Rovvilt og sauenæring i Norge (Carnivores and sheep farming in Norway). 4

Strategies for the reduction of carnivore - livestock conflicts: a review

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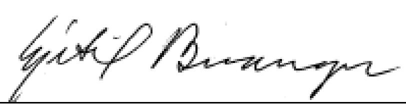

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I denne rapporten gjennomgås ulike tiltak og kombinasjoner av disse, som kan redusere tap av sau til rovdyr. Rapporten bygger på forutsetningen om å ha levedyktige bestander av rovvilt, og samtidig opprettholde saueproduksjonen på nasjonalt nivå.

Det ble foretatt et litteratursøk på emnene; (1) økologi og atferd hos store rovdyr, (2) tapsårsaker i ulike områder (3) tradisjonelle gjeterteknikker, (4) moderne tapsreduserende tiltak og (5) eksempler på forvaltning av konflikter i ulike områder. Et internasjonalt perspektiv ble brukt der det var mulig, selv om det ble lagt vekt på europeiske og skandinaviske forhold. Data ble samlet fra publiserte og upubliserte studier, samt personlig kommunikasjon med forvaltere og forskere fra hele verden. Det ble også forsøkt å identifisere de biologiske mekanismene bak de ulike tiltakene.

Begrensing av rovdyrpopulasjoner med en eller annen form for kontroll har historisk sett vært den mest benyttede metoden for å redusere rovdyr-predasjon på husdyr. Populasjonsbegrensing er fremdeles benyttet i områder hvor coyote og dingo opptrer tallrikt, og hvor konflikten med verneinteressene er minimale. Med truede rovdyrarter i små og spredte bestander vil en slik generell bestandsreduksjon ikke være forenlig med målet om sikring av levedyktige bestander av store rovdyr. I noen tilfeller vil det imidlertid være aktuelt å hindre at slike arter koloniserer nye områder med høyt konfliktpotensiale. En generell bestandsreduksjon vil kun være realistisk hvis den kombineres med et soneringssystem (se senere). Selv om mye oppmerksomhet har vært rettet mot å fjerne såkalte "problemindivider", eksisterer det lite data om hvorvidt problemindivider faktisk eksisterer, eller om det er spesielle kjønns- eller aldersklasser som forårsaker det meste av tapene (hanner synes generelt å forårsake større tap enn hunner). Mye arbeid må til for å bestemme om problemindivider eksisterer, og for å finne metoder som effektivt kan identifisere og fjerne dem. Flytting av enkeltindivider synes generelt ikke å være en brukbar metode da rovdyrene har vist stor evne til å finne tilbake til utgangspunktet. En viss grad av suksess er avhengig av at det finnes tilgang på store arealer med lav bestandstetthet, å flytte dyrene til. Generelt vil kostnadene forbundet med flytting kun kunne forsvares hvis det dreier seg om å flytte reproduserende hunner tilbake til små populasjoner, eller som en del av en reintrodusering.

Metoder for å redusere tap av husdyr til rovdyr har blitt benyttet siden husdyrene ble domestisert for 10 000 år siden. Bruk av rovdyrsikre stengsler har vært vellykket. Store kostnader og sekundære effekter på annet vilt gjør at rovdyrsikre gjerder kun er brukbart for små arealer som rundt bikuber og nattinnhegninger. Store rovdyr har ofte vist seg å kunne forsere gjerder, enten ved å hoppe over (f.eks kattedyr) eller ved å bryte seg gjennom (f.eks. bjørner). Elektriske gjerder med høy spenning har vist seg å være det mest effektive (og kostnadseffektive) rovdyrsikre stengsel. Lyd og lysinnretninger, avskylæring og bruk av andre kunstige skremselsmidler har i beste fall vist seg å ha svært kortsiktige effekter. En økning av de naturlige bestander av byttedyr er i mange områder en forutsetning for å kunne redusere predasjon på husdyr og samtidig opprettholde levedyktige bestander av rovdyr. En økning av de naturlige bestander av byttedyr kan imidlertid også føre til en økning av rovdyrbestandene, så tiltaket kan ikke brukes uavhengig av andre tapsreduserende tiltak. Fóring av bjørn kan være til nytte i spesielle tilfeller, men bjørner tilvendt utlagte kadavre kan få økt aggresjon mot mennesker. Vokterhunder har vist seg å være svært effektive når de har en flokk eller inngjerdede sauer å forsvare. Fjerning av kadavre fra beiteområdet kan kanskje redusere antall rovdyr tiltrukket til området. Sau og geiter er klart mer utsatt for predasjon fra rovdyr enn krøtter. En omlegging av driften til krøtter vil redusere predasjonen, spesielt med ekstra beskyttelse av kyr med unge kalver. Generelt er kalver og lam mer utsatt for predasjon enn voksne. Ekstra beskyttelse under kalving og lamming vil redusere predasjonen. Forsinket slipp så lammene er større når de slippes på beite vil også kunne redusere tapet. Unngåelse av områder eller sesonger spesielt utsatt for predasjon har også potensiale til å redusere tapet. Utbetaling av erstatninger for rovdyrdrepte dyr har ingen tapsreduserende effekt, det gjør kun tapet mer akseptabelt.

Generelt er de tradisjonelle metodene å beskytte buskapen på, de mest lovende. Kombinasjon av gjeter, vokterhunder og nattinnhegninger er meget lovende. Boksen nedenfor oppsummerer de tiltak og driftsformer som synes mest lovende. I prinsippet vil dette si gjetersystemer som har vært praktisert i hele Eurasia gjennom årtusener.

Et soneringssystem innebærer at årsakene til en konflikt fjernes fra store områder der rovdyrbestander vernes, mens rovdyr ekskluderes fra andre områder med uegnet habitat eller høyt konfliktpotensiale. Mange former for landbruk, skogbruk, jakt, fiske og industri er forenlig med vern av store rovdyr. Hovedårsaken til konflikten er frittgående sau. En omlegging av sauedriften vil redusere konflikten. Villmark er ikke en forutsetning for vern av store rovdyr. Sonering har solid biologisk basis i den stedstroheten rovdyrene viser til sine leveområder. Tettheten av rovdyr i nordlige områder er generelt lav, og de bruker meget store leveområder, vernesonene må derfor være store. Spredning av unge individer, og tilfeldige ekskursjoner ut fra territoriet hos enkelte voksne, vil kunne skape konflikt utenfor vernesonen og nødvendiggjør store buffersoner.

Ingen enkelttiltak vil alene kunne redusere tap av husdyr til et minimum. En eller annen form for sonering er helt nødvendig for å motvirke konflikten med ekspanderende rovdyrpopulasjoner i noen områder, og begrense området der kostnadskrevende tapsreduserende tiltak er nødvendig. En vellykket strategi for å redusere predasjon på husdyr vil innebære; (1) rovdyr blir vernet i store områder med egnet habitat der konfliktpotensialet blir redusert (dvs. innføring tapsreduserende tiltak, omlegging av drift etc.), (2) en buffersone med innføring av visse tapsreduserende tiltak, og der skyting av rovdyr for å hindre eller begrense enn kolonisering praktiseres, (3) et areal utenfor der store rovdyr blir ekskludert ved hjelp av forskjellige metoder.

- Omlegging av driften fra frittgående sau eller geiter til krøtter når dette er praktisk mulig.
- I noen situasjoner kan skifte av sauerase være effektivt.
- Lamming og kalving under kontrollerte forhold.
- *Rovdyrsikre* nattkve for sau og kyr med unge kalver.
- Samling av sauen til nattkve vil være mer effektivt med
  - konstant gjeting på dagtid
  - dyrene på inngjerdet beitemark. Flyttbare elektriske gjerder kan benyttes så man er i stand til å rotere til nytt beite gjennom sesongen.
- Bruk av vokterhunder både dag og natt. Inngjerding av sauer sikrer også at vokterhundene er effektive.
- Fjerning av kadavre fra beiteområdet når mulig.
- Unngå sesonger, habitat og landskapstyper med høy risiko for predasjon.
- Utvikling av avsky-stimulerende midler (muligens i kombinasjon med beskyttende halsbånd) i områder med kun gaupe eller jerv.

Det er helt nødvendig at landbruksinteressene og rovdyrforvaltningen samarbeider og koordinerer planene så deres samlede mål kan forenes. Klart formulerte og uttalte mål basert på et solid vitenskapelig grunnlag er en forutsetning for at en strategi skal kunne være vellykket. Nødvendigheten av informasjon og opplæring kan ikke understrekes nok.

Emneord: Rovdyr-husdyr-konflikter - rovdyrkontroll - tapsreduserende tiltak - driftsform - sonering - forvaltningsstrategier - bibliografi

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Abstract

Linnell, J.D.C., Smith, M.E., Odden, J., Swenson, J.E. & Kaczensky, P. 1996. Carnivores and sheep farming in Norway. 4. Strategies for the reduction of carnivore - livestock conflicts: a review. - NINA Oppdragsmelding 443:1-116.

This report aims to review individual methods by which the depredation of livestock by carnivores can be reduced, and ways in which these methods can be incorporated into management strategies. An underlying assumption is that joint goals exist of maintaining viable carnivore populations, and livestock production.

Data were collected on several related topics including; (1) Carnivore behaviour and ecology, (2) Animal husbandry, (3) Depredation studies, (4) Traditional herding practices, (5) Case studies. A world-wide perspective was taken where possible, although the main emphasis is for Europe, and Scandinavia in particular. Data were gathered from published an unpublished studies and personal communications. A clear effort was made to identify the biological mechanism behind a depredation reduction methods success or failure.

Population control of predators has been the most historically favoured method of reducing carnivore depredation on livestock. With abundant species like coyote and dingoes, population reduction through lethal control is still widely used and generally reduces depredation and does not conflict with conservation interests. With large and endangered species widespread population reduction is generally incompatible with carnivore conservation. However, in many cases such species will need to be prevented from colonising areas with unsuitable habitat and very high conflict potential. In general population reduction will only a realistic method if it can be combined with land-use zoning (see later). Although much attention has been directed at removing so-called “problem individuals”, there is little data to indicate if problem individuals really exist, or if it is a problem sex and age class causing most depredation (males are generally responsible for depredation than females). Much work is needed to determine if these animals exist, and if so, to find ways to identify and selectively remove them. Live-capture and translocation is not considered to be a generally usable method of controlling individual carnivores because of their demonstrated homing ability and their wide post-release movements. Only if large and unsaturated areas exist where the individuals can be released, will there be any measure of success. In general, only when returning breeding age females to very small populations or using an animal for a reintroduction project will the cost of translocation we justified.

Many husbandry methods have been used to reduce depredation since livestock were first domesticated 10 000 years ago. Erecting predator-proof fences has been a successful measure used, although large costs and secondary effects on other wildlife imply that is generally only useful to protect small areas, such as bee hives, lambing pastures or night-time enclosures (exceptions exist in Australia and Africa where very large areas are fenced). High-voltage electric fencing has been shown to be most effective. Visual and acoustic repellents, aversive conditioning and the use of other artificial repellents and deterrents have very short-term benefits at best. Increasing natural prey is a prerequisite for reducing depredation and maintaining carnivore populations, but it may also allow carnivore populations to increase so it can not be used independently of other improvements in husbandry. Diversionary feeding of bears may have limited application in some special circumstances, but the problems of having food conditioned bears concentrated around feeding sites can cause a host of other problems, including increased aggression towards humans. Livestock guarding dogs are very effective at reducing depredation when they have a flock or a defined pasture to protect. Removing carrion and carcasses from the pasture may help reduce the number of carnivores attracted to the area. Sheep and goats are much more vulnerable to depredation than cattle. Changing from sheep herding to cattle herding will definitely help reduce depredation, especially when cows with

young calves are afforded extra protection. Ensuring that calving and lambing occur under controlled and protected conditions will greatly reduce depredation as it neonates are always vulnerable to more predators than adults. Adjusting birth season so that neonates are larger when released onto open pasture may provide some benefits. Avoiding specific areas and seasons associated with peaks of depredation has the potential to greatly reduce depredation. Paying of compensation does not contribute to a reduction in depredation, it only makes the level of loss more acceptable.

In general, it is the traditional methods of caring for livestock which show the greatest promise. The combination of shepherd, guarding dogs and night-time enclosure shows the best promise. The following list provides a summary of the herding systems that show the most promise. In effect these are a return to patterns of husbandry which have been used throughout the Eurasia for millennia.

A zoning system implies that sources of conflict are removed from large areas were carnivore populations are conserved, while carnivores are excluded from other areas of unsuitable habitat or very high conflict potential. Many forms of agriculture, forestry, hunting, fishing and industry are compatible with the conservation of carnivores. Free-ranging sheep are the main source of conflict. This means that wilderness is not a prerequisite for effective conservation. Zoning has a sound biological basis in the fidelity to home ranges that most carnivore show. However, the low densities that northern temperate carnivores live at (usually 0.5 - 2.0 individuals per 100 km^2) and their large home range sizes (100 - 1000 km2) implies that conservation zones need to be large. Dispersal of juveniles, and occasional extra-territorial movements of adults will cause conflict around the edges of a conservation zone, requiring the use of a large buffer zone.

No single measure will reduce depredation on livestock. Zoning of land-use is vital at some level to prevent conflicts between expanding carnivore populations in some areas, and to limit the area in which husbandry measures to reduce depredation need to be applied. A successful strategy for reducing depredation will provide (1) a large area of suitable habitat as a conservation zone from which conflict potential is removed (i.e. greatly improved husbandry or changing to other forms of agriculture), and within which lethal control is not applied. (2) a buffer zone within which improved husbandry is encouraged and lethal control may be practised to prevent, or reduce the colonisation of the area by disperses. (3) the outside area from which large carnivores will be more or less excluded through lethal control.

It is vital that agricultural and environmental management agencies co-operate and co-ordinate their plans so that their joint goals are compatible. Clearly stated goals with a sound scientific basis are a prerequisite for any strategy to work. The importance for constant education and information cannot be overstressed.

Key words: Carnivore-livestock conflicts - carnivore control - depredation reduction methods - husbandry - zoning - management strategies - bibliography

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- Encourage a change from free-ranging sheep and goats to cattle when this is practical.
- Changing sheep breed may be effective in some situations.
- Ensure that lambing and calving occur under controlled conditions, as long before release onto pasture as possible.
- Construct *predator-proof* night-time enclosures for sheep and cattle with young calves.
- To enable sheep to be gathered into a night time enclosure they need to be either;
  - constantly herded during the day or,
  - fenced inside a limited area pasture. Electric fences enable this to move as each area is grazed.
- Encourage the use of guarding dogs by both day and night. The measures required for night time enclosure also allow guarding dogs to function.
- Remove carrion from the pasture when possible.
- Avoid grazing at all, or take most precautions in seasons, habitats or landscapes that have a high depredation risk.
- Develop aversive repellents (possibly in connection with protective collars) when lynx and wolverine are the only predators present.

Foreword

This report was commissioned by the Norwegian Directorate for Nature Management and The Ministry for Agriculture in response to dramatically increased levels of large carnivore depredation on livestock in Norway during the last decade. The project was a multi-institute arrangement between NINA, University of Oslo, Munich Wildlife Society, Hedmark Collge and North-Trønderlag College. The results of this cooperation are contained in six reports and are summarised in the main report (in Norwegian) «Rovvilt og sauenæring i Norge: Kunnskapsoversikt og evaluering av forebyggende tiltak». We have also written a long Norwegian summary of this report called «Rovvilt og sauenæring i Norge. 5. Strategier for å redusere av rovvilt - husdyr - konflikter: en litteraturoversikt», NINA Oppdragsmelding 444. Many people deserve our thanks as they helped by providing information, references, comments and by acting as reviewers for individual chapters. Their names are listed in the Acknowledgements section.

Hedmark, November 1996
John Linnell

Contents

1 Introduction

Ever since wild ungulates were domesticated at the beginning of the Neolithic period, carnivores have failed to perceive the difference between wild game and domestic livestock. The resulting conflict between predator and herder has been one of the main factors directly reducing the number and distribution of medium and large carnivores on the planet.

Public attitudes towards large predators have changed enormously *within* the present generation. From a status of vermin they have become conservation flagships and symbols of the dramatic changes that our economic development is having on planetary ecology. Management practices have changed from "shoot on sight" to "protect at all costs". In the eyes of some, carnivores are beautiful and spectacular animals that can do no "wrong" as they fulfill their survival needs by killing ungulates and other prey species. They still, however, kill domestic livestock. As conservation efforts succeed and large carnivores increase in density and distribution the old conflicts return. If anything the conflicts are now worse, because during the temporary absence of carnivores traditional herding techniques have been forgotten, leaving cattle, yaks, horses, goats and sheep more vulnerable than ever before. The economics of agriculture have also changed; the last fifty years have seen a dramatic decrease in the labour intensity of animal husbandry. Shepherds have changed in status from being indispensable to an unaffordable expense.

As the former "solutions" of extermination are no longer considered acceptable, new solutions (mainly old methods that are rediscovered) must be found to facilitate the integration of carnivores and livestock in our modern, crowded world. This is not an easy task as it involves give and take on the part of the herder and the conservationist, some of whom often hold extreme and polarised views. As usual, reason and logic dictate a middle ground approach. Quite simply, to allow conservation of carnivores anywhere outside of the world's few remaining wilderness areas, techniques that are compatible with the goals of maintaining viable carnivore populations need to be found to reduce carnivore depredation on livestock. This volume is a review of most methods that have been used in wildlife and agricultural management to reduce carnivore-livestock conflicts.

There is no single best approach, or magic solution that fixes all problems. The single factor that dictates the success or failure of a given approach is the question of management objective. What is a given policy or technique designed to achieve? Without clearly stated goals, success can never be achieved. Management goals for carnivores can vary from total extermination of a carnivore, through local extermination, and maintaining a given density, to protecting all individuals within a given area, or protecting all individuals globally. Similarly, agricultural objectives can vary from producing food at a subsistence level, producing the maximum tonnage of sellable meat, maintaining a strategic food supply, through maintaining a traditional industry even when economics dictate otherwise, to adopting an ethic to produce food of the best quality in the most environmentally friendly manner possible. Evaluating and balancing these objectives is beyond the scope of this report, the questions are political in nature, not scientific.

We will, however, make a distinction between two scenarios that present different limitations on the choice of conflict-reduction methods depending on the goal for the management of the offending carnivore;

Scenario 1. A carnivore species / population is abundant, with no danger of global or regional extermination.
Scenario 2. A carnivore species / population is rare with a risk of regional and / or global extermination.

Clearly, the management options for scenario 2 are very different from scenario 1, if the maintenance of viable carnivore populations is a stated goal. On the other hand if viable populations of large carnivores are not a stated goal, the difference is minor. We have tried to be as objective as possible in our evaluation of different methods to reduce conflicts. We do, however, base most of our evaluations on the premise that viable populations of carnivore species should be conserved on a national basis, or as a result of cross-border cooperation. This premise is assumed because it is a stated objective of almost every country in the developed and developing world which has signed the Berne and Rio conventions.

This report has reviewed as much of the worldwide literature as was available. A companion report to this study which reviewed the carnivore depredation data from 11 European countries (Kaczensky, P. 1996. Large carnivore-livestock conflicts in Europe. Wildlife Society of Munich. 106pp) provided much supporting information. The report is written as generally as possible to make it of interest to all international readers, although it is biased towards European, and especially Norwegian conditions. However, as situations vary on national and local levels, it is very unlikely that all conclusions will be relevant to all conditions.

2 Reducing depredation on livestock through carnivore control

2.1 The various objectives of carnivore control

Main points - Objectives of Control

- *Although control always involves the removal of carnivores from a population, it is often forgotten that predator control can have different ultimate objectives under different situations. These include;*
  - *causing local extermination of a carnivore species,*
  - *reducing the carnivore population to a lower level,*
  - *selectively removing individual carnivores,*
  - *preventing carnivores from colonising areas with high conflict potential.*
- *When planning "control" it is vital to state the exact management goal and determine if it is compatible with other management objectives, such as maintaining viable populations of carnivore species.*

Carnivore control has been the most researched method for reducing carnivore-livestock conflict. There has been much public debate about the rights and wrongs of control of carnivore populations in recent decades, and certainly no other conflict reduction method is as controversial. There is also much debate about its general effectiveness and the humanness of the specific methods used. One of the biggest problems has been the failure to recognise that predator-control can have at least four different objectives in the context of reducing conflicts with livestock;

- causing total (or local) extinction of a carnivore species,
- reducing the carnivore population to a lower level,
- selectively removing individual carnivores,
- preventing carnivores from recolonising areas with high conflict potential.

