (migrating organisms). A number of physiological parameters, such as weight increase at a definite age, are also required. When animals give birth to several litters/season, e.g. rodents, production estimates require intensive field studies during the reproductive season. For example, to calculate the number of individuals born during a certain time period, it is necessary to estimate litter size, time period of pregnancy, average number of pregnant females and their mortality.

7.2.1 Carbon in standing crop

The amount of carbon, measured as g C/m^2 can be estimated by summing the total mass m_i of each species (population density×average body weight), divide it with the area A and multiply it with 0.229, since carbon content in mammals is 22.9% of the total wet weight /Emsley, 1998/.

$$C_{pool} = \frac{\sum_{i=1}^{n} m_i}{A} 0.23 \tag{7-3}$$

7.2.2 Carbon flow

Carbon flow in a standing crop can be estimated by summing the total carbon intake by mammals during time t. Since some of the carbon is circulated within the mammal society, one has to decide if carbon flow shall be estimated as the total amount that is circulated within the mammal society, or as the amount that enters and leaves the mammal society.

A general model where carbon flow is expressed as g C/m^2×time unit can be used independent of what is decided.

$$C_{flow} = \frac{\sum_{i=1}^{n} m_i \times c_i}{A} \qquad (7\text{-}4)$$

The total mass m_i of each species is multiplied with the carbon intake of the species during time t in the area A. The carbon intake c_i depends on the type of food that is consumed and can for each species be expressed as:

$$c_i = \frac{\sum^{t} m_f \times c_{\%}}{t} \qquad (7\text{-}5)$$

Where m_f is the amount of food intake multiplied with the carbon concentration $c_{\%}$ and t is the time period. Carbon concentration of plant organic matter is variable but averages 45% in herbaceous tissues and 50% in wood /Sterner and Elser, 2002/.

Few studies have reported the relationship between intake and body mass within species /Andersen and Saether, 1992/. However intake can also be estimated by measuring the metabolic rate of an animal. Basal metabolic rate (BMR) is the rate of energy conversion in a homeotherm while it is resting quietly within the thermal neutral zone without food in the intestine /Brown et al. 2004/. Field metabolic rate (FMR) is the total rate of energy conversion for a wild animal including BMR, thermoregulation, locomotion, feeding, predator avoidance, reproduction, growth and other energy consuming activities. FMR can be estimated by using the allometric equation

$$y = ax^b \qquad (7\text{-}6)$$

in which y is the field metabolic rate in kJ/day and x is body mass in grams of wet weight. When analyzing energy budgets FMR is often separated into rate of production (growth and reproduction) and respiration (metabolic heat loss) and is expressed as:

$$FMR = A = P + R \qquad (7\text{-}7)$$

Where A is the assimilated energy, P = production and R = respiration.

Estimates of average production efficiency (P/A, Table 7-4) can be used to separate the assimilated energy into respiration and production /Humphreys, 1979/. Parameters for equation 7-6 was taken from Table 7-2 /Nagy, 1987/. Nagy also estimated the feeding rates (C in equation 7-1) using values of metabolizable energy and FMR (Table 7-3). Metabolizable energy (ME) in a diet is the total energy consumed minus the energy lost as egesta (Table 7-3). The feeding rate is converted to kJ/day by multiplying g/day with the total energy value of the food items /Golley, 1961/ (Table 7-5). To calculate the egestion (E) equation 7-1 can be used. Metabolic rate is converted to carbon consumption by equating 1 g carbon to 10.94 kcal = 45.8 kJ /Humphreys, 1979/.

Table 7-2. Summary of parameters in allometric equations for FMR and feeding rate (dry matter) of free-living mammals /Nagy, 1987/.

Group	Units of y	a	Units of x	b
All Eutherian	kJ/day	3.35	g	0.813
Mammals	g/day	0.235	g	0.822
Rodents	kJ/day	10.5	g	0.507
	g/day	0.621	g	0.564
Herbivores	kJ/day	5.95	g	0.727
	g/day	0.577	g	0.727

Table 7-3. Mean metabolizable energy content in different diets /Nagy, 1987/.

Diet	Metabolizable energy content (kJ/g dry matter)
Insects	18.7
Fish	18.7
Vegetation	10.3
Seeds	18.4

Table 7-4. Mean production efficiency (P/A) for different groups of mammals.

Group	Mean production efficiency P/A %
Insectivores	0.86
Small mammals	1.51
Other mammals	3.14

Table 7-5. Total energy content in different diets /Golley, 1961/.

Diet	Total energy content (kJ/g dry matter)
Insects	22.5
Small mammals	21.6
Vegetation	17.8
Seeds	21.2

7.2.3 Results from carbon budget calculations

Estimates of population density is the only site-specific data used in the calculations. We used the mean density of each species during the time period. For those rodents that were surveyed on one occasion during one season but on two occasions another season we used the mean value from the season with two trapping events. Results from the carbon flow calculations are summarized in Table 7-6. Detailed results are found in Appendix 6, where we also have attributed the carbon flow for each species to its habitat.

Table 7-6. Summary of carbon budget in mammal populations. Standing crop in (mg C/m^2). Other in units of (mg C/m^2/year).

Site	Standing crop (mg C/m^2)	Consumption (mg C/m^2/year)	Assimilation (mg C/m^2/year)	Production (mg C/m^2/year)	Respiration (mg C/m^2/year)	Egestion (mg C/m^2/year)
Forsmark (with rodents)	113	2,607	1,690	41	1,649	917
Simpevarp (with rodents)	103	3,126	2,155	45	2,109	972
Forsmark (no rodents)	100	1,644	953	30	923	691
Simpevarp (no rodents)	81	1,350	779	24	755	571
Hållnäs	77	1,189	690	22	668	500
Blankaholm	67	1,164	673	21	651	491

The carbon budget differs between the areas in several ways but the dissimilarities are attributed to a few factors. For instance the difference between standing crop in Forsmark and Simpevarp is to a large extent explained by the difference in roe deer density. Although the standing crop is lower in Simpevarp, the production is higher than in Forsmark because of higher densities of rodents. Maximum production in a mammal population, without mass occurrence, is about 46 mg carbon/m^2 and year /Petrusewicz and Hansson, 1975/. That figure is not even reached if the production of all populations in a study site is summed. However, as mentioned in section 5.2, the estimated densities do not deviate drastically from populations in other areas. If the production is calculated from the higher ranges of the densities presented in section 5.2 it reaches values similar to maximum production.

The production/standing crop ratio from the data in Appendix 6 can be used to compare the productivity of different species (Table 7-7). Small mammals are substantially more productive than large mammals. Variation in small mammal density can consequently, as the data from the survey also show, to a large extent explain variation in carbon budgets.

The production of the populations can also be used to get a rough estimate on the amount of carbon that is harvested by humans. Harvest rates are not available for the populations but mortality in large herbivores, which are the dominating game species, is mainly caused by hunting. If we assume that 80% of the production in ungulates is harvested each year, we get the figures of human carbon harvest in each area presented in Table 7-8. On average 18.4 mg carbon is harvested per m^2 each year, equal to 80 mg mammal per m^2, which means that it requires approximately 500 m^2 to make a meatball.

Table 7-7. Production/standing crop ratios.

Species	P/Crop
Pine Marten	0.96
Wild boar	0.32
Red deer	0.24
Roe deer	0.41
Moose	0.21
European hare	0.69
Mountain hare	0.73
Bank vole	1.18
Field vole field	1.03
Field vole forest	1.03
Water vole	0.66
Mouse field	1.18
Mouse forest	1.18
Common shrew	0.67

Table 7-8. Annual mammal carbon harvest by humans.

Study site	Annual harvest (mg C/m^2)
Forsmark	23.5
Hållnäs	16.6
Simpevarp	17.7
Blankaholm	15.8
Mean	18.4

8 Discussion and conclusions

Each section of this report contains a brief discussion about the obtained results. The objective of this section is to make a concise discussion of how the results accomplish the intentions of the report. In the introduction it was mentioned that the requirements from SKB were that the report should fit the following description:

- A general description of the mammals in the areas.
- A reference work for estimating parameters in models.
- A basis for Environmental Impact Assessment.

Site specific data on mammals in the areas comes from surveys which record presence of species and provide estimates of population density. Traits associated to demography, resource selection and spatial distribution were collected from the literature. All the described variables are varying in time and space, and the range that is presented for each variable is useful when parameter values are chosen to model scenarios for populations. Monitoring programs for populations provide site specific data that can be used to predict the development of populations more precisely. Subsequently, a monitoring program can be designed to fulfill the requirements of precision, with which future scenarios of populations shall be predicted. Furthermore, the suggested monitoring and modeling should be directed towards animal groups with similar position in the system (e.g. food choice), rather than their systematic classification. Finally, guidelines for the different contractors involved in such a monitoring program should be worked out, to achieve a coherent set of data.

The time series that are available from the surveys made by SN are not yet sufficient to draw any conclusions about how the populations are developing. For some species, conclusions can be drawn on a larger regional scale, using hunting bag statistics. However, to fully understand why populations change, it is required that demographic traits are surveyed as well. Estimating demographic parameters is the key to a successful understanding of why populations change over time.

The spatial distribution of animals, today and in the future, can be modeled with several degrees of spatial resolution. We have presented a general framework that can be used to describe development of populations in time and space. Modeling the development over time of mammal populations requires that conditions affecting the dynamics are specified. We saw no use in specifying some arbitrarily chosen conditions in this report. Instead we suggest that a realistic development of the environment is specified, and then scenarios for mammal populations can be modeled.

Ecosystem ecology studies the pools and fluxes of energy and material through the system /Chapin et al. 2002/. Population dynamics considers the standing stock (abundance or density) of individuals and their rates of change (dynamics). In this report population dynamics and energy pools/fluxes are treated separately. An emerging branch of system ecology called ‘ecological stoichiometry’ /Sterner and Elser, 2002/ deals with the balance of energy and chemical elements in ecological interactions and especially in trophic relationships. Integrating ecological stoichiometry with population dynamics has shown that the predictive power of population ecology can be improved both qualitatively and quantitatively /Andersen et al. 2004/. A comprehensive study of the ecosystems in an area, like the ones SKB are performing, could perhaps benefit of such integration.