Total (or local) extinction, either by deliberate action or the failure to avoid it, was regarded as being an acceptable goal for wildlife management during the 19th and early 20th centuries. This was a period associated with the widespread use of poison, uncontrolled hunting and bounty payments on carnivores. Protection of livestock and reduction of competition for wild ungulates were the twin motivations. However, by the 1970's public opinion began to change and campaigns for the preservation of populations of large carnivores were initiated. Early research projects on wolves, cougars and grizzly bear were instrumental in bringing about this change in public opinion.

Despite widespread animosity towards the fate of carnivores, and enormous expenditure and effort, no species was driven to extinction or even extirpated from a continent. However, many species lost over half of their range and were extirpated from many European countries and American states. The larger species with slower reproductive rates like brown bear, wolf, cougar, lynx, tiger, lion, and cheetah were most reduced in both range and density. The reduction in range and density of these species allowed more extensive agricultural practices to spread over Europe, eastern North America, and large parts of Africa and Asia, as less intensive husbandry was required in the absence of a depredation threat. However, the smaller carnivores with faster reproductive rates were harder to kill in sufficient numbers to reduce their population densities, and soon it was the coyote, jackals and foxes that were the major source of conflict with livestock. There is much to indicate that their populations have even increased in response to the decrease in larger carnivore populations (e.g. Palomares et al. 1995, Peterson 1988). These species were almost impossible to control to the point of extirpation, without the widespread use of poison (**see case studies 6.1 and 6.2**) which became socially unacceptable in Europe and the US after the early 1970's.

The principle of selective control of problem individuals sprang from two sources. In the case of large carnivores that were recognised as being endangered it was hoped that only killing the individuals involved in livestock depredation would allow populations to survive, while resolving the conflict. The other motivation was to try to make control of species like coyote more efficient by not wasting effort on those individuals that were not causing problems. The main problem with this approach is that it is not clear if problem individuals always exist, and if they do it is difficult to aim control measures specifically at them.

Finally, due to a new conservation ethic, better management and active reintroduction, carnivore populations are again increasing in density and recovering parts of their range in many areas of Europe and North America. This is leading to old conflicts with livestock reappearing in new areas. Few carnivore conservation plans take into account the problems that the carnivores can cause when they spread into livestock husbandry areas. Clearly there are many areas where the habitat is so changed, and agriculture so important, that there is little point in allowing populations to establish. In such areas it is logical to prevent colonisation through control (Mech 1995).

Control is an important wildlife management technique and will almost always be required to some degree. Apart from reducing conflict with livestock, carnivore control is used to;

- reduce the risk of disease transmission to man (e.g. rabies).

- protect endangered species from extinction (e.g. sea bird or turtle colonies) especially from areas where the carnivore has been introduced to (e.g. foxes in Australia, cats in Antarctica).
- reduce competition with rarer carnivore species.
- reduce competition with humans for game (Harris & Saunders 1993).

However, several important factors which are often forgotten in carnivore control programs are;
- to state the goal of a control operation.
- to analyse the cost-effectiveness and cost-benefit trade-offs.
- to ensure that appropriately humane and appropriately selective methods are used.
- *to ensure that the control operation is compatible with other conservation / management objectives*.

In the following sections we present an overview of the methods available for control, examine the use of translocation as a means of selectively removing problem individuals, examine the evidence for the existence of problem individuals which are responsible for a disproportionate amount of damage within a population, discuss what happens to the social gap after selective removal, and conclude with a discussion of the success of control for reducing carnivore-livestock conflicts. Case studies of the use of control in Australia, Alberta, North America and Western Europe are presented in **sections 6.1, 6.2, 6.5 and 6.11**.

2.2 The methods of carnivore control

Main points - Methods of Control

- *When choosing a method the following characteristics need to be considered;*
    - *effectivity at reducing populations,*
    - *effectivity at targeting correct species,*
    - *effectivity at targeting correct individual,*
    - *cost effectiveness,*
    - *humanness,*
    - *ecological side effects.*

In the following section we discuss various forms of predator control in use today. With the exception of immunocontraception techniques we define control as harvesting (hunting), removing (translocation) or killing (by management) some percentage of the predator population such that damage by that predator is reduced to tolerable levels. This damage may be inflicted upon (Texas A & M University 1996);
- human health and safety
- facilities, structures, and other property
- crops, timber, and rangeland
- livestock
- wildlife and other natural resources.

The definition of "tolerable levels" depends on numerous factors including type and severity of the depredation problem, real or perceived danger to humans, economic value of the depredated resource, and real or perceived value of the predator species involved. Most of these factors are not determined biologically but rather determined politically. It also should be stated that current techniques are not always successful in achieving these tolerable levels even when the political support is there. For example Bomford & O'Brian (1995) point out that: "Despite numerous large-scale attempts, no eradication program against any well-established vertebrate pest has been successful on any continent". While this refers to the extreme end of the control spectrum (i.e. eradication) there are numerous documented failures of partial control to reduce depredation losses as well (Harris & Saunders 1993).

Control of wild, free-ranging animals is a difficult and demanding task; success requires enormous investments of time and money for an extended period. Control will probably be impossible for some animals (r-selected species, i.e. early maturity, high reproductive rates, easily adapting to human encroachment, etc.). For others (k-selected species) control can easily be accomplished (for example by managing legal harvest), and when combined with other factors, such as habitat loss, can drive animals near extinction (e.g. European bear, lynx and wolf populations, **section 6.3**).

Most of the documented research on predator control techniques have concentrated on canids (coyote and wolf in North America, dingo and red fox in Australia and the red fox in the United Kingdom). The following section briefly describes the most common techniques.

2.2.1 Poisons

In the USA the use of all toxicants for predator control (Compound 1080, strychnine, sodium cyanide, and thallium sulphate) was banned in 1972 by direct presidential order and then allowed again in 1981. The new regulations for toxicants require that they be registered with the Environmental Protection Agency after stringent testing and documentation to ensure appropriate use (USDA-APHIS 1994). Currently ADC (Animal Damage Control) uses sodium cyanide in M-44 devices (described below), Compound 1080 in Livestock Protection Collars (LPC, described below), and charcoal-sodium nitrate toxic fumigants for gassing fox and coyote dens (Fall 1990, USDA-APHIS 1994). In other countries the use of toxicants is more widespread such as Australia (Thomson 1986, Saunders et al. 1995) and Zimbabwe (Jarvis & La Grange 1982). Here the aerial and ground distribution of toxic baits are still the primary wildlife damage control technique for dingoes and foxes (Saunders et al. 1995).

2.2.1.1 Thallium sulphate

This was poison first used for coyote control in the United States in 1937 (Andelt 1987). This poison was used at toxic bait stations (banned in 1972) consisting of injecting the poison into 20-45 kg of livestock meat and distributing these stations throughout the grazing range. Thallium sulphate was gradually replaced with Compound 1080 beginning in 1944 because it was safer to use and more selective for canid species (Andelt 1987).

2.2.1.2 Strychnine alkaloid

A white bitter-tasting poison very toxic to most mammals and birds. It is not water soluble and therefore maintains its toxicity for a very long time. These two factors combine to make strychnine a danger for poisoning non-target species. Historically strychnine was the most popular poison for use against foxes in Australia until the late 1960's when 1080 became more popular (Saunders et al. 1995). Today the use of strychnine is discouraged by the Australian government, though still used in two states for fox and dingo control (Saunders et al. 1995). In the USA strychnine use is limited to below ground applications for poisoning gophers (USDA-APHIS 1994).

2.2.1.3 Sodium cyanide

The use of this poison is limited to devices such as the Humane Coyote-Getter described by Robinson (1943) or a later version, the M-44 (Poteet 1967). Basically, it is composed of a hollow metal tube driven into the ground with a spring-loaded ejector and a bait-coated triggering system (Connolly 1988). When the coyote pulls at the bait a dose of sodium cyanide is propelled into the coyote's mouth causing death within minutes (USDA-APHIS 1994). These devices can kill non-target species, especially dogs, but bait type and placement can keep this to a minimum. Research continues to develop more specific lures and devices for coyotes and dingoes (Marsh et al. 1982, Turkowski et al. 1983, Fagre & Ebbert 1988, Stolzenburg & Howard 1989, Allen et al. 1989, Jolly & Jolly 1992, Hein & Andelt 1994).

2.2.1.4 Fumigants

These are used together with shooting at canid dens and with other burrowing animals. The technique has limited application because of the difficulty in locating dens and the limited suitable time period when young are in the den (USDA-APHIS 1994). Fumigants cartridges are lit and placed inside the dens, which are then sealed. The target animals die from oxygen depletion and carbon monoxide poisoning. Often the dens are observed and adults are shot upon return to the den site, though just killing of the young has been shown to give a measurable reduction in livestock depredation by coyotes (Till & Knowlton 1983).

2.2.1.5 Compound 1080

Sodium mono-fluoroacetate (1080) is the most common toxicant in use today. It is a colourless, nearly tasteless, highly water-soluble toxin for which reptiles and many mammals have a high tolerance. This helps to increase the popularity of using 1080 because there is less hazard for non-target, or secondary poisoning (Saunders et al. 1995). In Australia 1080 became more popular after the late 1960's and its use has continued to increase. In New South Wales the number of poison baits distributed annually has increased from 2000 in 1980 to 300 000 in 1994 (Saunders et al. 1995). Use of compound 1080 is controlled so that only government (or semi-government) employees can buy it and prepare the baits. Baits usually consist of meat injected with 1080 and allowed to dry (Saunders et al. 1995). Over most of Australia these are distributed from the ground and steps are taken to further increase their specificity such as; using baits highly favoured by dingoes or foxes, reducing poison concentration and increasing bait size such that smaller animals do not receive a fatal dose, selecting species-specific habitat for baiting, and burying the baits. In Western Australia aerial baiting is allowed and though this technique is very efficient (Thomson 1986) these aforementioned precautions can not be used. There has been an immense collection of research on various facets of 1080 including; sensitivity of Australian animals to 1080 poison (McIlroy 1981, 1986 - just 2 of a series of 9 articles, King 1989), the effect on wild dogs (McIlroy et al. 1986a, 1986b), 1080 loss of toxicity in the field (McIlroy et al. 1988), and effectiveness (Thomson 1986).

2.2.1.6 Toxic collars

In the U. S. 1080 was also a common predacide for canid control (Wade 1977) until banned from general use in 1972. After development and testing of the toxic collar or "Livestock Protection Collar (LPC)", 1080 was again registered but only when combined with the LPC (Rollins 1995). The LPC was invented by Roy McBride in 1970 and was tested and developed by the Denver Wildlife Research Centre, before obtaining EPA approval in 1985 (Connolly 1993). LPC's are an inflatable rubber bladder with Velcro neck straps to hold the bladder in place under the throat of sheep and goats with 15 ml (or 30 ml in the larger version) of the 1080 solution in each of two compartments in the bladder (Burns et al. 1988, 1996, Connolly 1990, 1993). The bladder is aligned such that a carnivore biting the throat area (normal killing technique of coyotes and many other carnivores) punctures this bladder and receives a lethal dose of poison (Connolly et al. 1976, Scrivner & Wade 1986). Like the other poisons many studies have examined various aspects of 1080-filled LPC's. Among these are secondary effects on non-target species (Hegdal et al. 1986, Eastland & Beasom 1986, Walton 1990, Burns *et al.* 1991, Burns & Connolly 1992), and effectiveness for reducing predation (Savarie & Sterner 1979, Walton 1989, Connolly & Burns 1990). The chief advantage of LPC's are their selectivity. Any carnivore killed with an LPC is certainly the individual involved in depredation, the main disadvantage is that a stock animal will be sacrificed (Andelt in press).

Typically LPC's are not placed on all individuals within a herd because of cost constraints. Behavioural research has been carried out to identify which lambs within a herd are most vulnerable, and into ways to make target lambs more vulnerable. In general lambs to low dominance mothers, or new lambs introduced into a herd are most vulnerable to predation (Blakseley & McGrew 1984, Gluesing 1977, Gluesing et al. 1980)

2.2.2 Trapping

2.2.2.1 Snares

Trapping is among the oldest professions, and the use of snares began before recorded history (Boddicker 1982). Depending on how the snares are set they can be lethal (neck snares) or nonlethal (foot and body snares). Modern snares are essentially loops of wire placed so that the animal will cross through the loop and the animal's forward momentum will then tighten the wire around the neck or body. Foot snares are placed so the animal steps into the loop and trips a spring that throws the loop tightly around the animal's foot (Flowers 1977, Jonkel 1993). Snares are available to capture all sizes of predators. There are numerous publications reviewed by Boddicker (1982) explaining the techniques employed for different species.

2.2.2.2 Leghold traps

These are probably the most common form of traps in use today. They are very versatile and are available in sizes suitable for small, medium, and large predators. Leghold traps can essentially be described as a pair of metal jaws under spring tension and held open by a metal stepping plate (pan) that releases the jaws when depressed (i.e. when stepped on by the animal). They can be set in a variety of situations both on land and under shallow water, but setting can be problematic under conditions of rain, snow, and cold weather (USDA-APHIS 1994). Leghold traps are under constant evaluation and development in part as a response to the increasing public pressure against this technique. In particular efforts are directed at making traps more species-specific (stop devices allowing smaller animals to pull free), causing fewer foot injuries (padded jaws, new designs), and reducing the trauma of restraint (tranquillising drugs released at the capture site) (Casto & Presnall 1944, Gipson 1975, Linhart *et al.* 1988, Onderka *et al.* 1990, Linhart & Dasch 1992). Increasing the frequency at which traps are checked is among the most effective ways of reducing trauma. The capture of non-target species with leghold traps is a problem that can also be helped with proper placement of the traps and adjusting the pan tension so lightweight animals will not trip the springs. When placed indiscriminately throughout the landscape, legholds can be very non-selective in terms of the individual caught. However, if placed around a freshly killed carcass they will often be selective in catching the correct individual.

2.2.2.3 Quick kill traps

These are for use with a limited number of smaller animals such as arctic fox, muskrats, and beaver (Proulx et al. 1993, USDA-APHIS 1994). These traps have a design similar to the leghold traps above but have a pair of rectangular wire jaws that close like scissors and kill the captured animal with a powerful body blow. Some of these traps can be hazardous to people and can not be used in populated areas (USDA-APHIS 1994).

2.2.2.4 Cage traps

These come in many varieties and are suitable for capturing all sizes of animals from rodents and mustelids to grizzly bears. These traps are used for live captures of animals to be relocated or where it is not safe to use the other trap types, such as in residential areas (USDA-APHIS 1994). The most common type is referred to as a box trap and is a rectangular cage made of wire mesh or wood and has a door that locks closed after the animal has gone inside to retrieve some bait placed within. Either odour or meat baits are used to lure animals inside, or the trap is placed in a track used by the target species. In Namibia multiple cages are used for capturing cheetah groups. After one cheetah is captured they leave it in a cage in the vicinity of several additional open cages. Eventually the other cheetahs in the area will come to investigate and be captured themselves (Marker-Kraus & Kraus 1996). Modified cage traps transportable by helicopter have also been used to capture grizzly and black bears in remote backcountry locations (Jonkel 1993). The main advantage of cage traps is their humanness and that non-target animals can be released.

2.2.3 Shooting

This is a relatively expensive method because it is labour intensive but is one of the most selective of the control techniques employed. Legal harvest is among the shooting options and causes the vast majority of the predator deaths. Some problem-animal populations can be effectively regulated by monitoring the level of problems and adjusting the harvest accordingly. However, when protected or endangered animals such as wolf, brown bear, tiger, or alligators cause problems, any control actions should be conducted by government personnel (Hines & Woodward 1980, Howard 1982, Fritts *et al.* 1992). In Australia shooting is not thought to be very useful as dingoes are mostly nocturnal, so shooting only occurs opportunistically (Saunders et al. 1995).

Other techniques to improve the efficiency of shooting include;

– Aerial gunning, shooting target animals from fixed-wing aircraft or helicopters. This method is commonly used for coyotes and has the advantage of covering large areas and can provide immediate relief when losses are particularly high, though the effectiveness of aerial gunning is reduced in forested or mountainous terrain (Lynch & Nass 1981).
– Attracting the target animals to baits or with calls that resemble a wounded prey species. This technique works well for coyotes, foxes and bobcats, particularly for those individuals that have become trap shy or learned to avoid the other control methods.
– Trained dogs can also be used to help in locating, pursuing and decoying various predators long enough for them to be shot or immobilised (USDA-APHIS 1994). If dogs are released on the trail leading away from freshly killed livestock it is likely that they will catch the correct individual carnivore.

2.2.4 Immobilisation

In cases where an individual carnivore is intended to be captured alive and translocated, immobilisation drugs are often used. These are usually delivered by air-propelled dart, fired from a pistol or rifle, with the use of stalking, dogs, a ground vehicle or helicopter to allow the shooter to approach close enough to the target animal.

2.2.5 Denning

As described under fumigants above, denning is the process of locating a den and then killing either the young and/or adults found there. Till & Knowlton (1983) have documented as much as a 98% drop in predation following the killing of suckling pups at coyote dens indicating that the need to provide food to pups is among the factors encouraging sheep depredation. The technique has been criticised for not specifically killing stock depredators and for the general difficulty in locating dens (Andelt 1987, USDA-APHIS 1994).

2.2.6 Immunocontraceptive vaccines

Research into the use of antifertility agents for control of predator population has been conducted since the late 1950s (Knipling 1959, Davies 1961 cited in Tyndale-Biscoe 1994, Balser 1964, Linhart 1964). Research has blossomed in recent years, perhaps because the public prefers the idea of immunocontraceptive vaccines over all other forms of predator control (Tyndale-Biscoe 1994). Techniques are clearly established that can inhibit reproduction in a number of wildlife species but the widespread use of these techniques is limited because they rely on surgical implants, injections or remote delivery by darts (Orford *et al.* 1988, Bradley 1994, Miller 1995, McIvor & Schmidt 1996, Berry 1996). New efforts are focusing on oral contraceptive vaccines that can be dispersed through baiting (Bradley 1994, Miller 1995). In Australia efforts are underway to produce a recombinant viral agent that will effectively inhibit fertilisation by causing the animal to mount an immune response against any embryos when becoming pregnant (Harris & Saunders 1993). This management tool offers the advantages of being nonlethal, reversible, and socially acceptable, and shows great promise as a management tool. However widespread use of these technologies must be carefully evaluated and new management policy guidelines to incorporate this level of control must be developed (Sanborn et al. 1994).

2.2.7 Conclusions

Each method has its advantages and disadvantages. **Table 2.2.1** summarises the main properties of each method described above. Ultimately the choice of method used depends on the goals of the control exercise, public opinion, other management objectives, the species concerned and the specific environment.

Table 2.2.1 The cost and effectivity of different control methods at reducing population density, selecting the right species and selecting the correct individual. * = selectivity depends on manner in which technique is used.

	Effectivity			
Method	**Reducing pop.**	**Species select.**	**Individ. select.**	**Cost**
Poisons				
- baits	High	Poor - medium	Poor	Low
- LPC	Low	High	High	Medium - low
Trapping				
- snares	Medium	Medium	Low	Medium - low
- leghold	Medium	Medium	High - low*	Medium - low
- quick kill	Medium	Medium	Low	Medium - low
- cage traps	Low	High	Medium	High
Shooting				
- lethal	Medium	High	Medium -high*	High
- immobilise	Low	High	High*	Very high
Denning	Medium	High	Low	Medium
Fertility inhibition	High - medium	High	Low	High - medium

2.3 Do problem individuals exist?

Main points - Problem individuals

- *It is unclear if problem individuals actually exist.*
- *Based on the little information available it appears that males are generally involved in depredation to a greater extent than females, although the reasons why are unclear. In some cases habitual livestock killers have been shown to be old and injured animals, although the majority are not.*
- *Surplus killing can be regarded as natural predation behaviour under unnatural conditions, and does not indicate the existence of a problem individual.*
- *Any management strategy based on selective removal needs to establish strict criteria to identify and target problem individuals.*
- *From a theoretical basis we predict that there will be a higher probability of problem individuals occurring where husbandry is most intensive.*
- *When the extensive sheep husbandry in Norway is considered, it is unlikely that there are any problem individuals. Nearly all carnivores that encounter sheep will probably kill sheep.*

The principle of selective removal of problem individuals, by selective lethal control or by live capture and translocation, assumes that there are individual carnivores within a population that cause most of the problems. Yet the question of the existence of problem individuals has never been addressed adequately. Do they in fact exist? If they do exist, what characterises them?

2.3.1 Which individuals are usually involved in livestock predation?

Most research has been carried out on livestock predation from the point of view of the livestock. There has been very little research from the view point of predation rates by individual carnivores. There are scattered observations from the literature which we have compiled here.