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Appendix 1

Summary on the status of mammal species in the Forsmark and Oskarshamn areas

		Body mass (g)	Red list status	Forsmark	Hållnäs	Simpevarp	Blankaholm
Carnivores (Rovdjur)	***Carnivora***						
Wolf (Varg)	*Canis Lupus*	36,500	CR	–	–	–	–
Lynx (Lo)	*Lynx lynx*	30,000	VU	O	O	–	–
Red fox (Rödräv)	*Vulpes vulpes*	6,000		O	O	O	O
Brown bear (Brunbjörn)	*Ursus arctos*	170,000	VU	–	–	–	–
Badger (Grävling)	*Meles meles*	12,000		P	P	P	P
Otter (Utter)	*Lutra lutra*	9,500	VU	O	O	–	–
Pine Marten (Skogsmård)	*Martes martes*	1,250		O	O	O	O
American Mink (Mink)	*Mustela vison*	785		O	O	O	O
Stoat (Hermelin)	*Mustela erminea*	220		O	O	O	O
Weasel (Vessla)	*Mustela nivalis*	220		O	O	O	O
Polecat (Iller)	*Mustela putorius*	700		P	P	P	P
Eventoed Ungulates (Partåiga hovdjur)	***Artiodactyla***						
Wild boar (Vildsvin)	*Sus scrofa*	60,000		–	O	O	O
Red deer (Kronhjort)	*Cervus elaphus*	170,000		O	–	O	O
Fallow deer (Dovhjort)	*Dama dama*	70,000		–	–	–	O
Roe deer (Rådjur)	*Capreolus capreolus*	25,000		O	O	O	O
Moose (Älg)	*Alces alces*	300,000		O	O	O	O
Lagomorphs (Hardjur)	***Lagomorpha***						
European hare (Fälthare)	*Lepus europaeus*	3,800		O	O	O	O
Mountain hare (Skogshare)	*Lepus timidus*	3,000		O	O	O	O
Rodents (Gnagare)	*Rodentia*						
Beaver (Bäver)	*Castor fiber*	20,000		–	–	–	–
Bank vole (Skogssork/Ängssork)	*Cletrionomus glareolus*	23		O	P	O	P
Field vole (Åkersork)	*Microtus agrestis*	30		O	P	O	P
Water vole (Vattensork)	*Arvicola terrestris*	74		O	P	O	P

		Body mass (g)	Red list status	Forsmark	Hållnäs	Simpevarp	Blankaholm
Yellow necked mouse (Större skogsmus)	*Apodemus flavicollis*	27		O	P	O	P
Wood mouse (Mindre skogsmus)	*Apodemus sylvaticus*	19		O	P	O	P
Dormouse (Hasselmus)	*Muscardinus avellanarius*	29	NT	–	–	–	–
Red squirrel (Ekorre)	*Sciurus vulgaris*	302		O	O	O	O
Insectivores (Insektsätare)	***Lipotyphla***						
Common shrew (Vanlig näbbmus)	*Sorex araneus*	8.5		O	P	O	P
Pygmy shrew (Dvärgnäbbmus)	*Sorex minutus*	3.5		O	P	O	P
Eurasian water shrew (Vattennäbbmus)	*Neomys fodiens*	12.4		O	P	O	P
Hedgehog (Igelkott)	*Erinaceus europaeus*	800		P	P	P	P
Mole (Mullvad)	*Talpa europaea*	90		–	–	P	P
Bats (Fladdermöss)	***Chiroptera***						
Brandt's bat (Brandts fladdermus)	*Myotis brandtii*	6		O	–	O	–
Whiskered bat (Mustaschfladdermus)	*Myotis mystacinus*	6	VU	O	–	O	–
Daubenton's bat (Vattenfladdermus)	*Myotis daubentoni*	10		O	–	O	–
Pond bat (Dammfladdermus)	*Myotis dasycneme*	15	EN	–	–	–	–
Natterer's bat (Fransfladdermus)	*Myotis nattereri*	10	VU	P	–	O	–
Common pipistrelle (Dvärgfladdermus)	*Pipistrellus pygmaeus*	5		O	–	O	–
Nathusius' pipistrelle (Trollfladdermus)	*Pipistrellus nathusii*	7	NT	O	–	O	–
Noctule bat (Stor fladdermus)	*Nyctalus noctula*	28		O	–	O	–
Northern bat (Nordisk fladdermus)	*Eptesicus nilssonii*	11		O	–	O	–
Frosted bat (Gråskimlig fladdermus)	*Vespertilio murinus*	17		–	–	O	–
Brown long-eared bat (Långörad fladdermus)	*Plecotus auritus*	8		P	–	O	–
Barbastelle (Barbastell)	*Barbastella barbastellus*	9		–	–	–	–
Seals (Sälar)	***Pinnipedia***						
Grey seal (Gråsäl)	*Halichoerus grypus*	100,000		P	P	P	P
Ringed seal (Vikare)	*Phoca hispida*	70,000	VU	–	–	–	–
Harbour seal (Knubbsäl)	*Phoca vitulina*	70,000	EN (Baltic)	–	–	–	–

Red list codes:
CR = Critically Endangered
EN = Endangered
VU = Vulnerable
NT = Near Threatened

Status codes:
O = observed during surveys
P = previously observed or probably present
– = status unknown or probably not present

Appendix 2

Home range data

Species	Study area	Sex	Age-class	n	Season	Method	HR (km^2) mean (median)	Reference
Large/medium sized mammals								
Lynx	Norway	M					1,906	/Sunde et al. 2000/
		F					561	
Red fox	Italy						0.86–4.85	/Cavallini and Lovari, 1994/
	Australia	M/F (rural)					5–7	/Coman et al. 1991/
	Australia	M/F (semi-urban)				0.6–1.3		
Badger	Poland	F/M					7.9–13.6	/Bartmanska and Nadolska, 2003/
	Switzerland						3.87	/Graf et al. 1996/
Marten	Poland	M					2.23	/Zalewski et al. 1995/
		F					1.49	
Wild boar	S Texas	F	> 1	4	Winter	95% MCP	1.59	/Ilse and Hellgren, 1995/
		F		5	Spring	95% MCP	0.82	
		F		5	Summer	95% MCP	2.33	
		F		5	Annual	95% MCP	3.36	
	Italy	F/M	Juv + Ad	18	Annual	MCP	12.26	/Boitani et al. 1994/
					Annual	Buffer Method	9.51	
	Sweden	F			Annual	95% MCP	7.25	/Lemel, 1999/
		M			Annual	95% MCP	8.22	
Red deer	Various (review)					several studies		/Mysterud et al. 2001/
Mainly MCP								
		F			Summer		1.96 (1.61)	
		F			Winter		3.67 (3.86)	
		M			Summer		3.34 (3.0)	
		M			Winter		4.13 (2.16)	
Roe deer		F			Summer		0.47 (0.38)	
		F			Winter		0.63 (0.43)	

Species	Study area	Sex	Age-class	n	Season	Method	HR (km²) mean (median)	Reference
Moose		M			Summer		1.42 (0.76)	
		M			Winter		1.61 (0.75)	
		F			Summer		26.1 (15.2)	
		F			Winter		32.6 (27.9)	
		M			Summer		20.9 (6.3)	
		M			Winter		16.3 (12.2)	
Fallow deer	New Zeeland	M				90% HM	1.89	/Nugent, 1994/
		F					0.66	
European hare	Holland	M/F				MCP	0.273	/Kunst et al. 2001/
	France						1.9	/Marboutin and Aebischer, 1996/
Mountain hare	Scotland	M				MCP	1.13	/Hewson and Hinge, 1990/
	Britain						0.22	/Hulbert et al. 1996/
	Britain	M/F					0.10	/Rao et al. 2003b/

n = number of animals used in the study

Species	Study area	Sex	Age-class	HR (m²)	Reference
Small mammals					
Yellow necked mouse	Germany	M		3,800–15,500	/Schwarzenberger and Klingel, 1995/
Common shrew	Russia	F	Ad	1,300	/Ivanter et al. 1994/
			Juv/Subad	360–500	
	Germany			1,058	/Kollars, 1995/
Microtinae (Voles)	Review	M		16,600	/French et al. 1975/
		F		5,800	
		M/F		8,900	
Muridae (Mice)	Review	M/F		5,000	
Insectivora (Shrews)	Review	M/F		5,200	

Appendix 3

Reproduction and survival data

Mammals with one litter/year (females only)

Species	Study area	Age class (x)	Litter size	Reproductive females (%)	Survival (S_x)	Reference
Lynx	Finland	> 1	2.33		0.53	/Pulliainen et al. 1995/
	Poland	0			0.5	/Jedrzejewski et al. 1999/
		1 –> 1			0.76	
Red fox	Review (USA)	0			0.19	/Storm et al. 1976/
		1 –> 1	4.6		0.26	
Pine Marten	Sweden	0	0			/Helldin, 1999/
		1	2.81	98		
		> 1	2.85	98		
Wild boar	Sweden	0	0		0.64	/Lemel, 1999/
		1	2.75		0.45	
		2	4.45		0.77	
		3	4.25		0.66	
		4	4.25		0.27	
Red deer	Review	0			0.615	/Gaillard et al. 2000/
		1			0.896	
		> 1	0.7		0.941	
Fallow deer	Review	0			0.82	/Gaillard et al. 2000/
		1 –> 1	0.88		0.93	
Roe deer	Review	1	1.40	61		/Andersen et al. 1998/
		1 –> 1	1.55–2.23	81		
	France	1			0.88	/Gaillard et al. 1993/
		1 –> 1			0.93	
Moose	Review	0			0.47	/Gaillard et al. 2000/
		1 –> 1	0.8		0.85	

Survival (S_x) = probability that an individual survives from age x to age x+1.

Mammals with several litters/year (females only)

Species	Study area	Litter size	No of litters	% Reproductive females	Survival	Reference
European hare	France	13.4 (seasonal)		93		/Marboutin et al. 2003/
Microtinae (Voles)	Review	5.86	3.32	81	3.05 (months)	/French et al. 1975/
Muridae (Mice)	Review	6.14	3.30	66	1.82 (months)	
Insectivora (Shrews)	Review	6.15	3.00	74	7.4 (months)	

Survival (S_x) = probability that an individual survives from age x to age x+1.