While almost all age and sex classes of various carnivore species (wolf, coyote, brown bear, lion) have been implicated in livestock depredation at some stage (Connolly et al. 1976, Fritts et al. 1984, Knight & Judd 1983, Stander 1990, Van Der Meulen 1977), there is some evidence that adult and sub-adult males have a higher probability of becoming habitual livestock killers. Evidence exists from observations of individual lions in Namibia and India (Saberwal et al. 1994, Stander 1990) and leopards in Kenya (Mizutani 1993), although most data comes from animals shot after depredation events. Examples include black bear (Armistead et al. 1994, Davenport 1953, Horstman & Gunson 1982), brown bear (Riley et al. 1994), cougars (Aune 1991, Cunningham et al. 1995), jaguars (Rabinowitz 1986), lions (Anderson 1980) and leopards (Hamilton 1981 in Bailey 1993, Esterhuizen and Norton 1985, Norton 1986). It is not clear if this trend is due to the intrinsic behaviour of males, or to the fact that males use larger home ranges and disperse over greater distances than females, which brings them into more frequent contact with areas of high conflict potential.

It is widely speculated that old or injured individuals become livestock killers. The only studies to support this generality are from jaguars in central America. Ten out of 13 animals in Belize, and 10 of 19 animals in Venezuela that were shot in response to cattle depredation showed evidence of previous injury (usually gunshot damage) that would have impaired their hunting ability (Hoogesteijn et al. 1993, Rabinowitz 1986, 1995). Scattered observations of injured lions and snow leopards that have turned to livestock predation exist (Fox & Chundawat 1988, Stander 1990). While it seems clear that old and injured individuals may become habitual livestock killers, it does not follow that it is only these individuals.

2.3.2 How good are juveniles at obtaining food?

Most conflicts between carnivores and man occur when carnivores try to exploit "easily captured" human food sources such as livestock, crops, bee hives, garbage or campground foods. Generally, young carnivores receive a long period of maternal care ranging from a year (for lynx) to several years (for bears). During this period of care their locomotory skills and experience increase although much food is provided by the mother. When they become independent they are forced to exercise these skills for themselves, often in unfamiliar areas away from the natal home range if independence is associated with dispersal. On these grounds it would seem reasonable to suspect juvenile carnivores of being involved in a disproportionate number of depredation incidents. Yet how good are young carnivores at obtaining food?

There have been surprisingly few studies of the ontogeny of hunting skills among free-ranging carnivores. Four detailed studies have been on sea otter, Eurasian otter, cheetah and polar bears during the period of maternal care (Caro 1994, Payne & Jameson 1984, Stirling & Latour 1978, Watt 1993). These studies have shown that young animals are poorer hunters than older animals, spend a longer time to catch each prey item, and feed on prey which is easier to kill during the period of maternal association. No data was available for recently independent individuals. Sub-adult tigers used less efficient killing techniques than adult tigers (Seidensticker & McDougal 1993). Juvenile and yearling individual bobcats are sometimes found to be in poorer condition and to have fed on smaller prey than adults in some (Litvaitis et al. 1986, Matlack & Evans 1992), but not all populations (Fritts & Selander 1978). Despite this indication of poorer hunting success among juveniles, starvation is rarely a cause of mortality among recently independent carnivores (Harrison 1992, Mech 1987, Schwartz & Franzmann 1992). Among cougars starvation has been observed among a few dispersing juveniles (Logan et al. 1986) although human caused mortality dominates in most studies (Lindzey et al. 1988). Subadult Asiatic lions were involved in a disproportionate number of attacks on humans in India, although this was believed to be a consequence of their being forced out of the saturated territory mosaic within the Gir-Forest reserve and onto farmland than anything associated with their age (Saberwal et al. 1994).

There is no data to support or refute the idea that juveniles are most involved with livestock predation or other problem behaviours, although their lack of hunting experience should predispose them to avail of easily killed prey such as sheep when the opportunity arises. However, as juveniles generally disperse from their natal area, they are the age class most likely to venture into areas with high conflict potential. Clearly more research is needed on this topic. Answers will only come by determining predation rates of radio-collared individuals.

2.3.3 Surplus killing - problem individuals or natural behaviour?

The frequent finding of livestock which are killed but not eaten by the predator (surplus killing) has often been taken as evidence for the existence of a “problem individual” that is not behaving “normally”. Surplus killing of livestock is widespread world-wide, for example, cougars, caracal, leopards, snow leopards, black bears and brown bears have been documented killing and failing to utilise multiple sheep (Anderson et al. 1992, Fox & Chundawat 1988, Horstman & Gunson 1982, Mysterud 1980, Stuart 1988) and coyotes and wolves kill surplus turkeys (Andelt et al. 1980, Fritts et al. 1992). However, such behaviour also occurs under totally natural conditions, with predators killing natural prey species. Examples include red fox killing black-headed gulls, hyenas killing Thomson’s gazelles (Kruuk 1972), wolves killing caribou and reindeer (Bjärvall & Nilsson 1976, Eide & Ballard 1982, Miller et al. 1985) and lions killing wildebeest (Schaller 1972). In all these examples more prey were killed than were eaten, which is true *surplus killing*.

Kruuk (1972) hypothesised that whereas searching behaviour was inhibited by having made a kill, killing behaviour was only inhibited by satiation. In a cross species review Curio (1976) regarded searching and prey recognition to be hunger dependent. In all the above situations where predators killed surplus wild prey there were special circumstances (such as extreme weather which confused the prey’s vigilance, deep snow or a concentration of vulnerable neonates) which allowed killing with no search time and little effort. In the extreme cases presented above this served no adaptive advantage as not all the meat could be consumed. However, there are circumstances were carnivores such as wolves, lynx, lions and cougars can make *multiple kills* of bison, musk-oxen, hares, springbok or wildebeest and utilise all of them (Carbyn et al. 1993, Haglund 1966, Mech 1988, Mech et al. 1995, Schaller 1972, Shaw 1977, Stander 1992). Even brown bears have been recorded making multiple kills of neonatal wapiti calves (French & French 1990, Gunther & Renkin 1990). Multiple kills are usually completely utilised by the carnivore. Many large carnivores cache extra meat which they are not able to immediately consume (Vander Wall 1990). Covering a large ungulate kill with debris or vegetation between successive feeding bouts is typical for felids and bears, and allows more complete utilisation of a carcass which cannot be consumed in one meal. Similarly, smaller predators often cache multiple kills to cover periods of shortage (Jedrzejewska & Jedrzejewski 1989, Oksanen et al. 1985, Vander Wall 1990). Thus the behaviour to take advantage of the possibility of making multiple kills can generally be considered as adaptive for most carnivores. It is only in very unusual situations that this leads to waste under natural conditions.

Unusual conditions prevail in almost all circumstances where livestock are concerned. Unnaturally high densities of easily caught prey which lack most of their natural anti-predatory instincts, and which are often placed in accessible (for the carnivore) but confined (for the livestock) areas, present very special situations for carnivores. Natural selection should not be expected to have favoured behaviour to only kill as much as can be eaten under such artificial circumstances.

The observation that some bears killed multiple sheep and only fed on the parts of the body containing most fat (udder, breast fat) led Mysterud (1980) to hypothesise that some bears were optimally foraging for the most digestible parts of the prey. This idea has never been further developed, although there are reports of some bears killing surplus salmon, and only feeding on the fattest parts (S. Knick pers. comm.).

2.3.4 Livestock husbandry and the development of problem individuals

The main factor leading to the formation of problem animals is likely to be the herding technique. In agricultural systems where sheep, goats or cattle are constantly herded, kept on open fields and / or are confined at night inside a fence or boma (Kruuk 1980), predation on livestock requires development of specialised behaviour on the part of the predator. To successfully kill livestock the predator has to either bypass the shepherd and his dogs, come out onto open habitat or cross physical barriers. These behaviours all require a process of learning and are unlikely to develop in young animals, or naturally more cautious females. Individuals must learn how to access this food. However, in grazing systems (such as that in use in Norway) were sheep are free-ranging and unattended in natural carnivore habitat such as forest and mountain, there is no perceptual difference between a sheep and natural ungulate prey, apart from the sheep being easier to kill. Under these conditions problem animals are unlikely to appear, because all animals are going to be problem animals to some extent. The scattered distribution of sheep throughout a carnivore's normal hunting habitat will also increase encounter rates between carnivores and sheep, without any search behaviour required by the carnivore. Also in areas with no natural prey for the carnivores, all individuals will probably kill livestock when it is available.

2.3.5 The identification and management of problem individuals

Management based around the selective removal of problem individuals is dependent on *selective control methods* and the ability to *define* and *identify* problem individuals. Livestock protection (toxic) collars are the only fool proof method of controlling the individual involved in depredation (**section 2.2.1.6**), however the method is not suitable for endangered species or for areas where husbandry is so lax that almost all individual carnivores within an area may kill livestock occasionally. Trapping on the carcass may be effective for felid species that habitually return to a kill, but may simply trap individual wolverine, bear and wolves that are scavenging on a kill made by another individual. Following spoor from a fresh kill with trained dogs may also be a valid approach to corner the correct individual.

Even when abundant carnivore species are considered, any form of selective control is ecologically preferable to blanket population reduction. Although for such species the criteria for selectivity and problem animal definition can be greatly relaxed. The management system should allow for rapid and effective response, although as with any control program it should be closely monitored.

When endangered populations of carnivores are concerned there is a management paradox with selective control. The successful control of a problem individual is usually dependent on rapid response upon discovery of a depredated domestic animal. However, before an individual that makes up a valuable part of a populations genetic pool is lethally controlled there should be a careful evaluation of its status as a problem animal or habitual livestock killer.

For example Jackson et al. (1994) proposed a possible set of criteria for defining a problem snow leopard that requires lethal control which could include the following;

- recommended herding practices should have been followed,
- predation should have been carefully documented as cause of death,
- livestock should have been repeatedly killed within a well defined area
- heavy dependence on livestock for food should be demonstrated (e.g. from scats),
- predator remained close to habitation and livestock for prolonged periods,
- animals could be seen to be sick or wounded.

We present a more complete set of criteria in **section 5.2**.

2.3.6 Conclusions

To date there is no detailed data on livestock predation rates by different age and sex classes of carnivores. No one knows if problem individuals generally exist. In situations when natural alternative prey are available it is hypothesised that the more intensive the form of agriculture used, the more likely it is that only a small proportion of available carnivores will kill livestock. Before selective control / removal programs are instituted, it is vital to find out if livestock predation is in fact due to a few problem animals or not. If not, removing an individual will have no significant effect as the vacancy will be immediately filled by juveniles or transients (**section 2.4**). If problem animals do exist, clear methods need to be established for their identification. The removal of a problem individual may have further effects on the population; dominant male removal may increase the risk of infanticide, whereas removal of a female with dependent young will probably reduce the possibility of her young surviving. These issues are especially important when endangered populations of carnivores are being managed.

2.4 Selective removal - who fills the gaps?

Main points - Who Fills the Gaps?

- *When an individual is removed from a social mosaic, the resulting gap can be filled by resident neighbours, transients, or dispersing neighbours. All situations have been observed under various conditions.*
- *Generally, in saturated populations replacement occurs very quickly, and in some cases two individuals may replace one.*
- *Removal of dominant males may cause increases in infanticide in species like bear and lions, increasing the disturbance caused by removal.*
- *Unless an individual is replaced by one that causes less damage to livestock, selective removal is unlikely to provide significant relief from depredation.*

When an individual carnivore is selectively removed, through lethal control measures or by being translocated, there will be a gap in the social mosaic of the population.

The principle of the operation requires that this gap either remains unfilled, or is filled by individuals that cause less damage to livestock.

Most carnivore populations, especially those of canids and felids (Sandell 1989) have a high level of social structure. Resident and reproductive individuals are not free to wander at will throughout the area without meeting social opposition, although there will always be a certain transient portion of the population composed of juveniles that have not yet found a territory. The removal of a transient should have little effect on the population apart from there being one animal less. However, the removal of a resident should cause greater changes. There are three possible ways in which a gap can be filled in solitary species;

- neighbours can expand their ranges to incorporate the vacant space,
- a juvenile offspring of one of the residents could colonise the space,
- a recently mature transient could occupy the area.

There has been little systematic research on this subject as emigration is more studied than immigration. However, many papers present a few case studies or observations that we have tried to collect here.

2.4.1 Summary of knowledge

Short term responses of both male and female bobcats in one study appear to involve neighbours expanding their range (Anderson 1988, Louvallo & Anderson 1995). However, in the long term it appears that transients fill the vacancies if there are not enough "home grown" juveniles to fill the gaps (Knick 1990). For female cougars it appears that primarily daughters of a removed female or daughters of her neighbours fill the gap, although transients were also found to move in to the vacancy. Neighbouring adults never expanded their ranges. Males were always replaced by immigrating transients (Laing & Lindzey 1993, Lindzey et al. 1988, 1992, 1994). Recent empirical data has also supported Hornocker's (1969) idea that removal of single residents could lead to multiple colonisers, i.e. if you remove one animal two could fill the gap. In removal experiments in Utah nine females that were removed or died were replaced by 13 younger animals, and three males were replaced by four (Laing & Lindzey 1993, Lindzey et al. 1992). This effect was used to explain why constant local removal of "problem" cougars did not reduce cattle losses (Shaw 1982). One negative effect on the population of the loss of a resident male can be increased risk of infanticide by the replacement male (Ross & Jalkotzy 1992), a common event in lions (Packer & Pusey 1983), and brown bears (Swenson et al. in prep, Wielgus & Bunnell 1995). Constant removals of males will affect the social structure of the population, although it appears that lions at least are able to behaviourally compensate for this change in breeding sex-ration (Yamazaki 1996).

Resident golden eagles, removed to alleviate sheep losses, were replaced within 2.5 days on average by transients from the non-breeding pool (Phillips et al. 1991). Only removal of a large proportion of the this non-breeding pool helped reduce predation problems significantly (Waite & Phillips 1994).

For pack-living animals like wolves the effects of removal depend on which animal is removed. Loss of a cub or other beta animal is unlikely to effect the pack's behaviour or predation rate significantly. However loss of an alpha animal will either lead to (1) the pack breaking up, (2) to a beta animal assuming the alpha role, or less frequently, (3) a transient immigrating and assuming the alpha role. In Alberta, following the control of the majority of the pack's members with poison, survivors either dispersed over large areas (up to 248 km), or starved to death (Bjorge & Gunson 1985, **section 6.5**). The vacant gaps were usually filled within 1-2 years by individuals breaking away from neighbouring packs, or by colonising transients. Similarly, in Norway there is circumstantial evidence that loss of alpha animals causes the remaining pack members to disperse over a larger area (Wabakken pers. comm.). By contrast in Minnesota, where more selective control is practised, it is felt that loss of alpha animals results in beta pack members adopting the alpha status and remaining within the former pack territory. In such cases it is even possible that beta animals will raise dependent pups of the alpha female if she dies (Paul pers. comm.). There is a relationship between wolf pack size and cub survival, so the loss of pack members may impact the survival of young. However, the nature of the relationship is dependent on prey availability (Harrington et al. 1983). Evidence exists that predation rates on natural prey can actually increase following control / harvest of a wolf population, even if the density is reduced. Such results are due to a break down in the social structure as a result of mortality (Haber 1996).

Dingoes have a much more flexible social system than wolves, depending on the habitat, prey base and the degree of human-related mortality. As a consequence territory borders are less rigid, and adults are not always faithful to their territory. Vacancies caused by human carnivore-control activities can be filled rapidly by dispersing neighbours of all age classes (Corbett 1995, Thomson 1992). In areas with high levels of control, packs may not be able to form, which may allow more females within the surviving population to reproduce (dominant female infanticide is an important factor in regulating undisturbed populations) and thereby increase local population density. Coyotes and red fox reproduction can also be stimulated after control exercises as social inhibition of reproduction is released if an alpha animal is controlled (Harris & Saunders 1993). This ensures a large potential pool of young animals to fill the gaps left by any control activity within a year.

2.4.2 Management implications

Within saturated populations the isolated removal of an animal is unlikely to have long lasting effects as the vacancy will rapidly be filled by either a juvenile or a transient. Benefits will come only if the individual removed is a more specialised livestock killer than the individual that takes its place. As discussed in section 2.3.4, the probability of depredation being due to one or a few individuals is expected to be proportional to the intensity of husbandry. Removal of individuals may cause further effects through the population by increasing rates of infanticide. Whereas in overabundant populations this may increase the effectively of control, the effect on endangered populations will be larger than expected. On the other hand, selective removal may increase local population density due to multiple colonisation or increased reproduction among survivors (Laing & Lindzey 1993, Haber 1996).However, all these situations only apply to established populations. On the edges of populations there is unlikely to be much social structure, and fewer candidates to fill vacancies. In such areas selective control will be much more effective at reducing depredation, although the crucial factor is the distance to the nearest source of dispersers and the timing of control relative to the timing of dispersal. In such situations loss of a few animals to control may not be compatible with maintaining viable populations of the species in question.

2.5 Translocations as a means of removing problem individuals

Main points - Translocation

- Translocation assumes that livestock predation is due to a few individual problem animals which can be captured alive, transported to an area with reduced conflict potential, where they will remain.
- Apart from the problems of capturing the right animal, all carnivores translocated so far show very wide ranging post release movements and an ability to return to the place of capture. Translocation will therefore only work when large areas without conflict potential exist. These criteria are unlikely to be met in many European situations.
- We cannot recommend it for use in Norway at the present.

2.5.1 Review of international experience

Translocation of carnivores has been a widespread tactic for the management of livestock predation problems and to reintroduce animals back into a part of their species range from which they have become extirpated (Griffith et al. 1989). The underlying assumption with translocation of problem individuals is that only a few individuals are causing the problem, that these individuals can be captured and placed in area with reduced conflict potential, and that they will not return to their original capture point. Generally, when removal of a problem animal is the motivation for translocation individuals are "hard released", that is they are simply released into a new environment without any period of acclimatisation. In contrast, many reintroduction programs use a "soft release" method where individuals are kept penned at the release site for a period varying from a few days to several months.

Here we shall firstly look at the behaviour and survival of released individuals from a series of case studies and then try to draw some general trends out of the results and comment on the success of the method as a means of reducing carnivore predation on livestock. As different predator groups have widely different behaviour and social systems we will examine the international experience by taxonomic grouping.

2.5.1.1 Bears

Black bears are among the most commonly translocated of all large mammals in the United States and Canada (Boyer & Brown 1988, Gunson & Markam1993), usually as a response to predation on livestock (Armistead et al. 1994) or other nuisance behaviour (Massopust & Anderson 1984, Fies et al. 1987), or to re-establish extirpated populations (Comly & Vaughan 1995, Smith & Clark 1994). The principle of translocating nuisance bears has become accepted as standard procedure within many national parks where public opinion would not accept lethal control methods (Gunther 1994).

Bears are usually trapped in snares or mobile culvert traps. After release few bears remain close to the release sites. Most individuals show strong, non-random homing instincts with the record for successful homing being 229 km (Rogers 1984, 1986, 1988). The longest post release movement recorded was over 400 km (Rogers 1988), although most values appear to be between 10 and 100 km. The distance that bears were moved, and the number of intervening physical / anthropomorphic barriers had a large effect on the probability of return (Comly & Vaughan 1995, McArthur 1981, **table 2.5.1**). Conflicting data exists as to which sex and age class shows the greatest homing ability (Fies et al. 1987, Rogers 1986). Generally young animals (of dispersal age) showed the weakest homing instinct (Rogers 1986). High mortality rates, mainly from road accidents, characterised radio-collared translocated bears in Virginia. Large post-release movements in unfamilar terrain obviously increase this risk. Female bears in this study generally had low reproductive rates during the first winter after translocation. Among other studies based on ear tagged animals, survival rates appeared not to differ between translocated and non-translocated animals, accept that cubs of the year appeared to suffer high mortality when translocated with the mother (Rogers 1986). In general, few translocated nuisance bears began to cause trouble again (Armistead et al. 1994, Fies et al. 1987, McArthur 1981), although this probably had more to do with the reduced conflict potential at release sites than the aversive conditioning effect of the capture procedure.

Grizzly/brown bears have also been routinely translocated in North America. In all cases bears have been hard released. For example between 1968 and 1984, 247 individual brown bears were translocated 375 times within Yellowstone National Park. Two separate evaluations of this and subsequent data have concluded that the method is not very successful due to the high return rates (Brannon 1987, Blanchard & Knight 1995). Although distance moved affected the return rate, especially for adult females, over 50 % of adult animals translocated between 75-100 km away returned to their capture point (**table 2.5.1**). Over 40 % of translocated bears were involved in a second nuisance event within 2 years. For bears translocated more than once the probability of return greatly increased. Both reports concluded that the method was largely unsuccessful at preventing nuisance problems and that efforts should be placed on removing the underlying causes of the problems, such as feeding by tourists and improper garbage disposal. Such efforts have greatly reduced the incidence of nuisance bears and attacks on people in Yellowstone (Gunther 1994). Only adult females, whose reproductive contribution to the isolated population is especially important, were recommended to be worth translocating.

In Alaska an experimental translocation of 47 brown bears, 34 of which were monitored, resulted in most adults returning to their capture location, despite a mean translocation distance of 200 km. The maximum distance from which an animal returned was 258 km. Non-returners were generally released further away than returners, 233 vs. 198 km. In general adults returned more often than juveniles. No animals remained in the region of the release site (Miller & Ballard 1982). Barriers such as roads and rivers may have slowed some returns, but in other studies bears have been reported to swim at least 10 km at sea as part of a 90 km trip home (Reynolds in Miller & Ballard 1982).

Transported brown bear cubs and yearlings suffered high mortality rates even when the mother survived, and adult females appeared to have a smaller than expected chance of reproducing the following year (Brannon 1987, Miller & Ballard 1982). Overall transported bears had lower survival rates than non-transported bears (Blanchard & Knight 1995).

There is relatively little experience from translocating European brown bears. The little data suggests that they can also show wide post-release movements (Rauer 1995, Wabakken & Maartman 1994). One male brown bear in Norway used 21 days to return home 124 km, where he was killed by a train. Another died of heat-stress during transportation. Translocation did not prevent a brown bear in Greece from continuing his

Table 2.5.1 Rates of return of translocated black and brown bears from North America (NA) moved different distances.

Site	Percentage bears homing (from translocation distance range in km)					Ref
Black bear						
7 NA studies	81 (8-64)	48 (64-120)	33 (120-220)	20 (220-271)		1
Yellowstone	67 (6-67)					2
British Columbia	69 (10-99)					2
New York	45 (14-64)	21 (64-107)				2
Pennsylvania	75 (<64)					2
Alberta	86 (<64)	20 (64-101)				3
Virginia	67 (1-16)	13 (17-48)	9 (49-80)	0 (>80)		4
Virginia	0 (300-400)					5
Tennessee	47 (<65)					6
Montana	64 (<80)					7
Brown bear						
Alaska	60 (145-255)					8
Yellowstone	83 (<75)	50 (>75)				9
Yellowstone	62 (1-25)	79 (25-50)	59 (50-75)	21 (75-100)	33 (100-125)	10
Norway *	100 (120-250)					11

* = sample only includes two male bears
1. Rogers 1986, 2. Cited in Rogers 1986 but not part data presented for ref 1, 3. Gunson and Markam 1993, 4. Fies et al. 1987, 5. Comly and Vaughan 1995, 6. Beeman and Pelton 1976, 7. McArthur 1981, 8. Miller and Ballard 1982, 9. Blanchard and Knight 1995, 10. Brannon 1987, 11. Wabakken and Maartman 1994, pers obs.

honey stealing behaviour (Mertzanis et al. 1995).

2.5.1.2 Wolves

Grey wolves have been translocated in 8 studies. Three of these involved captive bred animals, 3 involved a re-introduction attempt using wild caught wolves, and 2 studies were using translocation of problem individuals to reduce livestock predation problems (Fritts 1992). All except one study used hard release methods. The hard released wolves all showed extensive post-release movements, averaging 110 km (range 23-302 km) for 14 radio-collared wolves in the Minnesota study and ranging from 40-169 km for four wolves in Montana. A majority (9 of 15) of wolves in Minnesota released less than 64 km from their capture site successfully homed to their original location. None of those released more than 64 km away successfully homed (Fritts et al. 1984). Even captive bred wolves showed strong homing ability, one in Alaska homing 282 km, with two pack mates travelling 140 and 160 km towards home before being shot (Henshaw & Stephenson 1974). In general all wolves after release acted like normal dispersing wolves (Fritts et al. 1984). Presence of resident wolves in the release area did not appear to make any difference to post-release behaviour. Juveniles moved less than adults after being released. Wolves released together showed little tendency to remain associated (Fritts 1992). Survival of translocated wolves in Minnesota was not different from resident animals (Fritts et al. 1985), although limited results from Montana indicated a high mortality rate among translocated individuals, especially pups which tend to be abandoned after translocation (Fritts 1992). Overall human caused mortality dominates indicating that translocated wolves can survive the process.

Wild caught wolves were released into Yellowstone National Park and the Idaho Wilderness in 1995 as part of a reintroduction program. The Idaho wolves were hard released while the Yellowstone wolves were soft-released, spending up to 2 months in pens. After release the Idaho wolves scattered over a large area, whereas the Yellowstone wolves tended to remain together as pairs and remain in the general vicinity of their pens (Anon. 1995, Koch et al. 1995), although the concentrated prey available in Yellowstone may have also helped. Similarly, small post-release movements have been shown for soft-released red wolves in North-Carolina and Tennessee(Fritts 1992, Phillips et al. 1995).

There has been little evaluation of the effects translocation has had on levels of livestock predation. Only 14 % of 114 translocated Minnesota wolves were subsequently trapped in damage control operations. However, predation on livestock in Minnesota is generally low with respect to the wolf density (Fritts 1982, Fritts et al. 1992), and the availability of large areas with no livestock should be born in mind. Certainly the potential for future conflict was not removed by translocation when the wide post-release movements are considered.

2.5.1.3 Other canids

Few other canid species have been translocated because of livestock predation problems, however several species have been translocated as part of reintroduction attempts e.g. swift fox in Canada (Carbyn et al. 1994). A few red foxes have homed from distances ranging from 14-56 km (Rogers 1988).

2.5.1.4 Mustelids

Although some wolverines have been translocated in Finland in connection with predation on domestic reindeer, there has been no follow up of these individuals. However there is data on smaller species such as marten and fisher being translocated for reintroduction purposes. As their social system is functionally similar to wolverines, although on a smaller scale, the data should give some indication as to what can be expected (Banci 1994, Powell 1979).

Post-release behaviour of fishers and martens is characterised by large post-release movements, even when they are on-site acclimatised for some days before release and provided with carcasses as food (Davis 1983, Proulx et al.1994, Slough 1994). These movements are especially large when the body size (body weight 0.5-1.5 kg for marten, 2-5 kg for fishers) of the species is taken into account. Post-release movements of fishers of between 70 and 163 km have been reported from at least five studies (Powell & Zielinski 1994) and martens moved from 1 to 149 km from release sites in Wisconsin and Yukon (Davis 1983, Slough 1989). Release of fishers in summer time resulted in significantly smaller movements than releases in winter (1-16 km vs 10-72 km, Proulx et al. 1994), and soft release methods reduced (but did not prevent) long distance movements in martens (Davis 1983). Sea otters also showed a clear tendency to disperse from the hard-release site, with at least 30 % successfully homing, across distances of over a hundred kilometres in California (Estes et al. 1993) and 8 of 9 returning home from 23-54 km within 6 days of release in Alaska (Garshelis & Garshelis 1984).

2.5.1.5 Felids

Despite being frequently translocated for reducing livestock predation and reintroduction purposes there is surprisingly little data describing the post-release movement patterns and homing behaviour of felids. Most data exist as single observations and notes. For example, in central Europe at least 8 separate introductions of European lynx have been made during the last 25 years. In no case have post-release movements been described from radio-collared individuals (Breitenmoser & Breitenmoer-Würsten 1990). One captive-raised juvenile Iberian lynx settled within 10 km from its release point (Rodriguez et al. 1995). In South America, two jaguars were radio-tracked after being translocated for livestock predation. Both moved away from the release site, but one was shot for again killing livestock, and contact was lost with the second after it entered an area with poor accessibility (Rabinowitz 1986, Rabinowitz & Nottingham 1986). Further evaluation of the technique for jaguars is underway in Venezuela (Reintroduction News 9:1994). One tiger translocated in India was killed by a resident tiger at the release site (Seidensticker et al. 1976).

In south and east Africa leopards have been routinely translocated. In Kenya 108 leopards were transported from farmland to a 2000 km^2 national park. Of eight that were successfully radio-tracked, all left the park. Some of these began killing livestock again. One returned after 10 months and settled near the release point (Cobb 1981). In South Africa one individual was translocated 60 km for killing livestock. He immediately returned home and began killing livestock again (Norton 1986). Similar experiences were found for leopards translocated in Namibia (Ebedes 1970). Early attempts to move livestock killing lions in Zimbabwe resulted in lions returning home after a 27 km translocation, but not after a 45 km movement. The two lions that returned to their original area resumed their killing of livestock (Van Der Meulen 1977). The best evaluation of translocation concerned lions leaving the fenced Etosha NP in Namibia (Stander 1990). Lions that were known to be killing livestock for the first time (occasional raiders) were simply translocated back into their home range inside the park (< 30km). In 11 of 12 cases this prevented further livestock predation by these lions. The only lion that returned to killing livestock had a broken leg and presumably could not kill wild prey. Lions that were known to be habitual killers of livestock (problem animals) were translocated over 100 km. Three lions immediately began killing livestock again near the release site (100 km translocation) and were shot, while two others (200 and 300 km translocation), despite partially homing, settled in an area without livestock and did not resume predation.

Recently, cheetahs and lions that have killed livestock in various parts of southern Africa have been translocated to national parks and game reserves in Zambia, South Africa and Zimbabwe to augment or re-establish populations. In most recent cases soft release methods have been used, with up to two months acclimatisation before release. Although some cheetahs have been killed by territorial conspecifics or other predators after release the methods seem to hinder widespread post-release movements (Atkinson & Wood 1995, Hunter 1995, Mills 1991, Cat News 23: 1995). However, as many reserves were fenced it is difficult to judge how much they would have moved if there had been no fence (Hunter pers.comm.). The return of Asiatic lions responsible for attacks on humans to the Gir-Forest reserve was standard management practice. Despite these translocations the rate of attacks on humans increased. However, as most individuals responsible were sub-adult it was felt that it would do no good to return them as they would be forced out (again) from the saturated territory mosaic (Saberwal et al. 1994).

Two of three captive bred servals established home ranges near their release point, while a third was killed after travelling 17 km (Van Aarde & Skinner 1986), a long movement when serval home ranges (<10 km^2) are considered. Most bobcats (of a total of 15) reintroduced into New Jersey, remained near the release site, however one was found dead 157 km away.

The best data exist from cougars which have been experimentally translocated in the United States. In New Mexico 14 cougars were translocated (hard release) an average of 477 km (range 342-510 km). Of these two adult males homed over 400 km, and the rest of the animals settled between 3 and 285 km from the release site. The mean distance travelled by females was 134 km and by males 254 km. Only five of 14 settled within 100 km of the release site. Almost all animals travelled in a homeward direction before settling. Young, but independent animals settled closer to the release site than adults. Mortality was high among the translocated cougars (70% within 2 years of release) although some females reproduced (Ruth et al. 1993, 1995). In Florida 7 cougars were translocated (soft-release with one week acclimatisation), of which four were monitored. These all settled within 32 km of the release site, although they all made large exploratory movements in the direction of home. These showed low survival in the wild due to high levels of human activity in the area. One adult female translocated in Alberta after killing livestock died from infection and starvation two months after release.

2.5.1.6 Eagles

Eagles have been translocated in at least four studies in response to livestock predation. In 14 of 16 cases where territorial adult golden eagles in Wyoming were translocated, the eagles returned from 11 to 316 days after release, despite having been transported from 416-470 km away. During their absence non-territorial individuals took over the vacant territories within a mean of 3 days (Phillips et al. 1991). In South Dakota 19 subadult golden eagles were translocated 322 km. Although the post-release behaviour of the birds is not reported, it did reduce predation on the farms in the short-term (Waite & Phillips 1994). Between 1975 and 1983 a total of 432 golden eagles (145 in 1975 alone) were translocated distances of between 160 and 750 km in response to depredation complaints. There was no follow-up of the individual eagles. Although lamb losses decreased during the study period it was felt to be due an increase in the rabbit (the eagles natural food) population and milder weather during lambing rather than the translocation program. As a result, translocation was discontinued (Matchett & O'Gara 1987). In South Africa, 42 eagles (black eagle, crowned eagle, and martial eagle) were translocated . Of eight for which subsequent movements were known, five (adults and subadults) returned from distances between 28-105 km, to their capture location. Those not homing were found to travel up to 215 km from the release site (Boshoff & Vernon 1988).

Generally, eagles appear to be able to home remarkably well over distances of greater than 400 km. Even when not returning they cover large areas during post-release movements.

There is a lack of data from re-introductions because in these cases juvenile or captive bred birds are generally used.

2.5.2 Capture and transport considerations

For translocation to work the right animal must be captured, alive. Live capture of any carnivore is a very expensive and time-consuming activity, and always presents a slight risk to the carnivore’s survival. In addition catching the right individual is a very difficult task. While at very low densities, such as for an individual dispersing or wandering beyond the boundaries of a stable population, it may be possible to catch the right animal because its the only one present. However, within a stable population with overlapping animals that use large home ranges it is only a question of probability, unless the individual is “caught in the act”. Transportation also poses risk, especially if the individual is kept drugged during the entire journey. One point which has only recently begun to attract attention is the risk of spreading wildlife diseases from one population to another (Griffith & Scott 1993).

2.5.3 Factors affecting homing behaviour

Homing and post-release movements are almost universal among translocated carnivores. Eagles appear to hold the overall record for homing (470 km). Of terrestrial species, bears are by far the most consistent at finding home, regularly finding home over 100 km, and in some cases from up to 200 km. Most wolves and cougars appear to fail to find home if translocated more than 70 km, however the record movements of 282 km for a wolf and over 400 km for a cougar must not be forgotten. The existence of geographic and anthropomorphic barriers can slow, and in some cases block movements, but these need to be fairly substantial before they can be guaranteed to stop movement. Generally, young animals remain at the release point more than adults, and females have a lower threshold distance for their ability to home than males. However the only method which provides a degree of guarantee of the animals staying near (within 100 km) the release point is a soft-release system, involving a month or two of acclimatisation to the new area. This appears to inhibit the homing response. The technique is also expensive, requiring the construction of a holding facility and constant care.

2.5.4 Effectivity

There has been very little evaluation of the effectivity of translocation at reducing the problem (livestock predation, nuisance behaviour) at the place where the carnivores are moved from. Only Armistead et al. (1994) who removed bears before the sheep season as a preventative action, Waite & Phillips (1994) who removed the majority of sub adult eagles from an area, and Stander (1990) who removed individual lions, reported any significant decline in livestock predation. In most other cases the effectivity is not reported. As many carnivores return home or move over large areas after being released, the potential for future conflicts is high, unless they can be translocated to an area several hundred kilometres from any source of conflict. While this may be practical in the large wilderness areas of North America or Africa it is not realistic to expect it to work under European conditions. The only possible circumstances where it might work would be to use some form of soft-release method to encourage the animals to remain near the release point. Despite its widespread use as a method to handle problem individuals in North America, more and more scientists and managers are regarding it as an expensive exercise in public relations, useful only if the population is highly endangered (Blanchard & Knight 1995). In remote and inaccessible areas, and parts of the work which lack a basic infra-structure it is completely impractical (Jackson et al. 1994). Accordingly the emphasis is starting to switch to fixing the factors that lead to the development of problem behaviour, i.e. removing the potential for problems (Gunther 1994, Clarkson & Marley 1995), rather than spending money to fix it afterwards.

2.6 Evaluation of predator control as a method for reducing carnivore-livestock conflicts

Main points - The value of control
- *Control assumes that a reduction in carnivore population density, or the removal of certain individuals, will lead to a reduction in depredation on livestock.*
- *Control has been the most used method to reduce depredation throughout the world ever since domestication began. The extermination of many populations of large carnivores is a result of human control efforts.*
- *It may be effective at reducing depredation provided sufficient numbers of carnivores are killed and is popular among livestock herders.*
- *Wide scale control of carnivores will in many cases be incompatible with stated conservation objectives of maintaining viable populations of carnivores.. Not often considered acceptable by the public outside the livestock industry.*
- *Population of carnivores are so low in Norway that widespread population-reduction control would be incompatible with maintaining stated conservation objectives. Only when combined with zoning would such an approach be compatible.*

The previous sections have detailed the various forms that predator control can take, and the degree to which it is used world-wide. Population reduction of carnivores through control clearly helps to reduce depredation levels on livestock (**previous sections, and sections 6.2, 6.3, 6.5**). Not enough data exist to evaluate the success of selective removal of "problem animals". When evaluating the success of control the question is not one of whether or not control works , but rather is in fact five different questions;
- is it socially acceptable?
- is it cost effective?
- is it compatible with management objectives like conserving viable carnivore populations?
- is it the only solution?
- is it possible to monitor, so that its effectiveness can be evaluated?

Only when all these aspects are considered can the success of control be evaluated properly.

2.6.1 Changing attitudes

Control was once considered to be the only method of resolving carnivore conflicts with livestock, as the eradication of bears, wolves, lynx, cougars, lions and tigers from most of their range's testifies. Even as late as 1985 a book (Gaafer et al. 1985) in the World Animal Science series (aimed at providing scientific knowledge to improve livestock husbandry world-wide) dedicated all of six chapters to predator control after building up a moral argument for this policy (Howard 1985). Not one other conflict reduction method, such as improved husbandry, was even mentioned.

Since the early 1970's there has been a widespread change in public and professional opinion towards carnivore conservation, and the entire ethic of nature conservation and exploitation. As well as discouraging the use of poisons, especially widespread baiting, there has been much interest in other methods of reducing depredation through both improved husbandry and some modern hi-tech solutions (see **next sections**). Yet is there still a need for lethal control to reduce livestock depredation to acceptable levels? The answer to this question clearly depends on the situation and on the definition of management objectives.

2.6.2 Control and abundant species

At global and national levels the present level of carnivore control for the purposes of limiting livestock depredation is unlikely to have any serious impacts on the survival of abundant species such as coyote, dingo, jackals and many of the foxes. The scale of their depredation on livestock, even when husbandry is optimal, is still likely to require some form of population reduction brought about by lethal control measures, at least on a local scale. The greatest limitation on the use of control lies in the cost and its effectiveness. As discussed by Harris & Saunders (1993) a full cost : benefit analysis of the value of canid control operations has rarely, if ever, been carried out. The debate on which form of control, and at what level, is more a discussion about the welfare of individual animals than about the conservation of viable populations.

2.6.3 Control and endangered species

When the larger species of carnivore (most of which are endangered, at least on national scales) are considered, a whole new debate occurs. In many cases population reduction by lethal control would be completely incompatible with the conservation goals of maintaining viable populations. These species can often cause disproportionate levels of damage to livestock. However, in most areas of Europe, Africa, Asia and North America large carnivores exist at very low densities, with many populations having low numbers and being relatively isolated from other populations. Clearly most of these populations can not be reduced any further without threatening their existence. On the other hand these species are often relatively easy to control, and their slower reproductive rates implies that control can have greater population level effects. Therefore there is great potential for pushing these populations over the edge of local extirpation if depredation is responded to through lethal control. If a few problem individuals are responsible for a disproportionate amount of the depredation these can theoretically be removed. As we have discussed, translocation can not be considered to be a valid technique for general application unless there is a large area with low conflict where the individual can be released, or a need for captive animals. In most cases problem individuals will need to be controlled lethally. In the case of endangered carnivores and depredation there is clearly a need for solutions other than population reduction. These solutions lie in improved husbandry and in integrated land use planning (**sections 3.0, 4.0, 5.0**).

An exception is when endangered large carnivores expand in range and increase in density in some areas due to effective conservation, there may be a need to prevent their expansion into certain areas where the potential conflict is too high to be acceptable (Fritts 1982, Mech 1995). Failure to control individuals in such areas will turn public opinion against their conservation in general, and relying on illegal control to limit numbers will lead to a weakening in the authority of the management authorities. The drawing of borders for management zones and deciding on levels as to what is acceptable or not are probably the biggest problems facing large carnivore management (**section 4.1.3**).

2.6.4 Other possible solutions

When control is not cost-effective, not socially acceptable or incompatible with other management objectives it is important to look for other solutions to the problem of depredation. These can be grouped under the headings of improved husbandry and zoning of space use and will be discussed in the next two sections.