Appendix 4

Dispersal data

				Dispersal	Dispersal distance		Dispersal	
Species/study site	**Sex**	**n**	**Age-class**	**Range (km)**	**Mean (km)**	**Median (km)**	**rate (%)**	**Reference**
Lynx								
Canada	M/F	91		17–930				/Poole, 1997/
Poland				5–129				/Jedrzejewski et al. 1999/
Red fox								
North Dakota	M		0.5 –< 1.0	1–153	24	12	64	/Allen and Sargeant, 1993/
	M		1.0 –< 2.0	0–147	35	21	77	
	M		2.0 –< 8.0	8–131	46	26	97	
	F		0.5 –< 1.0	0–302	19	3	29	
	F		1.0 –< 2.0	1–246	24	5	36	
	F		2.0 –< 8.0	0–274	33	9	52	
Wild boar								
Sweden	M		Ad	0–105	16.6		86	/Truvé, 2004/
	F		Ad	0–33	4.5		43	
Roe deer								
Sweden	M		0–3.5	0.8–40		2.9	73	/Wahlstrom and Liberg, 1995/
	M		0–2.5	0.9–2.1		1.4	53	
	F		0–3.5	0.6–57.9		1.2	54	
	F		0–2.5	0.8–3.8		2.4	44	
Moose								
Quebec	M/F	35	1	< 1–101	14.8	5.7		/Labonté et al. 1998/
Sweden	M/F	15	1		1.5–2		100	
	F	42	> 2				0	/Cederlund et al. 1987/
Red deer								
Scotland	F						< 10	/Clutton-Brock and Albon, 1989/

Appendix 5

Density data

Large/medium sized mammals

Species	Study area	Habitat	Season	Method	Density (ind/km^2)	Reference
Lynx	Canada				0.03–0.3	/Poole, 1994/
	Poland				0.03–0.053	/Jedrzejewski et al. 1999/
Fox	Poland		spring	ST/DC	0.27	/Goszczynski, 1999/
	Britain		spring	SPT	0.16–1.17	/Heydon et al. 2000/
	Britain		autumn	SPT	0.59–2.62	/Heydon et al. 2000/
Badger	Poland		spring	ST/DC	0.36	/Goszczynski , 1999/
	Poland				1.6–2.6	/Goszczynski and Skoczynska, 1996/
	Britain			Review	0.86–30.7	/Kowalczyk et al. 2000/
	Poland			Review	0.16–1.52	/Kowalczyk et al. 2000/
Marten	Poland				0.36–0.76	/Zalewski et al. 1995/
Wild boar	California				0.6–40	/Waithman et al. 1999/
	Texas				2.7–3.2	/Gabor et al. 1999/
	Italy			DS	10.6	/Focardi et al. 2002/
Red deer	Scotland				0.3–35	/Latham et al. 1996/
Fallow deer	Italy			DS	22.2	/Focardi et al. 2002a,b/
	Italy			DS	9.9	/Focardi et al. 2002a,b/
	Texas				14	/Hirth, 1997/
Roe deer	Italy			DS	8.5	/Focardi et al. 2002/
	Sweden				11–31	/Wahlstrom and Liberg, 1995/
	Europe				2–18	/Hewison et al. 1998/
Moose	Canada				0.08–4.5	/Ferguson et al. 2000/

Species	Study area	Habitat	Season	Method	Density (ind/km²)	Reference
	Canada				0.25–0.4	/Schneider and Wasel, 2000/
	Sweden (north)				0.48–0.85	/Broberg, 2004/
	Sweden (south)				0.36–1.27	
European hare	Poland			ST	8–28	/Panek and Kamieniarz, 1999/
	Sweden				2–3	/Lång et al. 2004/
Mountain hare	Sweden				0.3	/Lång et al. 2004/

Method: ST = snow track, DC = double count, SPT = spotlight transect, DS = distance sampling, ST = strip transect

Small mammals

Species	Density range (ind/hectare)	Median density (ind/hectare)	Reference
Bank vole	0.6–99	20.2	/French et al. 1975/
Field vole	5–120	30	
Water vole	0.01–116	61.5	
Mouse	0.37–44.7	8.15	
Shrew	1.8–18.5	12.8	

Appendix 6

Estimated standing stock and carbon flow based on density estimates from the surveys within the site investigations

Simpevarp

	Body mass	Density	Density	Standing stock	Carbon flow mg C/m²/year					
	(g)	Ind/10 km²	Ind/0.01 km²	mg C/m²	C	A	P	R	E	Habitat
Carnivores										
Pine Marten	1,250	1.30		0.04	1.85	1.14	0.04	1.11	0.71	F
Eventoed Ungulates										
Wild boar	60,000	1.50		2.06	42.31	21.17	0.66	20.51	21.13	F, A
Red deer	170,000	0.30		1.17	15.58	9.03	0.28	8.74	6.55	F, A
Roe deer	25,000	49.00		28.05	631.36	365.97	11.49	354.48	265.39	F, A
Moose	300,000	6.75		46.37	529.60	306.98	9.64	297.34	222.62	F
Lagomorphs										
European hare	3,800	35.10		3.05	114.97	66.64	2.09	64.55	48.33	A
Mountain hare	3,000	5.20		0.36	14.34	8.31	0.26	8.05	6.03	F
Rodents										
Bank vole	23		4.45	2.34	229.65	182.55	2.76	179.79	47.11	F
Field vole – field	30		4.20	2.89	251.79	197.14	2.98	194.16	54.66	A
Field vole – forest	30		0.30	0.21	17.99	14.08	0.21	13.87	3.90	F
Water vole	74		5.70	9.66	568.61	422.86	6.39	416.47	145.76	W
Mouse field	23		6.40	3.37	330.29	262.54	3.96	258.57	67.75	A
Mouse forest	23		6.85	3.61	353.51	281.00	4.24	276.75	72.51	F
Insectivores										
Common shrew	8.50		1.00	0.19	24.42	15.21	0.13	15.08	9.21	F, A
Sum				**103.37**	**3,126.26**	**2,154.62**	**45.14**	**2,109.48**	**971.64**	