3 Reduction of carnivore depredation on livestock through improved herding techniques and domestic animal management

Main points - Introduction to husbandry methods for reducing depredation

- *Husbandry methods have been used to reduce depredation since domestication began.*
- *The traditional methods have rarely been evaluated using scientific experiments, however, many thousands of years of experience must be regarded as one long experiment. In contrast many modern methods have been tested experimentally.*

Husbandry in its broadest sense includes all measures that a herder uses to maximise survival, growth and production of his herd. This section examines the ways in which changes to the way the animals are herded and managed might decrease livestock depredation. One problem is the lack of experimental analysis of the success of traditional herding methods. In areas with predators these methods are used by all herders because they work, failure to use them would be regarded as an invitation for predators to depredate livestock. Thus the success of certain methods can only be determined based on their long-term traditional use. Supporting this view is the trend that many of the largest carnivore-livestock conflicts in Europe are from areas where carnivores were originally exterminated and the traditional methods forgotten (Kaczensky 1996). On the other hand many of the modern, hi-tech, attempts to reduce depredation are well documented and evaluated through experimental studies. Some of these methods attempt to improve on (e.g. electric fencing) or rediscover original techniques (e.g. guard dogs), however most attempt to achieve the same effect but with less human labour involved (e.g. aversive conditioning, sirens and lights).

This section presents most of the different husbandry methods (modern and traditional) which have been used to reduce depredation of livestock. As well as describing and evaluating the different methods we present a series of case studies that describe the different levels of depredation from various parts of the world that use different husbandry methods.

3.1 Common traditions of livestock herding

Main points - Common traditions of livestock herding
- *There is an almost universal system of herding livestock in environments where large carnivores exist. This consists of night-time enclosure in solid corrals and constant shepherding in day-time, often with the use of dogs for both guarding and herding.*
- *The largest carnivore-livestock conflicts today occur in areas from which carnivores have been absent and have recently returned. Such areas have generally abandoned traditional herding in favour of free-ranging and unsupervised grazing.*

There has been an almost universal pattern of herding livestock in environments containing predators. By day the animals were allowed to graze as a herd, under the care of a shepherd. Livestock were prevented from spreading out, either by the shepherd or a herding dog. The shepherd directed their movement and selected the areas to be grazed during the day time. At night the flock was rounded up and either herded into a fenced area or bedded under supervision in an open area. A shepherd usually slept near the flock. Only adult cattle and perhaps horses would be allowed to wander free at night, and these would remain near the night time enclosure. In most European and middle-Eastern regions large guarding dogs were also kept with the flocks by both day and night. Such measures also protected against theft and allowed better care of flocks. Accidents during day time could be prevented, and local overgrazing could be avoided by keeping the flocks on the move. This constant care and rounding up of animals was also important when milking of sheep and goats (and in some cultures horses and yaks) was more common (Farson 1951, Kaczensky 1996).

As many carnivore populations were lethally controlled to the point of local extinction these labour-intensive husbandry methods were abandoned. Many of the carnivore-livestock conflicts today are associated with either increases in carnivore populations in areas where they have been temporarily absent, human expansion into carnivore areas, or changes in social-economics which effect the cost effectivity of labour intensive agriculture.

3.2 Protection of livestock with fences

Main points - Protecting livestock with fences
- *Carnivore-proof fences physically prevent carnivores from entering livestock areas. Such fences are generally constructed from wire netting and are often electrified.*
- *In Australia and many African countries entire ecosystems are fenced to reduce contact between carnivores and livestock, whereas in Europe and North America only areas as large as individual pastures or night-time enclosures are fenced.*
- *In view of the costs and ecological side effects of large scale fencing, carnivore-proof fencing is likely to be most effective and practical for night-time enclosures.*

Fences have been used to protect livestock and fields from animal and human depredations since ancient times (Wade 1982). An anti-predator fence operates by physically preventing a carnivore from gaining access to livestock.

Different forms of livestock protection fences have been developed and persist world-wide. Materials used in the construction of fences range from earth and vegetative materials to wire, electric shock, and synthetic materials (review in Fitzwater 1972, Wade 1982). The area fenced off can differ in size from whole regions to small pastures or focal attraction points.

Fencing can be used to reduce carnivore predation on livestock in different ways;
- Predators can be kept out of the whole grazing area by building predator-proof fences around it.
- Livestock can be kept inside predator-proof night-time enclosures, and let out during daytime. This might be combined with daytime grazing areas inside ordinary sheep fences.
- Whole regions might be fenced in with predator-proof fences (see **section 6.2 and 6.8**).

The type of fencing used depends on which of the above mechanisms is the objective. This chapter reviews the international experience on different techniques on protecting livestock with fences.

3.2.1 Fences made of earth and vegetation

A wide range of materials have been used in the construction of fences throughout history. The most primitive barriers were made of earth and rocks (Fitzwater 1972). Remnants of these primitive fences are still visible in several parts of Norway (Bevanger & Henriksen 1996). Stone and earth fences have also been combined with ditches filled with water (Fitzwater 1972). Pits or trenches, often filled with water, have been used

Box 1 Animal husbandry in the Marsabit district, Kenya

Kruuk (1980) conducted a survey in the western Marsabit District, Kenya, to assess the amount of livestock taken annually by carnivores and the circumstances under which the animals were killed. The tribes in the area protected their livestock with herdsmen and bomas. Bomas are thorn fences in and around the villages where the tribe keeps their livestock at night. Spotted hyenas, lions and black-backed jackals were the most important cause of livestock losses in the area. Night-time confinement was so successful that almost 90% of the predation occurred away from the manyatta (village) either when the livestock was foraging (by lions, cheetah, wild dogs) or when it had gone astray at night or was returning late from grazing areas. The most important function of the bomas was to contain the livestock, but it also served to keep predators out. The tribe with the most solid bomas had the lowest predation rate.

to protect crops and livestock from wildlife in general, including carnivores and elephants in Africa (e.g. Woodley 1965).

Natural vegetation is used extensively in fences around the world. Barriers of thorny shrubs are used as protection of sheep at night from depredation, for example by jackals in India (Fitzwater 1972) and against a range of large predators in Africa (Kruuk 1980, **box 1**, **section 6.8**).

3.2.2 Conventional netting fences

Wire is probably the most common fencing material used world-wide today (Fitzwater 1972). Wire fences include conventional netwire or combinations of net and barbed wire (Wade 1982). The construction and materials used varies with local husbandry practices and which carnivore is to be excluded. Despite the reported widespread use of fences for the control of depredation, evaluations of effectiveness have been limited.

Most pen and field tests of anti-predator fences have been carried out in Canada and the United States. Most of these have been directed to the exclusion of dogs, coyotes, black bears, grizzly bears and polar bears.

3.2.2.1 Dingo

The longest wire fences in the world are found in Australia (McKnight 1969). Netting fences have been used in the eastern states of Australia for many decades and generally act as a barrier along the extensive and distinct boundaries between sheep grazing areas and cattle country. The major sheep-raising areas of Queensland, New South Wales and South Australia are protected by a 5 200 miles long dingo fence (Bauer 1964). The Australian dingo fences are 6 feet high with 4-inch hexagonal mesh. The fences do not function up to the ideal of total exclusion. Even well-maintained fences are sometimes crossed by dingoes, although it is felt to decrease the rate of immigration, making control more feasible (Thomson 1984, 1986).

3.2.2.2 Coyote

Well-maintained and properly built non-electric netwire fences have been effective in excluding coyote. Thompson (1978, 1979) evaluated the effectiveness of 34 electric and non-electric wire fence configurations in deterring crossing by 15 captive coyotes. The results indicate that a coyote-proof fence should be at least 168 cm high, have meshes no larger than 15.2 x 10.2 cm, and have an overhang and apron projecting at least 38 cm. DeCalesta & Cropsey (1978) field-tested this recommended design with promising results. Fences were constructed around 2 pastures on ranges with histories of sheep losses to coyotes. No sheep were killed during the first year of the test.

3.2.2.3 Bears

An extremely strong and high, non-electric fence has been used to prevent polar bears from entering a permanent research camp located near Churchill, Manitoba (Bromley et al. 1992). Chain link and woven fencing have also been used to deter grizzly and black bears, but the bears have been able to penetrate the fence by making holes in it, digging underneath or climbing over the fence (Clarkson & Marley 1995).

3.2.2.4 Felids

Little or nothing is known about the effectiveness of exclusion fences in deterring livestock predation by felids, although their natural jumping and climbing ability would indicate the need for a very high fence.

3.2.3 Electric fences

Electric fences have been developed to exclude a variety of carnivore species (reviews in Wade 1982, LeFranc et al. 1987). Some make use of an existing fence and incorporate one or two electrified wires on outriggers, others are constructed as plain wire fences with alternating live and earth wires. The number of wires and voltage in use depends on which carnivore species are to be excluded. Reducing the wire spacing and increasing the number of wires increases the effectiveness of

Box 2 The components of electric fences

Electric fences can be permanent or temporary. A successful electric fence depends upon several factors:
- electric fence energiser
- wire and posts
- grounding conditions
- type of carnivore to be excluded

Energisers and Batteries: Many models of electric fence energisers are available, from those designed for a short one-wire fence to ones designed for up to 60 kilometres of wire or more. Battery operated fences are useful on locations where portability is desired or no electrical supply exists. Twelve-volt electronic energisers are most effective, generating up to 5000 volts output.

Wet cell batteries are commonly used for 12-volt energisers. These require charging every 2-3 weeks. In recent years solar charged electric fence energisers have been perfected. While initially more expensive they become cost effective because batteries are unnecessary.

Wires and posts: Wire acts as the conductor of the electrical fencing system and is available in a variety of formats. The number and spacing of wires used depend on which animal is to be excluded. Reducing the wire spacing and increasing the number of wires increases the effectiveness of electric fences, but also increase their cost. Wooden posts are ideal for permanent fences. Materials such as plastic, fibreglass and metal are also used especially for temporary fencing. Metal posts need insulators to avoid the danger of short circuiting.

Grounding: All electric fences must be grounded. A metal rod is driven into the earth and a wire is attached from the ground connection of the energiser to the metal rod. There is no need for the ground wire to be insulated. When the carnivore makes contact with the fence, the current passes from the energiser and fence through the animal to the soil and completes the circuit via the ground rod back to the energiser. Achieving an effective ground can be difficult on dry or frozen substrate. This problem can be corrected by laying a grounded, wire-mesh mat around the fence.

Fence maintenance: Care must be taken to see that vegetation does not touch the hot wires of the fence as this will cause a short circuit and render the fence inoperable. Storage batteries must be kept charged and should be checked every two weeks. Batteries should not be in direct contact with the ground and should be protected from the elements, for maximum operating life.

Fence baiting: Electric fences can be made more effective by baiting. Perforated cans of sardines or bacon may be wired to the hot wires of the fence to induce bears to lick the fence. This may help condition the bears to avoid bee hives and electric fences.

Type of carnivore controlled: The type of animal to be controlled has a direct effect on the design of the fence and the choice of electric fence energiser. The number of wires and their spacing is determined according to animal size and physiology. The voltage required for the fence depends on the insulating qualities of the animal's coat.

Permanent fences: When an apiary or livestock protection fence is used year after year, one might consider constructing a permanent type of electric fence. Pressure treated wooden fence post or steel fence posts are driven 60 cm into the soil at 3-4 m intervals. The corner post should be firmly braced with guy wires or struts. Plastic or porcelain insulators are nailed or fastened to the outside perimeter. Smooth solid wire or plastic woven electric fencing wire is suitable for permanent electric fences; barbed wire is difficult to work with but will help deliver the shock to animals with thick coats.

Portable Electric Fences: If an apiary site or pasture is moved annually or during the season, portable electric fences are desirable. Several types of portable electric fences have been tested. The Alberta government in co-operation with beekeepers developed an effective portable electric fence which has been in use since 1977. The fence consists of 120 cm lengths of 18 mm diameter PVC plastic posts, metal rod or rebar stakes and 1.7 mm wire rope. No insulators are required. Four or five 3 mm holes are drilled through each PVC post coinciding with the wire heights starting at 20 cm from ground level. The wires are then threaded through the appropriate holes and subsequent rounds are spaced at 18 cm. Metal stakes are made by cutting rebar into 65 cm lengths and welding 33 mm washers, 18 cm from end. The stakes are driven into the ground at 3-3.6 m intervals to the washer level allowing the 18 cm end to protrude. The PVC posts are placed over the stakes. The corner post must be firmly secured with guy wires. When moving, the fence posts are lifted from the rebar stakes and the fence is rolled up.

electric fences, but also increases their cost. The different components of an electric fence are explained in **box 2**.

3.2.3.1 Coyote

Properly constructed conventional netwire and electric fences can effectively exclude coyotes from pastures containing domestic livestock (DeCalesta & Cropsey 1978, Gates et al. 1978, Thompson 1978, 1979, Dorrance & Bourne 1980, Linhart et al 1982, Wade 1982, Nass & Theade 1988). Gates et al. (1978) tested a 1.5 m high electric fence that successfully excluded coyotes in a penned test of 2 weeks duration. Gates et al. (1978) constructed two 1.8 ha enclosures within a 64 ha coyote-proof test pasture. One enclosure was constructed to approximate a conventional sheep fence. The other was an electric fence of 12 wires (alternating charged and grounded) with an additional charged trip wire 20 cm from the fence around the outside perimeter. Eight lambs were placed in each enclosure and 2 coyotes were placed within the 65 ha pasture. During two-week tests, all the lambs within the conventional fence were killed within 9 days, but no losses occurred within the electric fence.

Dorrance & Bourne (1980) evaluated the use of electric fences for the prevention of coyote predation of domestic sheep during the grazing seasons on five farms in the forested area of Alberta. The fences eliminated or sharply reduced predation, and the authors concluded that these fences provide an economical, effective, non-lethal method for preventing coyote predation of domestic livestock.

Linhart et al. (1982) conducted field tests to evaluate electric fencing for protecting pastured sheep from coyote predation in North Dakota and Kansas in 1977 and 1978. In 1979 37 sheep producers using electric fences to exclude coyotes were interviewed. An all-electric 12-wire, 168 cm high fence with alternately charged and grounded wires spaced 13-15 cm apart stopped ongoing coyote predation on the two North Dakota test sites. Four or five strands of electric wire, offset 13 cm from existing woven and barbed wire sheep fences, effectively prevented further coyote predation at two Kansas sites. Sheep producers interviewed expressed a high to moderate degree of satisfaction with the use of electric fencing.

Nass & Theade (1988) investigated the use of anti-predator electric fences for reducing predation on sheep by interviewing 101 sheep producers in the Pacific Northwest. Significant reductions in sheep losses to predation were reported after installation of electric fences compared to pre-fence losses.

3.2.3.2 Bears

lectric fences are also widely and successfully used to isolate attractants like bee yards, garbage dumps, live stock and construction camps from black and grizzly bears (e.g. Storer et al. 1938, McAtee 1939, Wade 1982, LeFranc et al. 1987, Clarkson & Marley 1995, Kaczensky 1996). Much of the relevant literature on electric fences relates to the prevention of black bear damage to bee yards or apiaries.

Several types of electric fences have been used to deter black and grizzly bears, including;

- a portable, totally electrical fence of at least four strands of wire for black bears,
- various designs combining electric wires and sturdy welded wire or chain link fence to keep out black and grizzly bears (Bromley et al. 1992).

Electric fences were used to exclude grizzly bears from garbage dumps in and around Yellowstone National Park beginning in the early 1970s. A high voltage (12 000V), low amperage (22 ma) electric fence, 2.7 m high and 0.9 m buried, was 100 % effective in preventing bear penetration (Hepburn 1974 cited in LeFranc et al. 1987). The same design was later used successfully in Denali National Park (Herrero 1982 cited in LeFranc et al. 1987).

Several electric fence designs have been used to deter polar bears (Bromley et al. 1992);

- a simple two strand, high voltage fence for use only in moist or wet areas,
- an electric fence with a charged chain-link skirt on the ground outside the fence for use on dry or frozen ground.

Simple electric fence designs have in some cases not successfully stopped polar bears. Bears did not receive a shock from the fence because of either insulation provided by their fur and footpads, or poor grounding conditions associated with snow or dry, frozen soil (Bromley et al. 1992). A 60 cm high, 2-strand, electric fence kept polar bears out from a research station in Manitoba, Canada, for the 23 weeks it was operational. The fence was powered by a 12 volt battery, and gave an operational output of 8 000 volts.

LeFranc et al. (1987) provide a review of successful fence designs, and drew the following conclusions:

- Various charges have been used, but in general, high voltage (10000 V or more) and low amperage (1 amp or less) will ensure a sufficiently painful jolt if contact is made.
- Barbed wire will ensure better contact than smooth wire
- Achieving an effective ground can be difficult on dry or frozen substrate. This problem can be corrected by laying a grounded, wire-mesh mat around the fence.
- Baits might be attached to the charged wires so that the bear would contact the wire with the non-insulated nose or mouth and receive a more effective shock. Some authors caution against the use of baits before bear problems develop because it could act as an unnecessary attractant.

- Bears must be prevented from digging beneath a fence. A wire mat, buried fence, concrete pads or other physical obstructions could be used.
- Fences must receive regular, proper maintenance to operate effectively
- Gates represent an unavoidable weak point with any electric or physical barrier

A portable electric fence may be preferable in some cases to the permanent structures described above. For example, if an apiary site is moved annually or during the season, portable electric fences are desirable. Several types of portable electric fences have been tried out. The Alberta government in co-operation with beekeepers developed an effective portable electric fence which has been in use since 1977 (Wynnk & Gunson 1977 cited in LeFranc et al. 1987). A portable, high-visibility electric fence was effective in preventing depredation in 95% of 500 black bear incidents (Hunt 1985 cited in LeFranc et al. 1987).

3.2.3.3 Felids

Few studies have been published concerning different electric fence designs to keep out felid species. Observations of mountain lions gaining access to pastures surrounded by netwire and electric fencing indicate that the species is difficult to exclude with fences (Fitzwater 1972). South African sheep farmers reported that adding a few strands of electric wire to existing jackal proof fences was successful at excluding caracals, and in some cases leopards (Boland 1986).

3.2.4 Effects of fences on non-target species

The construction of fences might have secondary effects on non-target wildlife species. Bevanger & Henriksen (1996) review possible effects of fences and other man-made barriers. They conclude that human made barriers may cause appreciable bird mortality, but mammals also become trapped and killed in them. In addition to the direct killing of several species of birds and mammals, fences (and other barriers) might destroy habitats, fragment the landscape and reduce the overall quality of habitats. The effect is obviously going to be linked to the length and the height of the structure. While a standard sheep fence may have little effect on most species, a substantial predator-proof fence may black movements of most terrestrial species.

3.2.5 Conclusions

It is possible to construct fences that can protect livestock against most carnivore species. However, fences appear to be most useful and cost-effective on small open pastures or around night-time enclosures and appear to be least successful on large pastures with high vegetative cover. Difficulties and costs of fence maintenance are related to terrain, soil types, dense vegetation, fence damage by livestock and other animals, heavy snows, floodwaters and other causes. Electric fences are more cost-effective than conventional netwire fences. Generally speaking, excluding large predators from large areas of pasture is unlikely to be economically viable or even acceptable because of the side effects on other wildlife. An exception is when virtually entire ecosystems are fenced, like in Australia and many reserves in southern Africa. Fencing on this scale permits the close association of carnivores and other wildlife with livestock. However, there are few places where fencing on such a scale is an economically viable solution today. A system where livestock movement is restricted to ease husbandry, coupled with predator-proof night-time enclosures is likely to be both cost-effective, practical and successful. Lambing or calving areas should also be fenced to ease surveillance. These fences could easily be electrified to exclude the smaller, more abundant predators that are most likely to cause damage on new-born livestock.

3.3 Visual and acoustic repellents

Main points - Visual and acoustic repellents

- *Devices that emit frightening sounds or flash lights have been tested to determine if they can scare carnivores away from sheep pastures.*
- *While there has been limited success at preventing depredation on discrete pastures, there has been virtually no success on open range. These methods are only useful to prevent depredation on discrete areas for short periods of time - for example on lambing pastures.*
- *Carnivores generally habituate within a period of days or weeks.*

3.3.1 Principles and concepts

The basic goal of using frightening devices/stimuli is to prevent or alleviate damage by depredating mammals by reducing their desire to enter or stay in the area where livestock are kept or where attractive points like crops, livestock and campsites are located (Bomford & O'Brien 1990, Koehler et al. 1990). Various visual and acoustic devices have been used for this purpose. The manufacture and sale of such devices has become a large industry in North America (e.g., Stewart 1974, Blackshaw et al. 1990). Most visual and acoustic repellents rely on fear or perceived danger avoidance for their effect (Bomford & O'Brien 1990). Carnivores are often sensitive to changes in their environment. Thus, the presence of any unusual sound, sight or smell may keep carnivores away from an area for a certain period of time. A variety of visual stimuli are used to scare animals from livestock, crops and gardens. These include stimuli which generally involve lights, movements, and/or various types of reflective objects, plus traditional scarecrows (Koehler et al. 1990).