C = consumption, A = assimilation, P = production, R = respiration, E = egestion. Habitat types: F = forest, A = agricultural land, W = wetland.

Blankaholm

	Body mass	Density	Standing stock	Carbon flow mg/m²/year					
	(g)	Ind/10 km²	mg C/m²	C	A	P	R	E	Habitat
Carnivores									
Pine Marten	1,250	0.50	0.01	0.71	0.44	0.01	0.43	0.27	F
Eventoed Ungulates									
Wild boar	60,000	0.85	1.17	23.97	12.00	0.38	11.62	11.98	F, A
Red deer	170,000	1.50	5.84	77.88	45.14	1.42	43.72	32.74	F, A
Fallow deer	70,000	0.40	0.64	10.89	6.32	0.20	6.12	4.58	F, A
Roe deer	25,000	51.60	29.54	664.86	385.39	12.10	373.29	279.48	F, A
Moose	300,000	4.00	27.48	313.84	181.92	5.71	176.20	131.92	F
Lagomorphs									
European hare	3,800	19.10	1.66	62.56	36.26	1.14	35.13	26.30	A
Mountain hare	3,000	3.20	0.22	8.83	5.12	0.16	4.96	3.71	F
Sum			**66.57**	**1,163.55**	**672.58**	**21.12**	**651.46**	**490.97**	

C = consumption, A = assimilation, P = production, R = respiration, E = egestion. Habitat types: F = forest, A = agricultural land, W = wetland.

Forsmark

	Body mass	Density	Density	Standing stock	Carbon flow mg/m²/year					
	(g)	Ind/10 km²	Ind/0.01 km²	mg C/m²	C	A	P	R	E	Habitat
Carnivores										
Lynx	30,000	0.20		0.14	3.88	2.33	0.07	2.26	1.55	F
Pine Marten	1,250	2.40		0.07	3.41	2.11	0.07	2.04	1.30	F
Eventoed Ungulates										
Roe deer	25,000	76.45		43.77	985.05	570.98	17.93	553.06	414.07	F, A
Moose	300,000	8.05		55.30	631.60	366.11	11.50	354.61	265.49	F
Lagomorphs										
European hare	3,800	3.20		0.28	10.48	6.08	0.19	5.88	4.41	A
Mountain hare	3,000	3.35		0.23	9.24	5.36	0.17	5.19	3.88	F
Rodents										
Bank Vole	23		2.75	1.45	141.92	112.81	1.70	111.11	29.11	F
Field vole field	30		0.25	0.17	14.99	11.73	0.18	11.56	3.25	A
Field vole forest	30		0.10	0.07	6.00	4.69	0.07	4.62	1.30	F
Water vole	74		5.25	8.90	523.72	389.47	5.88	383.59	134.25	W
Mouse field	23		3.40	1.79	175.46	139.47	2.11	137.37	35.99	A
Mouse forest	23		1.75	0.92	90.31	71.79	1.08	70.70	18.52	F
Insectivores										
Common shrew	8.50		0.45	0.09	10.99	6.84	0.06	6.79	4.14	F, A
Sum				**113.17**	**2,607.05**	**1,689.78**	**41.00**	**1,648.77**	**917.28**	

C = consumption, A = assimilation, P = production, R = respiration, E = egestion. Habitat types: F = forest, A = agricultural land, W = wetland.

Hållnäs

	Body mass	Density	Standing stock	Carbon flow mg C/m²/year					
	(g)	Ind/10 km²	mg C/m²	C	A	P	R	E	Habitat
Carnivores									
Pine Marten	1,250	4.20	0.12	5.97	3.69	0.12	3.58	2.28	F
Eventoed Ungulates									
Wild boar	60,000		0.00	0.00	0.00	0.00	0.00	0.00	F, A
Red deer	170,000		0.00	0.00	0.00	0.00	0.00	0.00	F, A
Fallow deer	70,000		0.00	0.00	0.00	0.00	0.00	0.00	F, A
Roe deer	25,000	42.85	24.53	552.12	320.04	10.05	309.99	232.08	F, A
Moose	300,000	7.45	51.18	584.52	338.82	10.64	328.18	245.71	F
Lagomorphs									
European hare	3,800	12.65	1.10	41.44	24.02	0.75	23.26	17.42	A
Mountain hare	3,000	1.90	0.13	5.24	3.04	0.10	2.94	2.20	F
Sum			**77.06**	**1,189.29**	**689.60**	**21.65**	**667.95**	**499.69**	

C = consumption, A = assimilation, P = production, R = respiration, E = egestion. Habitat types: F = forest, A = agricultural land, W = wetland.

Appendix 7

Elemental composition of the human body

Element	Mass in a 70-kg person (g)	%
oxygen	43,000	61.4
carbon	16,000	22.9
hydrogen	7,000	10
nitrogen	1,800	2.57
calcium	1,000	1.43
phosphorus	780	1.11
potassium	140	0.2
sulfur	140	0.2
sodium	100	0.143
chlorine	95	0.136
magnesium	19	2.71E–02
iron	4.20	6.00E–03
fluorine	2.60	3.71E–03
zinc	2.30	3.29E–03
silicon	1.00	1.43E–03
rubidium	6.80E–01	9.71E–04
strontium	3.20E–01	4.57E–04
bromine	2.60E–01	3.71E–04
lead	1.20E–01	1.71E–04
copper	7.20E–02	1.03E–04
aluminium	6.00E–02	8.57E–05
cadmium	5.00E–02	7.14E–05
cerium	4.00E–02	5.71E–05
barium	2.20E–02	3.14E–05
iodine	2.00E–02	2.86E–05
tin	2.00E–02	2.86E–05
titanium	2.00E–02	2.86E–05
boron	1.80E–02	2.57E–05
nickel	1.50E–02	2.14E–05
selenium	1.50E–02	2.14E–05
chromium	1.40E–02	2.00E–05
manganese	1.20E–02	1.71E–05
arsenic	7.00E–03	1.00E–05
lithium	7.00E–03	1.00E–05
cesium	6.00E–03	8.57E–06
mercury	6.00E–03	8.57E–06
germanium	5.00E–03	7.14E–06
molybdenum	5.00E–03	7.14E–06
cobalt	3.00E–03	4.29E–06
antimony	2.00E–03	2.86E–06
silver	2.00E–03	2.86E–06
niobium	1.50E–03	2.14E–06

zirconium	1.00E–03	1.43E–06
lanthanium	8.00E–04	1.14E–06
gallium	7.00E–04	1.00E–06
tellurium	7.00E–04	1.00E–06
yttrium	6.00E–04	8.57E–07
bismuth	5.00E–04	7.14E–07
thallium	5.00E–04	7.14E–07
indium	4.00E–04	5.71E–07
gold	2.00E–04	2.86E–07
scandium	2.00E–04	2.86E–07
tantalum	2.00E–04	2.86E–07
vanadium	1.10E–04	1.57E–07
thorium	1.00E–04	1.43E–07
uranium	1.00E–04	1.43E–07
samarium	5.00E–05	7.14E–08
beryllium	3.60E–05	5.14E–08
tungsten	2.00E–05	2.86E–08

Data from /Emsley, 1998/.

Appendix 8

Survey methods

There are two main ways of estimating animal density: indirect and direct methods. Direct methods have in theory no actual limitations and gives absolute numbers of density, for example animals per square kilometre. Data can be used in many ways and are easily adapted as input to models.

Indirect methods provide us with data that are proportional to the actual number of individuals of a given species. It is usually used as index and gives trends rather than actual figures on density and can give relevant information when following long-term trends in population development. One disadvantage is that relevant comparisons between areas and species are limited. Furthermore, data are usually insufficient for e.g. predicting flows of energy between trofical levels.

There is a vast literature about methods for estimating animal abundance and related parameters. Some of the most well known hand books are: Seber, G.A.F. /Seber, 1982/ The estimation of animal abundance and related parameters (Charles Griffin & Company Ltd, London) and Krebs C.J. /Krebs, 1989/ Ecological methods (Harper & Row, New York).

All methods used in the surveys are presented below.

1 Aerial survey

Species: Moose, deer, wild boar

The method is primarily adapted for large cervids and gives direct density estimates, but observations of all larger mammal species are recorded (although we have not yet tried to calculate their absolute densities).

Aerial surveys are normally done during mid winter when land areas are covered with > 20 cm snow. If possible, the survey is initiated 1 day after snowfall, which makes the tracks easy to detect. We use small helicopters (Hughes 300) that are relatively cheap and easy to manoeuvre. At least two helicopters are used on each occasion. One reason is to reduce the operating time with good weather conditions (e.g. between snowfalls). Another reason is that the system requires control surveys by two independent observation teams (see below).

In each study area sample plots (2 km^2) are evenly distributed, covering 25–30% of the entire area. Each plot is thoroughly searched for animals. Each observation is recorded in a computer as to sex and age, time etc. Location is achieved by GPS. With the computer it is possible to discriminate observations that only are within the plot. The mean density (like moose/km^2) and variance is then easily calculated.

It is then important for the final density estimate to calculate the probability to observe animals in the plots since some animals will not be observed. Weather conditions, flight speed, snow depth, etc, might influence the observation rate. Therefore, two teams independent of each other search 30–40% of the plots. Time lag between the visits in the plots should not be more than 5 minutes so the chances to observe the same animals are as high as possible. By comparing the results from the two teams using a capture-recapture procedure /Seber, 1982; Skalski and Robson, 1992/ it is possible to calculate the observability of a given species each day and to correct the mean values calculated from the standard methods.