Two main approaches using sound as a repellent exist. Non-biosonic repellents utilise sound with high frequency and pressure levels (intensity in dB) to cause pain or discomfort to the target animal, and include devices like bangers, crackers, clangers, poppers, bombers, and sirens. Biosonics use biologically significant sounds to cause distress in an animal. Examples of biosonics include broadcasts of recorded alarm calls to drive birds from airfields, and aggressive sounds of polar bears to keep bears away from garbage sites (LeFranc et al. 1987, Bomford & O'Brien 1990).

3.3.2 Review of international experience

The majority of the scientific literature on the use of visual and acoustic repellents are descriptive and concern coyotes, grizzly bears, black bears and polar bears (review in Conover 1981, LeFranc et al. 1987, Bomford & O'Brien 1990, Koehler et al. 1990). Few experiments have been designed to evaluate the effect of these devices on predation on livestock range, and most of the tests are done in areas with depredating coyotes.

3.3.2.1 Coyotes

A variety of visual and acoustic devices have been used for years to reduce coyote depredations of sheep. Examples of devices used include vehicles, scarecrows, electric lights, radios, belled sheep and propane or acetylene exploders (Pfeifer & Goos 1982, Linhart et al. 1984, Koehler et al. 1990) (**table 3.3.1**).

Gas exploders have been used to deter coyotes temporarily from praying on domestic livestock. Gas exploders ignite a quantity of propane gas at timed intervals resulting in a brilliant flash and a rifle-like boom. Gas exploders are portable, easy to operate, and have relatively low operation costs (Andelt 1996). Pfeifer & Goos (1982) obtained information from 26 North Dakota sheep herders who used propane exploders to prevent coyote predation. The ranchers were told to activate the exploders from before dark until daybreak, the exploder locations were changed every 4-5 days, and exploder timers were set to "fire" every 7-8 minutes. Exploders deterred coyote depredations on sheep for an average of 31 days (range 1-180 days). The authors concluded that the most important factor determining exploder efficacy were their proper use and maintenance by producers. Propane exploders also deterred coyotes from killing sheep for 6 weeks on 1 ranch in Saskatchewan (Rock 1978, cited by Linhart 1984).

Battery-operated strobe light/siren devices have been tried to reduce or prevent coyote predation on sheep. Linhart et al. (1984) examined the effects of 2 different portable and battery-operated strobe light/siren devices on coyote predation on pastured sheep. The two devices were composed of an electronic timer wired to a commercial strobe light, siren (110-dB and 123-dB) and a 12-v battery. Ten-second signals were generated at a fixed interval sequence (2-15 min) during night and for 1-2 hours after sunrise. The two devices protected pastured sheep from coyotes for a mean of 53 nights (10 trials) and 91 nights (5 trials). Further field tests of a 12-v battery-operated electronic frightening device were made on high mountain summer sheep range in three different geographic areas (Linhart et al. 1992). Sheep were moved to the grazing allotments in early July and removed in September. Herders stayed close to the sheep during the whole season. The experimental frightening device consisted of a PVC case, a timer, a blinking strobe light, and a warbling type siren that was activated for 7-10 seconds at about 6-7 minute intervals throughout the night. One device was placed in the centre of the bed ground, and 3 others around the edges. Sheep losses were reduced on average by about 60% compared to summers without the use of the devices.

Other methods of deterring coyote predation include parking vehicles or playing a radio near areas where predation occurs (Andelt 1996). Robel et al. (1981) reported that producers placing lights over corrals sustained lower losses than producers that did not use either technique. The presence of bells on sheep in pastures did not deter coyote predation.

Table 3.3.1 Tests of the effect of various sound and light emitting devices on depredation by coyotes on sheep

Carnivore species	Device tested	Husbandry technique	Av. days deterred	% red. pred.	Method	Ref.
Coyote	Gas exploder put out near sheep bed grounds. Set to "fire" every 7-8 min. all night. Shifted after 4-5 days	Sheep on pastures	29 (1-180 days)	yes	Questionnaire 24 sheep farmers	1
Coyote	2 different strobe light and siren devices.	Fenced and pastured sheep	53 and 91 days	yes	Started field trials after 5 coyote kills recorded	2, 3
Coyote	12 V battery operated blinking strobe light and siren device. Activated for 7-8 sec. at 6-7 minute intervals every night.	Herded sheep on high mountain summer ranges		60%	Losses this season compared with losses in previous season	4

1. Pfeifer and Goos 1982. 2. Linhart 1984. 3. Linhart et al. 1984. 4. Linhart et al. 1992

The experiments show that depredation from coyotes may be delayed, reduced, or prevented for a certain time with the proper use of non-biosonic repellents (**table 3.3.1**). However, in the absence of experimental controls, it is difficult to assess whether these results are an indication of device effectiveness or an artefact of temporal clumping in coyote predation on sheep (Bomford & O'Brien 1990).

3.3.2.2 Wolves

No systematic research trials have been done to test the effect of frightening devices on livestock depredations by wolves. Flashing highway lights and sirens have been deployed at farms in Minnesota in response to wolf predation on livestock (Fritts 1982, Fritts et al. 1992). The method seemed popular among the livestock owners, but whether these devices actually were successful in frightening away wolves was not certain.

3.3.2.3 Felids

Little or nothing is known about the effect of acoustic and visual repellents on livestock predation by felids. Visual and acoustic stimuli like scarecrows, portable radios playing loud music and tape recordings of barking dogs have been tried against bobcats and mountain lions, but there is little evidence as to whether the techniques are effective or not (Koehler et al. 1990).

3.3.2.4 Bears

Several acoustic deterrents and repellents for bears have been tested (review in LeFranc et al. 1987). Wooldridge & Belton (1980) recorded the aggressive sounds of captive polar bear and tested it on captive and free-ranging polar and brown bears. All captive and free-ranging bears except the two individuals that were the source of the sounds were intensely frightened by the recordings. Wooldridge (1983) tested 74 free-ranging polar bears with the same acoustic repellents as described above. 51 were strongly repelled, 8 showed no response, and 15 investigated the sound.

Miller (1983) tested the repellent effects of recorded, aggressive polar and grizzly bear vocalisations on captive and free-ranging bears. In 50% of the field tests, polar bears were repelled . The most promising acoustic repellent was a hand-held, freon-powered boat horn. Captive grizzly and polar bears were repelled by this device in 81% of 31 lab tests; however bears were also repelled during 50% of the control tests. The horn repelled free-ranging polar bear in 81% of 31 field tests but, again 50% of the control tests elicited an escape response. The horn has also been tested on captive and restrained black bears without success (LeFranc et al. 1987). The bears reacted with increased aggression. Taped sounds of male grizzly bear also caused male black bear to charge and remain aggressive.

Recordings of barking dogs have been tested as a deterrent for polar bears at Cape Churchill, Manitoba (Stenhouse 1982. 1983, cited in LeFranc et al. 1987). In the first field season, 87% of the approaching bears (n=26) were not deterred and in 4 cases became aggressive. In the second year (n=131) no bears were deterred by the recordings.

Flares, thunder flashes and various other pyrotechnic devices have been used as bear repellents (LeFranc et al. 1987). Captive black bears have responded aggressively to flares during tests. However, other tests of "flare/scare-cartridges" have showed that these devices might have a potential as repellents on free-ranging polar bears. A propane cannon noisemaker was used to frighten a grizzly bear away from a sheep allotment near Yellowstone National Park, but was only temporarily effective (Matejko & Franklin 1983, cited in LeFranc et al. 1987).

Portable radios and blaring music have also been tested on bears. While these may give some short time relief, animals tend to become accustomed to these in a few days or weeks (Koehler et al. 1990).

3.3.3 Conclusions

Properly used visual and acoustic devices represent non-lethal methods that seem to work as carnivore deterrents at least for a limited time period. Small areas and attractive points are easier to protect with sound and light producing devices than big pastures. Open range is impossible to protect with these method. One significant advantage is that these methods can give immediate results. The biggest problem with the use of acoustic and visual repellents seem to be the process of habituation. After some time animals tend to adjust to and ignore the new sound. Bomford & O'Brien (1990) have reviewed the literature dealing with evaluation of devices using sound to control animal damage. They concluded from these laboratory and field trials that best effect are obtained when:

- Sound is presented in random intervals.
- A range of different sounds are used.
- The sound source is moved frequently.
- Sounds are supported by additional methods, such as distress calls or visual devices;

and

- when sounds are reinforced by real danger, such as shooting.
- While such devices may help protect a focal pasture from depredation for a critical period such as lambing, or help repel carnivores from a night-time enclosure or guarded bed ground, they do not represent a magic solution to ending depredation problems. The social acceptance for noise producing devices by neighbours is clearly important, as is the fire risk from flare and explosive devices.

3.4 Aversive conditioning, deterrents and repellents

Main points - Aversive conditioning, deterrents and repellents

- *Aversive conditioning aims to provide negative experiences for carnivores depredating or approaching livestock. The principle is that the individual carnivore will learn to avoid livestock in the future so as to avoid the negative experience.*
- *Conclusions from most trials have been inconclusive, however it appears that the main problem is to get the carnivore to link the negative experience with the act of depredation on sheep.*
- *Many methods exist to scare carnivores away from certain areas during close encounters.*

3.4.1 Introduction

Aversive conditioning refers to the elimination of an established, undesired behaviour, by associating that behaviour with some disagreeable conditioning stimulus. There are many types of conditioning stimuli designed to affect subjects physiologically and psychologically. Stimuli (sights, sounds, tastes, etc.) are applied such that the subject associates a negative event (illness, pain, fear, etc.) with performance of the undesired behaviour. If conditioning is successful the undesired behaviour is stopped or moderated (a conditioned response). The retention time of the conditioned response and the number of treatments necessary to achieve it are important measures of the success for a particular conditioning stimuli. For predators most aversive conditioning attempts have focused on establishing taste or smell aversions to certain prey items (food aversion learning) or eliminating aggressive, or overly-curious behaviour towards people (deterrents and repellents).

Deterrents, defined by Follmann *et al.* (1980), include any physical, chemical, acoustical or other device designed to discourage the presence of an animal in a specific area (campgrounds, landfills, etc.). Repellents include chemical sprays, projectiles, explosives, visual stimuli, or any other technique designed to cause an approaching, or attacking animal to stop that approach. To be effective, deterrents should have a long-lasting effect whereas repellents may provide only an immediate, short-term effect. Thorough reviews of these topics have been published previously by Follmann *et al.* (1980) and Hunt (1984). This article reviews these techniques, and explains their limitations in application.

3.4.2 Food aversion learning

There is no question that animals can be taught to avoid selected foods with aversive conditioning and there is a vast body of literature from laboratory investigations, mostly on rats (Dorrance & Gilbert 1977; Riley & Clarke 1977). Most predator research on aversive conditioning has concentrated on attempting to instil coyotes, bears, and wolves with an aversion to a target prey by lacing baits (rabbit, sheep, chickens, etc.) with an emetic chemical compound that causes severe nausea. Most studies have tested lithium chloride (LiCl) (Gustavson *et al.* 1974) but other emetic compounds used include cupric sulphate ($CuSO_4$) (Dorrance & Roy 1978), anthelmintic thiabendazole (TBZ) (Ziegler *et al.* 1983, Gustavson *et al.* 1983), emetine hydrochloride (EHCl) and alpha-naphthyl-thiourea (ANTU) (Wooldridge 1980).

Theoretically, aversive conditioning of carnivores against a selected prey could be a useful tool for managers for a number of reasons. It is non-lethal, thus reducing management related mortality of carnivores in endangered populations, and addresses the increasing public pressure against control actions for all populations. If the predator in question is territorial, then aversively conditioned individuals would continue to defend their territories from other non-conditioned individuals, thus reducing depredation by transients and immigrants. Lastly this technique probably would have limited negative effect on non-target species if the chemicals and dosages used are carefully selected.

There continues to be a great deal of controversy over this technique with inconsistent results leading to questions as to whether an aversion to eating a particular animal will deter killing of that animal. We will attempt to present both sides of this debate though readers are strongly encouraged to read the selected articles and form their own opinion.

3.4.2.1 Laboratory studies

Gustavson *et al.* (1974) indicate that captive coyotes may acquire LiCl based aversions for selected prey. These results were somewhat inconclusive because 2 of 3 coyotes continued killing lambs after the first treatment and subsequent treatments included an intraperitoneal injection of LiCl. Additional testing of 3 coyotes, using LiCl-laced rabbit carcasses together with a LiCl injection instilled an aversion to live rabbits after 2 treatments, that lasted for 4 weeks, 2 weeks, and 1 week for the 3 coyotes (Gustavson *et al.* 1974). These results were criticised by Bekoff (1975) because of the use of two treatment methods (first bait then bait and injection) and the inappropriateness of these methods to field applications. Gustavson *et al.* (1975) responded that the methods for the hypotheses they tested were appropriate and that positive results indicated further testing of LiCl-laced baits and carcasses was appropriate.

Acknowledging that the use of injections as a management tool is useless for aversive conditioning, Gustavson *et al.* (1976) next considered the aversive effects of LiCl laced carcasses and baits on predators.

They tested rabbits and chickens on captive coyotes, sheep meat on captive wolves, and deer meat on a captive cougar. Results indicated an aversion to the treated carcasses after 1 or 2 treatments while continuing to take alternate, untreated, prey. Other researchers have had less success in producing these aversions. Conover *et al.* (1977) failed to instil aversions in 5 coyotes to LiCl treated chicken carcasses; they continued eating the baits (avoiding only the lithium chloride injection sites, reflecting the detectability of the salty taste of LiCl). The coyotes also continued killing and eating live chickens. An aversion to mice baits was produced but no change in the killing and eating of live mice by conditioned coyotes was noted (Conover *et al.* 1977). Lehner & Horn (1977 cited in Griffiths *et al.* 1978) looked at the effectiveness of various methods of administering LiCl and found that conditioning was not as easily established or as long lasting as reported earlier by Gustavson *et al.* (1974, 1976). However they had better results after combining other cues (ribbons, bells, perfume) with the LiCl baits and prey (Lehner & Horn 1977). In another study, Burns (1980) attempted to document the transfer of an aversion to chickens from adult coyotes to their offspring. This failed because the adults never formed the initial aversion to chickens. Adults avoided chicken carcasses laced with LiCl but continued to kill and eat live chickens. Later testing with the same coyotes showed higher consumption of chicken carcasses laced with water than those laced with table salt (NaCl), thus, indicating that the coyotes had developed an aversion to the salty taste of LiCl and not an aversion to the meat itself. This same conclusion was reached in an experiment testing the olfactory discrimination of LiCl by coyotes (Ellins & Martin 1981); they recommend that future research should attempt to develop another emetic compound with weaker taste and smell cues. Griffiths (1978-cited in Griffiths *et al.* 1978) attempted aversive conditioning of 5 coyotes with presentation of LiCl laced baits on 2 subsequent days followed by a LiCl laced sheep carcass on the 3rd day. All 5 coyotes killed live lambs on their first opportunity after being "conditioned".

Griffiths *et al.* (1978) summarise the work of the various studies and concluded that no valid judgement as to the effectiveness of LiCl could be made yet but that the process deserved further research. Gustavson & Nicolaus (1987) in their review of the various studies found fault with those giving negative results because they: lacked the conceptual understanding of taste aversions, had poor study design, or had other compounding factors that mitigated the aversive properties of LiCl.

3.4.2.2 Field studies

The first field test was conducted by Gustavson *et al.* (1976) who distributed sheep flavoured baits around a 1200 ha. sheep ranch in western Washington, to register effects on naturally occurring predation. They had difficulty evaluating exact sheep losses to coyotes but reported at least a 30% decrease and as much as a 62% decrease relative to mean losses from the previous 3 years. Stream (1976a cited in Griffiths 1978) continued the work for an additional year and found a similar reduction. This reduction was initially ascribed to the LiCl treatments but after re-examination of the data this conclusion was retracted (Stream 1976b cited in Griffiths 1978). Reanalysis, correcting for the different lengths of time in the field and the increasingly smaller herd sizes, showed that the percentage of lambs killed during this period actually increased (Griffiths *et al.* 1978). Next, 2 flocks of free-ranging sheep in the Antelope Valley, in Southern California were released on ranges where LiCl laced baits or carcasses were distributed (Ellins *et al.* 1977). They reported a drastic reduction in sheep kills after 3 weeks of treatment until the end of the grazing season in one herd and from 7 weeks onward in the other herd.

These field studies have received strong criticism for their lack of controls, poor experimental design, or inappropriate conclusions not supported by the data (Griffiths *et al.* 1978, Sterner and Shumake 1978, Conover *et al.* 1979). For specifics the reader is referred to the articles listed and to the rebuttal comments published by Gustavson & Nicolaus (1987) and Ellins *et al.* (1979). Regardless of perspective it was clear that no definitive conclusion had yet been reached on the use of LiCl.

Numerous additional studies were conducted with mixed results. Positive results: Gilbert & Roy (1977) had reduced beehive damage by black bears using LiCl baits especially in combination with electric fencing; Cornell & Cornely (1979) successfully instilled an aversion in coyotes to a campground by lacing foods typically obtained from tourists with LiCl; Ellins & Catalano (1980) suppressed predation of sheep and turkeys; Gustavson (1982) reported no change in wolf predation in Minnesota but reported fewer management removals of wolves from the study area as a positive result of LiCl baiting (though this connection is rather unclear); Gustavson *et al.* (1983) found in preliminary testing that anthelmintic thiabendazole (TBZ) instilled aversions to mutton in dingoes and deserved further study as an alternative to LiCl; Ziegler *et al.* (1983) had mixed results testing TBZ on wolves eating 4 different foods, 1 was averted, 1 exhibited no aversion, and 2 reduced bait consumption; Polson (1983) had positive preliminary results using TBZ to keep black bears away from beehives.

Negative results were obtained by: Dorrance & Roy (1978) who failed to reduce black bear damage at beeyards using LiCl and cupric acid ($CuSO_4$); Burns & Connolly (1980) found no difference in the killing and eating of live prey between coyotes conditioned to avoid LiCl baits and non-conditioned coyotes; Horn (1983) failed to establish an aversion of captive coyotes in 2 of 3 experiments using baits and injections of LiCl; Burns

(1983a) found that coyotes that had developed an aversion to baits laced with encapsulated LiCl continued to kill and feed on live sheep; Burns (1983b) in summarising the current literature concluded that results have been equivocal or inconsistent and that other delivery systems or chemicals should be tested; Cardoza (1985) had mixed results averting black bears from beehives with aversions of a few days to a few months reported; Rathmore (1984) found that aversions instilled in domestic dogs lasted less than 24 hours; McCarthy & Seavoy (1994) failed to instil an aversion in black bears habituated to raiding human garbage cans using among other things TBZ baits.

In addition to the above studies there have been two large-scale programs involving LiCl-based aversive conditioning. In the first, the Saskatchewan Agriculture Department (Canada) initiated an aversive conditioning program in 1976 where they taught farmers how to use the technique and provided ground mutton baits laced with LiCl. Jelinski *et al.* (1983) and Gustavson *et al.* (1982) evaluated the initial results and reported a reduction in predator losses of 66% from 1975 to 1976. These results are subject to the same criticisms as the earlier studies, including between year variation in ranch management, coyote numbers, and alternate prey availability and unknown impact of several other coyote control measures in effect at the same time. The authors argue that this major reduction in predation can only mean that LiCl must be having a major effect even though it is impossible to isolate the impact of LiCl alone.

In a follow-up study of the Saskatchewan Program (SP), Conover & Kessler (1994) interviewed numerous participants in the 1976 program and found that only 1 of 41 known participants were still using LiCl. Of the SP participants still raising sheep, 69% reportedly stopped using LiCl because it was not effective enough to be worthwhile.

In the second large scale field study, Bourne & Dorrance (1982) tested LiCl at sheep ranches in each of 4 different areas in Alberta. They baited 8 farms with placebos and 9 farms with LiCl and found no measurable reduction in predation on the LiCl baited farms and no reduction in predation as the grazing season progressed.

Recently attempts to enhance the effect of LiCl with various odour, auditory, and visual cues showed greater suppression of predation but these effects were short-lived (Sterner 1995). Conover (1989, 1990) successfully conditioned racoons, opossums, and striped skunks from eating untreated eggs by first feeding them eggs treated with emetine dihydrochloride. This aversive conditioning is much simpler than that described for coyotes because the conditioning stimulus (treated eggs) is identical to the unconditioned stimulus (untreated eggs). Connolly (1995) in summarising the results of the Denver Wildlife Research Centre concludes that they have been unable to reduce predation of live animals with this technique and have terminated their studies of LiCl.