2 Capture – recapture

Species: Badger, moose, roe deer, fox

This method is commonly named The Peterson method /Seber, 1982/ and includes a number of methods based on the capture – recapture technique. The basic idea is that the population density can be calculated if we have knowledge of the number of marked individuals and the proportion of marked and unmarked animals in a sample of the total population at a specific time. The method is flexible and does not necessarily require physical marking (like ear tags, collars, rings etc), but can also be used by comparing observations by two or more independent teams made at the same time (see aerial surveys of moose, 1). The Leslie method can be associated with the capture technique and can also be used when harvesting a population, marking, observing or doing effort estimates etc /Ricker, 1975/. This method might be useful for roe deer, foxes and badger.

3 Line transects

Line transects includes a variety of methods and can be used both as indexes and for actual density estimates.

3.1 The Buffon method

Species: Wolf, lynx, marten

The method is normally used in snow. It is based on the classical problem called the “Buffon´s needle problem” /Becker et al. 1998/. We have adapted the method for large animals by using line transects in the snow and the possibility to follow tracks crossing the transects. If the procedure is repeated it is also possible to get variance estimates. The method is adapted for species that roams over relatively large areas and occurs at low densities (marten has normally relatively small home ranges but is easy to track and occur at low densities).

The tracking must not be started until 8 hours after snowfall. The method is quite uncomplicated in the field. One moves along transects that are evenly distributed over the research area. The first line is randomly chosen but the additional lines are parallel and distributed 4 km apart. Each track crossing a transect is followed backwards to the position where the first track is found after snowfall and onwards until the animal is observed, the day bed is found etc. The shortest distance to a transect from the outer ends of the track is calculated. Positioning is done with GPS. If possible sex, age and number of animals are recorded.

3.2 Transects along water areas

Species: Otter, mink, fox, beaver, wolf, lynx, marten

The method is actually a combination of the Buffon method and an ordinary line transect method. The entire area is divided in 1 km^2 squares. Since we expect that it is more likely to find tracks along the coast and the larger streams than in any other areas, we have stratified the landscape into the two categories: 1) coast/larger streams; 2) other water areas. Data are sampled from randomly chosen 1 km^2 squares.

The transects are adjusted to the edges of all the water areas within the selected square. Larger ditches are included if they are considered to be filled with water most of the year. Tracks are recorded and followed in the same manner as in the Buffon method (see above). Burrows, dens and other signs of the presence of the species are recorded as well as crossing tracks of other mammals.

4 Fecal counts

Species: Moose, red deer, roe deer, wild boar, hares

The method is basically used as in indirect estimate of local densities. However, we intend to calculate absolute numbers and calibrate with other survey methods (aerial surveys of moose for example). In this study pellets are counted in early spring when pellets are easily found and are dropped during the period between leaf fall and the day of counting. Given that we know number of pellet groups or pellets (hares) produced per day, the number of days since leaf fall, it is possible to get a rough estimate of population density.

In order to do data collection more efficient than in 2002 (sample plots along line transects crossing the entire area) sample plots are distributed along transects, forming a square (500×1,000 m). Each square, or sub area, is randomly distributed over Hållnäs and Forsmark, respectively.

Moose, deer species and wild boar. No stratification is done. The distance between plots is 50 m.

Many species, hares for example, use small patches quite heavily. If pellets are rare or expected to be found in clusters, adaptive sampling /Thompson, 1990/ can be used. When pellets are found in a plot, searching is also done in the adjacent plots until no plots contain pellets. This also means that plot clusters with pellets between transects are not included in the data set if they are not "hit" by the sampling procedure.

Hares – Forest. For hares we basically use similar sampling plot system as for moose and deer.

Hares – Field. In addition to the ordinary plot system hare pellets are also counted in a stratified plot system associated to fields and arable land. From the 1 km^2 square system (see Transects along water areas, 3.2) we randomly selected squares containing fields and arable land. Plot density is higher than the ordinary system with 10 m between individual plots. The transects start and stop in the forested area 10 m from the edge of the open area. The procedure is similar as described above.

Specification of the sampling units

- **Moose, red deer, wild boar** Plot size is 100 m^2 (radius 5.64 m).
  Only pellet groups containing > 20 pellets are counted.
  Pellet groups with > 50% of the pellets within the plot are counted.
- **Roe deer** Plot size is 10 m^2 (radius 1.78 m).
  Pellets are counted as above.
- **Hares** Plot size is 1 m^2 (1×1 m square)
  All pellets are counted.

5 Frequency of capture of small rodents and insectivores

The method is well known and used frequently by many biologists all over the world /Williams et al. 2002/. In order to get sufficient data from different habitats and enough sample size to calculate total density for each of the species captured, we randomly selected 25 areas as sample units. Each area contains 100 steel traps (similar to ordinary "mouse traps") at a distance of 10–15 m. Each trap is baited one day and checked the following 3–5 days (depending on the trapability). If necessary, the trap is baited again during the period. Animals captured are aged (adult or juvenile) and sexed.

In order to catch water voles, 25 traps are put out on 5 randomly chosen sample areas along streams and ditches (other species might also be captured). Distance between traps is approximately 20 m.

To get data on the rate of increase within the year, capturing is accomplished in seasons when they are supposed to have: 1) low density (May–June); and 2) reach peak density (September–October).