3.4.2.3 Conclusion

To summarise we must conclude that aversive conditioning techniques using emetic chemicals, especially LiCl, have not shown conclusive results. Further research on LiCl applied in the same fashion appears unlikely to provide new solutions to depredation problems. The concept still has merit but perhaps further research should concentrate in another direction or attempt new approaches. The following excerpt from Sterner (1995) seems particularly appropriate:

> *Results also point out the need for new models of conditioned taste aversion and predatory behaviour. Scrutiny of past models suggests that researchers may have ignored premises of food novelty and that attack, kill and ingestion behaviours of large carnivores are elicited by distinct prey stimuli (e.g., experience, movement, odour). Drug effects may have to be paired with movement and odour responses of prey, rather than taste/ingestion responses, to inhibit attack.*

3.4.3 Deterrents and repellents

Deterrents and repellents fall into several groups including acoustic devices, projectiles, explosives, and chemical repellents. Deterrents will serve to discourage the presence of an animal in a specific area (Follmann *et al.* 1980) and repellents are designed to immediately stop an undesired behaviour or near approach (Hunt 1984). An annotated bibliography of these topics was compiled by Hunt (1983) with a focus on bear management but including much of the pertinent literature on other species as well. The Department of Renewable Resources, Government of the Northwest Territories (NWT), Canada has been the chief architect in developing and testing numerous types of acoustic and projectile repellents (for use on polar bears), and Animal Damage Control (ADC, under the U. S. Department of Agriculture) has been primarily occupied with developing aversive techniques for smaller animals, especially birds and rodents. The Border Grizzly Project, University of Montana investigated the effects of various olfactory attractants (Cushing 1983) and repellents (Miller 1980, 1983) on polar bears and grizzly bears in the late 1970's.

3.4.3.1 Chemical repellents

Most successful repellents have been developed as chemical sprays to make food (grass, crops, grain bins, feed lots) unpalatable to birds, rodents, and deer (USDA 1994). However, numerous chemical repellents have been investigated for use on coyotes (Jankovski *et al.* 1974 cited in Lehner *et al.* 1976, Linhart *et al.* 1977, Teranishi *et al.* 1981, Lehner *et al.* 1976) and were recently reviewed by Lehner (1987). In summarising the above research Lehner (1987) concluded that though they had found several promising chemicals (capsaicin, undecenovanillylamide (nor-capsaicin), cinnamaldehyde, and commercial products "Bittrex" and "Off-Limits") none had long-term or widespread efficacy for control of coyote predation without harming the sheep. In other tests Burns *et al.* (1984) found that non-lethal doses of various chemicals placed in sheep collars did not reduce predation. Hatfield & Walker (1994) found that «Pred-X» eartags (a commercial repellent) also failed to reduce predation. Researchers from the National Wildlife Research Centre tested sheep collars containing capsaicin (the "active" chemical in red peppers) and found attacks to be undiminished and that coyotes simply changed attack method (USDA 1996).

Current research with olfactory and taste aversions of wolverines against sheep predation has shown great promise in preliminary testing (Landa *et al.* 1993, 1994, 1995). These researchers have attached strong-smelling, foul-tasting chemicals to eartags and collars on sheep released on open ranges in Norway. Preliminary testing has shown a substantial reduction in lamb losses and will be followed up in 1996 with a large scale field study involving thousands of sheep released into areas with traditionally high predation rates.

Other researchers have investigated the use of chemicals as repellents or deterrents against bears (Miller 1980, 1983, Hastings *et al.* 1981 cited in Hunt 1985, Rogers 1984, Hunt 1984, 1985, Smith In-prep). They tested numerous chemicals and commercial products on polar bears, grizzly bears, and black bears and found capsaicin was again the most effective repellent and full strength ammonia was the most effective deterrent (Hunt 1985).

In a recent review of 66 cases of field applications of capsaicin products against bears, Herrero (In-Press, reviewed in Kendall 1995) found that: they were reasonably effective (though not 100%) against sudden encounters with grizzly/brown bears; grizzly/brown bears searching for human food or garbage were stopped and left the area after being sprayed; and that only half of food-conditioned black bears were deterred when sprayed. Capsaicin sprays have the advantage of being light weight, easy to use, and relatively inexpensive as an alternative to carrying firearms. However, they are not foolproof; the spray has a limited range (5-8 m), and can be affected by strong winds and extreme cold.

Chemical repellents and deterrents have yielded mixed results depending on the species of predator and the situation. They generally appear ineffective against coyotes but effective so far against wolverines, and to some extent, bears. There are a number of technical difficulties with delivery techniques and individuals must design a system appropriate for their particular situation. In some cases this may prove impossible. Further research is necessary and additional effective chemicals must be identified so that a number of chemicals are available to be used as predators become habituated and the repellents lose their effect. Research must also continue on chemical repellents designed for personal safety to develop dispensers with an effective range at greater distances.

3.4.3.2 Projectile repellents

Projectiles have a long tradition of use in problem bear management, (throwing rocks, shotgun blasts of rocksalt or birdshot, etc.) though the effectiveness of this technique was unknown. In 1981 NWT began a comprehensive program to test polar bear detection and deterrent systems at Cape Churchill, Manitoba (Hunt 1985). They tested two types of projectiles: 38 mm anti-riot rubber batons (Schermuly Ltd.), [hereafter "batons" will be referred to as bullets to avoid confusion with the European connotation of batons as clubs] and 12 gauge "Ferret soft-slugs" (AAI Corporation, Hunt Valley, Maryland). Later research has included the use of similar products: 32 mm "Thumper" rounds (plastic bottles filled with 30 cc of water) fired from a modified tear-gas gun and "Stinger" rounds fired from a 12 gauge shotgun (Mountain Scent Research, Stevensville, Montana).

Anti-riot 38 mm rubber bullets. NWT tested these bullets on 405 polar bears and all but 1 bear left the area (though a few bears required 2-4 hits). Of the 42 marked bears 71.4% did not return to the test site after the first test (Stenhouse 1982, Stenhouse & Cattet 1984 cited in Hunt 1985). Stenhouse (1985 pers. comm. reported in Hunt 1985) also tested these bullets against 20-25 grizzly bears near fishing or mining camps and successfully repelled them all. Smith *et al.* (unpublished data) tested the bullets 8 times on grizzly bears at a landfill in Elkford, British Columbia and measured an average return time for 5 bears of 32.8 minutes while 3 bears did not return. In these tests Smith *et al.* (unpublished data) encountered difficulties because the non-aerodynamic shape of the bullets caused extreme inaccuracy. Stenhouse (1985 pers. comm. in Hunt 1985) also pointed out that the gun and bullets are expensive and that accuracy with the weapon is difficult, requiring intensive training.

Ferret soft-slugs. NWT began work with the commercial product "Ferret Slugs" and helped to develop the "Bear Deterrent Round" that was heavier and could be fired from a greater distance than the earlier versions. In recent years they have also tested plastic slugs from another manufacturer under the name of "Stinger" (Clarkson 1989). Clarkson (1989) provides an excellent review of the 12 gauge plastic slugs and shows how their effectiveness has improved with the later versions of these plastic slugs. All of the bears tested (n = 85) with the later versions of the slugs have been successfully repelled (Wooldridge 1984, Clarkson 1987: cited in Clarkson 1989, Dalle-Molle & Van Horn 1989). Gillin *et* *al.* (1994) report success using “Thumper”, “Bear deterrent rounds” and “Ferret slugs” on 5 grizzly bears though the results were not identified by the type of round used. They recorded a total of 27 hits, and though their sample was too small to fully evaluate the conditioning stimulus, they were successful in forcing all but one bear to flee the conflict site.

These projectiles have many advantages over the rubber bullets in that they are much less expensive, can be fired from a 12 gauge shotgun, have better aerodynamics that substantially improve accuracy, and enable greater flexibility in type of shot used. Clarkson (1989) promotes the use of the 12 gauge shotgun as an all-around bear management tool as it can quickly discharge “cracker shells” (shotgun shells that explode with a loud bang after being fired some distance), plastic slugs, and as a last resort lead slugs should the bear need to be killed.

The projectiles give a generally positive result for use with bears, but the scope of their use is rather limited as they will kill or injure smaller predators or even bears if improperly used. Additionally, only trained bear management personnel should be allowed to shoot an animal with these slugs. Multiple shots are often required and the offending bear should be shot again when it first re-enters the conflict area, thus requiring an expenditure in time to observe the area and be prepared to shoot the problem animal again. In situations where predators are in the early stages of becoming habituated to humans these tools may prove most valuable, the predator receives punishment instead of reward and will be less likely to associate human areas with an easy meal. Projectile repellents will be difficult to employ against livestock killing bears (must shoot them while they are in the act of killing livestock) and are unlikely to provide much help against depredation.

3.4.3.3 Explosive and visual repellents

Many of the simple, immediate responses to the presence of predators fall under this category. Among these are: firing warning shots; Cracker Shells and Screamer/Bangers (firecrackers fired from a shotgun or pistol); blank pistols, and pencil flare guns (Clarkson & Marley 1995). All can be effective at times but they will not work on all bears, effectiveness will diminish with repeated use, and many present a real fire danger. Another device that has been relatively effective is the propane cannon, commonly used for scaring birds, but found to be effective in reducing livestock depredation as well. These devices ignite a quantity of propane gas at timed intervals resulting in a brilliant flash and a rifle-like boom. These have had success against coyotes, deterring predation of sheep for an average of 31 days (Pfeifer & Goos 1982, **section 3.3**). It was also used to frighten away a grizzly bear from a sheep allotment (Matejko & Franklin 1983 cited in LeFranc *et al.* 1987). However the effects from such devices will probably be relatively short-termed as animals habituate to the stimuli. Other types of electronic devices that combine lights and sounds emitted at irregular intervals and in differing combinations have had much better success in preventing habituation by predators (Linhart *et al.* 1984, USDA 1995, **section 3.3**).

Most of these repellents are for short-term, emergency type confrontations and yield inconsistent results. For that reason none of them can be relied upon for resolving all conflict situations. However if they are taken together and included as elements in a larger repertoire of management solutions, then the variety of repellent stimuli increases and predators are less likely to become habituated to any single element.

3.4.3.4 Other Repellents

Some initial work has been conducted to evaluate the use of dogs as bear repellents (Gillin *et al.* 1995). Laika dogs have apparently been used historically to drive off large predators from human habitation and have in recent times been used for hunting. Care must be taken to use only trained dogs because pets have been known to attract bears back to the humans accompanying them. The use of dogs for guarding livestock is reviewed elsewhere in this volume (**section 3.7**).

Another little-documented repellent takes the form of human face masks worn on the back of the head of workers while working in the fields and forests of India (Nowell & Jackson 1996). Apparently tigers normally attack from behind and are less likely to attack a person who appears to be facing it. Carnivore odours are being developed in the hope that the smell of a larger carnivore will prevent smaller carnivores from entering an area with livestock. So far no field trials have been made (Rodney Jackson pers. comm.).

3.5 Protection of beehives from bears

Main points - Protecting beehives from bears

- *The best method in use to protect beehives from bears is to place a physical barrier around the beehives. Electric fencing is the most practical, although stone and log walls have been traditionally used.*

Damage to beehives by bears seem to be a problem wherever bear populations co-exist with beekeeping. The problem has been well documented in Europe and North America (Calvert et al. 1992, Garshelis 1989, Kaczensky 1996, Hygnstrom & Hauge 1989, Nyholm 1989, O'Brien & Marsh 1990) but almost certainly occurs world-wide throughout the range of bears.

Most of the literature concerning protection of beehives come from North America. Two basic non-lethal strategies exist for preventing damage to beehives by bears. One approach is placement of physical barriers to separate beehives from bears. Conventional and electric fences are examples of such physical barriers. A second approach is to modify the bear behaviour using frightening devices and repellents. Often it is necessary to use a combination of different approaches to successfully prevent or reduce bear damage (Calvert et al. 1992).

3.5.1 Physical barriers

The most common way of preventing bear damage to beehives is the building of bear-proof fences around the site. Bee hives can also be protected from bears by building bear proof wooden or stone enclosures (cabins) around the site or by limiting bear access by placing bee hives on platforms. A more thorough discussion about the use of fences to prevent carnivore damage is given in **section 3.2**.

3.5.1.1 Conventional fences

Conventional wire netting or chain link fences may initially prevent bears from entering a site, but have had little long-term success as persistent bears were able to penetrate the fence by making holes in it, digging underneath or climbing over the fence (LeFranc et al. 1987, Bromley et al. 1992, Clarkson & Marley 1995). It is unknown how many less persistent bears were successfully stopped by barriers of this type.

3.5.1.2 Electric fences

Electric fences have been developed to exclude a variety of carnivore species (reviews in Wade 1982, and LeFranc et al. 1987). Some make use of an existing fence and incorporate one or two electrified wires on outriggers, others are constructed as plain wire fences with alternating live and earth wires. Reducing the wire spacing and increasing the number of wires increase the effectiveness of electric fences, but also increases their cost. Electric fences have been used for many years in the prevention of black bear damage in bee yards in North America (e.g., Storer et al. 1938, McAtee 1939, Wade 1982, Calvert et al. 1992). The use of electric fences to protect beehives is increasingly common in Central Europe (Kaczensky 1996), and Scandinavian (Karoniemi 1996).

Early electric fences used relatively low secondary voltages (Storer et al. 1938). Later experiments have found that high-voltage electric fences are generally far more effective in excluding bears. Trials found electric fences to be 88.7% effective in excluding black bears from apiaries. Later findings (by Gunson 1979 cited in Wade 1982) indicate that fences were 81 % effective over a 3-year test period in excluding black bears. In Saskatchewan, prior to the implementation of an electric fencing program damage to beeyards were over $100 000 per year. Since the electric fencing program 95% of bear-apiary problems have been eliminated (Clarkson & Marley 1995). Electric fences do not only prevent the bears from entering a beeyard, the electric shock might also condition the bears to avoid the bee hives and the electric fence in the future.

Several types of electric fence have been used to deter black and grizzly bears, including: 1) a portable, totally electrical fence of at least four strands of wire for black bears, and 2) various designs combining electric wires and sturdy welded wire or chain link fence to keep out black and grizzly bears (Bromley et al. 1992). Successful fence designs generally have the following construction (LeFranc et al. 1987, Bromley et al. 1992);

- Various charges have been used, but in general, high voltage (10000 V or more) and low amperage (1 amp or less) will ensure a sufficiently painful jolt if contact is made.
- Barbed wire will ensure better contact than smooth wire.
- Achieving an effective ground can be difficult on dry or frozen substrate. This problem can be corrected by laying a grounded, wire-mesh mat around the fence.
- Baits might be attached to the charged wires so that the bear would contact the wire with their non-insulated nose or mouth and receive a more effective shock. Some authors caution against the use of baits before bear problems develop because it could act as an unnecessary attractant.
- Bears must be prevented from digging beneath a fence. A wire mat, buried fence, concrete pads or other physical obstructions could be used.
- Fences must receive regular, proper maintenance to operate effectively.
- Gates represent an unavoidable weak point with any electric or physical barrier.

A portable electric fence may be preferable in some cases to the permanent structures described above. If an apiary site is moved annually or during the season, portable electric fences are desirable. Several types of portable electric fences have been tested. The Alberta government, in co-operation with beekeepers developed an effective portable electric fence which has been in use since 1977 (Wynnk & Gunson 1977 cited in LeFranc et al. 1987). A portable, high-visibility electric fence was effective in preventing depredation in 95% of 500 black bear incidents (Hunt 1985 cited in LeFranc et al. 1987).

When high voltage electric fences are being used, there may be some concern for human safety. Although there have been no reports of accidents with humans resulting from these fences, they should be clearly marked with signs. A low barrier may also help present accidental encounters.

3.5.2 Frightening devices

Visual and acoustic repellents have been used with varying success by livestock producers in North America to reduce livestock losses caused by depredating coyotes, wolves and bears. Several types of devices have been tried including vehicles, scarecrows, electric lights, radios, and propane or acetylene exploders (see **section 3.4**). Most visual and acoustic repellents rely on fear or perceived danger avoidance for their effect (Bomford & O'Brien 1990). Carnivores are often sensitive to changes in their environment. Thus, the presence of any unusual sound, sight or smell may keep carnivores away from an area for a certain period of time.

Correctly used visual and acoustic devices represent a non-lethal method that seems to work as deterrents for carnivores, at least for a limited time period. Several acoustic deterrents and repellents have been successful in scaring bears away from attractive points (review in LeFranc et al. 1987). This includes recorded aggressive sounds of captive bears (Wooldridge & Belton 1980, Wooldridge 1983, Miller 1983), freon-powered boat horns (Miller 1983), portable radios and blaring music (Koehler et al. 1990), flares, thunder flashes and various other pyrotechnic devices (LeFranc et al. 1987).

The biggest problem with the use of acoustic and visual repellents seem to be the process of habituation. After some time animals tend to adjust to, and ignore, the new stimuli (Bomford & O'Brien 1990). Longer lasting success can be achieved using multiple stimuli that occur in unpredictable patterns, combinations and sequences. Such devices are unlikely to prevent bee hive depredation alone.

3.5.3 Aversive conditioning

Aversive conditioning is a specialised form of learning that involves pairing a normally desirable food, space, object or event with a negative reinforcement. This process should lead to an avoidance of the former attractive stimulus (LeFranc et al. 1987). Aversive conditioning has been tested to try and prevent black bear damage on beehives. Gilbert & Roy (1977) found that lithium chloride showed good potential for reducing the amount of black bear damage to Alberta beeyards. The best result were achieved by using both LiCl baits in combination with electric fences, However, Dorrance & Roy (1978) concluded in subsequent testing that LiCl was not a suitable emetic for this purpose. Several other emetics for aversive conditioning have been tried in experiments with captive and free-ranging black bears and polar bears (e.g. emetine hydrochloride and alfa-naftyl-thiourea) (Wooldridge 1980). A number of problems with the use of emetics for aversive conditioning have been noted (LeFranc et al. 1987, **section 3.4**). Bears may be conditioned to avoid only the particular food used as bait and animals can "learn" the taste of an emetic and avoid the treated baits. Aversive conditioning has also been tried with other means than emetics. Gillin et al. (1993) “shot” nuisance grizzly bears with rubber bullets in Yellowstone National park, but the bears only changed their behaviour temporarily.

3.5.4 Conclusions

Beehives are easier to protect from bears than livestock. The best defence against bear depredations on beehives is prevention. Colonies should be located as far as possible from known bear trails. The best and most reliable way of protecting bee hives from bears seem to be a properly constructed and maintained permanent or portable electric fence. This is also probably the most cost-effective method. When an apiary or livestock protection fence is used year after year, one might consider constructing a permanent type of electric fence. If an apiary site is moved annually or during the season, portable electric fences are desirable, although the foundation and poles can be permanent. In areas with heavy predation a combination of high currency electric fences and various visual and acoustic frightening devices might be preferable.

3.6 Increasing the availability of prey and other food for carnivores

Main points - Increasing the availability of natural prey and artificial feeding

- *The existence of alternative natural prey is a prerequisite for carnivores to stop depredating livestock. Steps to ensure a good prey base are vital for effective carnivore conservation.*
- *However, attempts to increase natural prey may eventually increase carnivore populations, so this measure alone is unlikely to reduce total levels of livestock depredation.*
- *Artificial feeding of bears has been used successfully in Slovenia to reduce depredation surrounding a bear core area, although experience from North America indicates that feeding can greatly increase the possibility of bears attacking humans.*

It is logical to expect carnivores to kill more livestock when natural prey are not available. The ecological process of switching between different prey depending on their relative availability is well documented. For example, coyote predation on ungulate fawns decreased in years when rabbits were more common (Hamlin et al. 1984). Although there are few studies demonstrating that predation rates on livestock are higher in areas with less natural-prey (e.g. Mech et al. 1988, Schaller et al. 1994, Shaw 1982), there are good indications that predation on livestock may peak seasonally when natural prey is less available (e.g. Karani et al. 1995, Kumar & Rahmani 1995, Fritts et al 1992, **section 3.18**). This behaviour could form the basis of a management strategy designed to ensure the supply of food available for carnivores. The underlying principle of this strategy is to increase the availability of non-livestock food sources so that carnivores do not need to depredate livestock. There are two different approaches using natural food sources or artificial food sources.

3.6.1 Increasing the availability of natural prey species

Clearly any attempt to conserve populations of large carnivores within a region is dependent on the existence of a suitable prey / forage base for carnivores within that region (Schortemeyer et al. 1991). If this prey base is inadequate it is not surprising that carnivores kill and eat livestock when they are the main available food source. In many areas of southern Europe populations of ungulates such as roe deer and red deer have been depleted and even eradicated during the last 150 years. The paradox is that these areas often contain large populations of wolves, which now predate heavily on livestock, or feed on garbage (Boitani 1982, 1992, Blanco et al. 1992, Salvador and Arab 1987). Many other areas in Asia and South America are characterised by a low availability of natural prey due to overhunting, resulting in carnivores becoming increasingly dependent on livestock. Increasing natural prey levels has been consistently advocated to ease jaguar-livestock conflicts in South America (Quigley & Crawshaw 1992, Hoogesteijn et al. 1993, Rabinowitz 1995). However, there has never been an experimental test of the success of the effects of increasing natural-prey on livestock predation.

Natural prey populations can be increased in several ways, ranging from reintroduction of ungulates, better protection or management of hunting, and improvement of habitat for prey (Boitani 1992, Hoogesteijn et al. 1993). For bears this includes providing both good habitat for ungulates and good access to preferred plant foods (Eggers 1986, Holland 1986).

3.6.2 Providing artificial supplementary foods

Carnivores, especially bears, will utilise artificial food sources when they are available. The fact that carnivores kill domestic livestock is one example. Bears readily feed on garbage dumps throughout their range, with complex results. Body weight and survival may improve because of the energetic benefits, although social aggression and infanticide may increase (Rogers 1989, Stringham 1989). These artificial food sources may also provide a buffer against seasonal / annual variation in natural-food availability (Rogers 1989). Generally this use of supplementary foods is a result of opportunistic behaviour on the part of the carnivore rather than a result of deliberate management.

In Washington State, black bears were provided with pelleted food during spring in an attempt to prevent damage on forest plantations associated with their stripping bark to fed on sap. The method was apparently very successful at limiting this damage (Ziegltrum 1990). During 1990 and 1991, wolves and bears were provided with moose carcasses dropped from a helicopter in Alaska in an attempt to reduce predation on neonatal moose calves. Observations showed that the carcasses were utilised rapidly. Although calf survival improved in 1990, there was no significant effect in 1991. These results indicated that over 15 kg of meat per square kilometre would be required to increase moose calf survival. As a result the method was considered to be impractical and too expensive (Boertje et al. 1992).

In both Slovenia and Italy, supplementary feeding is provided to bears in an attempt to maintain high populations inside limited core areas and national parks to prevent predation on livestock. Although there is little data to fully evaluate the success of this strategy, there is a dramatic difference in predation rates on livestock and in the destruction of beehives inside the Slovenian bear core area compared to outside (Kaczensky 1996).

3.6.3 A cautionary note

Although the presence of natural wild prey populations or supplementary food does not guarantee that predation on livestock will stop or even decrease, food availability is a prerequisite for the success of other measures and therefore for carnivore conservation. However, an increased food supply will probably lead to an increased carnivore density and this might in turn lead to even further predation on livestock (e.g. Nass et al. 1984, Boertje et al. 1992, Knowlton 1989, Kumar & Rahmani 1995). This will be especially true if livestock is only seasonally available and the alternative prey / supplementary food allows carnivores to survive through previously limiting periods at higher densities than before. For example, the availability of garbage lead to unnaturally high golden jackal populations in Israel, which in turn led to very high predation rates on calves of cattle (Yom-Tov et al. 1995). Therefore supplementary feeding will only reduce predation on livestock in the long term if it is provided only during the period of the year in which livestock are available. Attempts to increase year round natural prey availability, or to feed carnivores through a limiting period of the year when livestock are not available, will ultimately lead to increases in carnivore density. This should only be actively pursued in areas where increased carnivore densities are a stated management objective and are compatible with agriculture.

Additionally, the artificial feeding of carnivores could lead to the phenomena of food conditioning. This occurs when an individual carnivore associates food with people, and begins to loose its fear of humans. The result is an increased risk in the probability of attacks on humans.

The process is well documented for black and grizzly bears in North America, grizzly bears in Russia, and for Asiatic lions in India (Gilbert 1989, Gunther 1994, Saberwal et al. 1994, Swenson et al. 1996). This situation has been avoided in the Slovenian example by placing the dumps in remote areas, effectively limiting tourist access to these areas, and hunting those individuals that use the feeding sites most (Kaczensky 1996).

In general, we do not recommend providing artificial supplementary food as a means of reducing carnivore conflicts with livestock. Costs are high, the practical problems are enormous and the side effects are difficult to predict because predation is a very complex process, especially when multiple prey species are involved. Providing an adequate natural-prey base for carnivores must be regarded as a vital requirement for effective conservation, and predation rates on livestock should decrease when natural-prey are abundant. However, manipulation of natural-prey levels must be seen inside a wider management strategy of zoning and / or improved husbandry.

3.7 Guardian animals

Main points - Guardian animals

- *Guardian animals, mainly dogs, are imprinted on sheep at an early age (usually six weeks). They believe that the sheep are part of their social group and will actively protect them from large carnivores.*
- *Such dogs live with the sheep all the year round and are not used for herding.*
- *Traditions exist for the use of guarding dogs in Europe that go back many thousands of years. In all modern trials they have been shown to be effective against most carnivore species.*
- *However, to be successful they need to have a flock or discrete area to defend, which requires either the presence of a shepherd or fencing to hold the flock together.*

3.7.1 Introduction to guardian animals

The idea of using one species of domesticated animal to provide predator protection for another species of domestic animal (livestock) is an ancient concept. Archaeological excavations have revealed the remains of domestic dogs and sheep together (though not necessarily employed in a guarding capacity) dated as far back as 3685 BC (Olsen 1985 cited in Coppinger & Coppinger 1993).

By far the most prevalent and most successful guard animals in use today are various breeds of livestock guarding dogs, though donkeys and llamas are also found in use under certain circumstances. In addition to these we find certain cattle breeds, goats, and even ostriches and baboons in use as some kind of a guard for "their" flock of animals (Franklin & Powell 1993, Marker-Kraus et al. 1996).

The type of guard animal employed will depend upon the type of livestock being defended, the predator species, the intensity of predation, the grazing habitat of the livestock, and the management system employed by the producer. For example in North America llamas may be adequate protection of sheep from individual coyotes and dogs but may fall prey themselves to predators like grizzly bears, wolves, mountain lions, and dog packs.

Guard animals have been used with varying success to guard various forms of livestock including horses, cattle, sheep, goats, camels, llamas, ostriches, emu, turkeys, chickens, ducks, and pheasants. Guard animals have been used against such predators as coyote, feral and domestic dogs, bobcat, lynx, dingo, foxes, mountain lion, wolf, bear, jackals, spotted hyaena , striped hyaena, African wild hunting dog, caracal, baboons, lion, and cheetahs (Kruuk 1980, Green & Woodruff 1989a, Green et al. 1993, Floyd 1995, Coppinger & Coppinger 1996, Andelt 1996, Marker-Kraus et al. 1996).

The majority of the scientific literature concerns the use of livestock guarding dogs (LGD), but there is an increasing emphasis on experiments using alternative animals. The following information focuses on protection of sheep from predation but apply to protection of other livestock species as well.

For those readers wishing more detailed information the following three publications are excellent reviews of LGD and should be consulted directly (Coppinger & Coppinger 1993, Green and Woodruff 1990a, Andelt 1996). In addition we have reviewed as much of the original literature as possible and include an extensive literature cited section.

3.7.2 Livestock guarding dogs (LGD)

3.7.2.1 History

The actual techniques of using dogs as guardians were thoroughly described in a collection of papers written in ca. 150 BC that describe Roman farm management (Anon 1913 cited in Coppinger & Coppinger 1993). In a few European countries (e.g. Italy, France, Portugal) LGD have been in continuous use for thousands of years. In other areas, where predators were virtually extirpated, the tradition of using LGD has been forgotten. Today, the use of LGD is most common in the United States, with thousands of dogs in use, distributed over the entire country. Ironically with the re-establishment of carnivores, some European countries must now import new bloodlines of LGD back from the USA and relearn the techniques of using them.

It is important to distinguish between the LGD and the herding dog, the latter is thought to have become more prevalent as large predators became less of a threat. The first evidence of herding dogs originated from Iceland and the Faeroe Islands around 1200-1220 and were then further developed in Great Britain (after wolves were extirpated), and used to help farmers drive their sheep (Laurans 1975). In France and Italy (where wolves persist) sheep are still together with a herder and a mastiff or wolfhound for protection (Thomas 1983 cited in Coppinger & Coppinger 1993). The herding dogs are much nearer actual predators behaviourally and threaten the sheep into going where they are directed with clear predatory mannerisms. Guarding dogs are long removed from the predator end of the canid behaviour spectrum. LGD are "permanent adolescents", genetically adapted to retain some adolescent behavioural traits (compared to other canid species or breeds) as adults thus encouraging behaviour that can be described as TRUSTWORTHY (will not harm the flock), ATTENTIVE (stays with the flock), and PROTECTIVE (barks and defends the flock) (Coppinger et al. 1983, Coppinger & Coppinger 1996).

Most of the available scientific literature arises from two separate research groups, both begun in 1976 in the United States. The first scientific evaluation of LGD began at the Denver Wildlife Research Centre (then under U.S. Fish and Wildlife Service) testing Komondor dogs as guards against coyotes (Linhart et al. 1979, McGrew & Blakesley 1982). This work was continued under the U.S. Department of Agriculture, Agricultural Research Service, at the U. S. Sheep Experiment Station (USSES), Dubois, Idaho. The USSES work focused on observations of controlled coyote-dog confrontations and subsequently distributed dogs to active sheep ranches with follow-up surveys as to the dogs effectiveness (Green & Woodruff 1980, 1983, Green et al. 1984).

The second group independently began research in the same year, establishing The Livestock Dog Project at Hampshire College in Amherst, Massachusetts. This group investigated existing LGD operations in Europe and imported several breeds back into the USA for a breeding program (Coppinger & Coppinger 1980b, 1982). These dogs and their offspring were also distributed to farmers and evaluated annually. An active research program centred on understanding the basic behavioural aspects of LGD: what defines a "good" livestock guard dog; how these behaviours are acquired and maintained; and the evolutionary significance related to other breeds and wild canids (Coppinger et al. 1987, Coppinger & Coppinger 1993, Coppinger & Schneider 1995).

3.7.2.2 Breeds

The majority of breeds in use as LGD today are European or Asian breeds (**table 3.7.1**) bred specifically for useful characteristics in guarding against predators (Coppinger & Coppinger 1980a, b, Green & Woodruff 1980). Nearly all the breeds are similar in appearance: large, 35-45 kg and standing 65 cm or more at the shoulder (Andelt 1996); and most have white coats (several are brown and/or black) in various lengths. One exception to the Eurasian breeds are the small mongrel dogs traditionally used by the Navajo Indian Tribes of Arizona and still effectively used today (Black 1981, Black and Green 1984, Coppinger et al. 1985, Black 1987).

3.7.2.3 Techniques

The use of LGD now is substantially different than the techniques employed 2000 years ago in response to different livestock management requirements. Earlier, the LGD was used together with small flocks and a herder, while today dogs guard flocks of 1000 or more sheep and work more or less independent of the herder. To be effective today LGD are therefore required to be more strongly bonded to sheep than people. There are several publications from both research groups and Agricultural Extension Services from various States that fully explain the process of selecting, rearing and using LGD (McGrew & Andelt 1985, 1986, Lorenz & Coppinger 1986, Lorenz

Table 3.7.1 Breeds used as livestock guarding dogs and their country of origin (Coppinger & Coppinger 1980, Pye 1980, Kruuk 1980, Lorenz 1989a, Green & Woodruff 1990a, Sims & Dawydiak 1990).

Breed	Country	Breed	Country
Great Pyrenees	France/Spain	Hungarian Komondor	Hungry
Anatolian Shepherd Dog	Turkey	Akbash Dog	Turkey
Karabash (Kangal Dog)	Turkey	Rhodesian Ridgeback	Zimbabwe
Estrela Mountain Dog	Portugal	Briard	France
Castro Laboreiro	Portugal	Spanish Mastiff	Spain
Maremma-Abruzzese	Italy	Kuvasz	Hungry
Shar Planinetz	Yugoslavia	Polish Tatra	Poland
Bernese Mtn. Dog	Switzerland	Great Swiss	Switzerland
Caucasian Ovtcharka	Russia	Appenzeller	Switzerland
Slovak Tchouvatch	Slovakia	Entlebucher	Switzerland
Karst Shepherd	Yugoslavia	Leonberger	Germany
Tibetian Mastiff	Himalayas	Hovawart	Germany

1989a, Green & Woodruff 1990a, Andelt 1995). Rearing techniques vary, depending on the individual dog (and owner) personalities and the sheep husbandry system in use. In general the most important factor is early bonding to the flock, accomplished by placing pups together with sheep at 6-8 weeks old. For example, one rancher we visited kept a ewe together with the bitch and her pups from 2-3 weeks of age (Hansmire/Cambell Ranch, Cisco, Utah 1996). Pups older than 8-10 weeks have gone past the primary socialisation stage (Coppinger & Coppinger 1993) where bonding is most successful, though some individuals have been bonded as late as 12 weeks or more (however with less positive results). As the pups grow they are sometimes moved into increasingly larger pens, but are always kept together with sheep until ready to join the flock. The only "training" during this period is to reinforce "staying with the sheep," (correcting the dog when it leaves them), and correcting negative play behaviours before they can result in injuries to sheep ("play-chasing", ear and wool pulling, etc.). From about 6-8 months old the dogs can start being left alone on the open range with continued observation to ensure no bad behaviours develop. A rancher in Eastern Washington would place pups as young as 2-3 months old (together with their mother) out with the sheep on the open range. They would be moved together with the shepherd's camp but were nevertheless exposed to their working environment from a very early age (Martinez Livestock, Moxee, Washington, 1996). Throughout the entire process it is critical to remember that the dog is a working dog and not a pet. Human contact is important, but not to the extent that the dog becomes more bonded to humans than to sheep. For more specific details the reader is referred to the previous references.

3.7.2.4 Effectiveness

The reported percentage of LGD that are successful guardians varies from 66% to 90% (Green et al. 1994, Coppinger et al. 1988) and the reduction in predation varies from 11% to 100% (Linhart 1979, Pfeifer & Goos 1982, Green & Woodruff 1980, 1984, 1988, McGrew and Blakesley 1982, Black & Green 1985, Andelt 1987, Coppinger et al. 1988, Lorenz 1989b, Andelt 1996). What appears to be particularly enlightening are a number of surveys conducted over 15 years to register the opinions of active sheep producers regarding LGD in their operations (Coppinger et al. 1988, Green et al. 1984b, Lorenz et al. 1986, Green 1989, Green & Woodruff 1990b). For example Green & Woodruff (1988) found in a survey of 400 producers using 763 dogs that 82% of the dogs were "an economic asset" and 9% were a "break-even" investment. In Colorado, Andelt (1992) found that sheep producers with LGD lost fewer sheep to all causes than producers without LGD. Because LGD are often used in conjunction with other predator control methods it is difficult to attribute such reductions to LGD alone, however many ranchers have been able to reduce other control measures after incorporating LGD into their management (Andelt 1992).

In the United States the majority of predation on livestock is from coyotes and the previous results are naturally most related to reductions in coyote predation. The original breeds of LGD were bred in Europe to combat predation by brown bear and wolves, however no scientific publications are found documenting their success (Coppinger & Coppinger 1995). Popular accounts have been well documented in the Coppingers' articles and in their own experiences while touring Europe (Coppinger & Coppinger 1982, 1993, 1996a). And of course simple logic tells us that if the dogs did not help they would not have been in use for thousands of years.

(1) Bears: In recent years there has been an increased effort to document LGD interactions with these large carnivores and some experimental trials have been conducted expressly for that purpose. Green & Woodruff (1989a) document 20 encounters between LGD and bears (17 black bears and 3 grizzly bears) with 75% of these resulting in the bears being chased off or shot before predation occurred. Grizzly bears appeared more difficult to dissuade than black bears but a small sample (n = 3) makes generalisation impossible.

In 1992 another demonstration of LGD was conducted in the Absoroka Mountains, a wilderness area in Montana just north of Yellowstone National Park (Green et al. 1993). In this area of high bear densities and limited control possibilities due to the protected status of the grizzly bear, 2 LGD were placed with the flock for a test of their effect. Over 7 weeks the herder documented 10 bear-dog encounters (night occurrences so bear species was not determined) resulting in 4 sheep being killed. On 5 occasions the herder helped and on 3 occasions the dogs acted alone to frighten the bear away without depredation. On the 2 occasions that losses occurred both dogs were occupied with separate bears. No coyote predation occurred in spite of numerous sighting. Another article expanding the information above with data from 1990 through 1993 (including before dogs were used) documented 40 bear-sheep encounters. Of these encounters 29 sheep were killed in the 2 years before employing dogs and 7 sheep were killed in the 2 years after employing dogs. The dogs were observed to successfully frightened away the bears prior to killing sheep on at least 12 occasions working alone and on 6 occasions together with the herder (Wick 1995). Wick (1995) points out that an important additive factor to the LGD effectiveness was the attentiveness of the herder, disposing of carcasses (burned), and regularly moving the herd. Woodruff (1996 pers. comm.) also believes that this combination of herder and dogs working together as a team was essential for their effectiveness.

Several confrontations have been filmed between 3 Great Pyrenees and brown bears in the Pasvik region of Northern Norway. Over a period of several days these dogs repeatedly harassed a female with yearlings and a large male (4 or 5 separate confrontations) until they eventually left the area (NRK-TV News, Oslo; Svanhovd Miljøsenter, 9925 Svanvik, Norway).

In another study conducted in the Snåsa area (central Norway) 3 radio-collared dogs were released within 100 m of a radio-collared brown bear (Hansen 1996). The dogs closed with the bear about 10 minutes after the last dog was released and they subsequently chased it for 25 minutes over a distance of ca. 1 km. The dogs appeared to work independently of each other with one dog consistently near the bear and another dog that regularly returned to check on the people. The bear was radiotracked and appeared to be on his way back after about 1 hour indicating little long term effect with just one dog encounter (Hansen 1996).

Studies of conflicts between bears and sheep on the Targhee National Forest, USA, showed that improved herder techniques were most responsible for reducing all losses, including bear depredation (Jorgensen 1983). She went on to say that portable corrals, sheep-protecting dogs, and aversion methods could provide additional help in reducing sheep losses.

(2) Felids: Predation by large cats on livestock has been a substantial problem in many places around the world and the main reason for many cat species threatened or endangered status (Sawarkar 1986, Rabinowitz 1986, Cunningham 1995, Nowell & Jackson 1996). In recent years protection and reintroduction programs have led to increasing conflicts outside of protected areas in largely livestock dominated agricultural zones (Nowell & Jackson 1996). Little has been documented specifically about LGD encounters with the various felid predators. However, there are innumerable anecdotal reports from LGD users in the United States that report great success against mountain lions (and assumedly bobcats as well). Mountain lions only represent 7.7% and bobcats 2.5% of the total predation on sheep and goats in the U.S. **(table 3.7.2**), but can cause a severe impact locally. Because so few ranches are exposed to mountain lion predation, it is difficult to statistically ascertain the effect LGD have on the overall rates.

In Kenya Kruuk (1980) found that for some tribes dogs were a common form of protection around the village at night but they seldom used dogs out with the herds while grazing. The dogs observed were not typical guard dog breeds but rather are described as "pie dogs" or pariah dogs typical of Africa and Asia (thought to be similar to Rhodesian Ridgebacks). Kruuk further shows reduced levels of predation between members of the Gabra tribe (the tribe with the highest percentage of dog use) with many versus few dogs. The specific effect of dogs on individual predator species was not determined but the villages have most depredation problems with lion, spotted hyaena, cheetah, wild dogs, and black-backed jackals.

In Namibia, the Cheetah Conservation Fund has imported LGD for use by local livestock owners as a non-lethal alternative for reducing cheetah predation (Marker-Kraus & Kraus 1993, Marker-Kraus et al. 1996). They are trying to re-establish dwindling populations of cheetah in non-protected areas, traditionally used for livestock grazing. Though the project is in its infancy they are reporting success, with reduced predation and observations of the dogs repelling attacks by cheetah, caracal, jackal, and baboons (Cheetah Conservation Fund 1995).

(3) Wolves: The use of LGD against predation by wolves has a long tradition in Europe and Asia (Coppinger & Coppinger 1996). The Coppingers' (1996a) review the available European literature noting that there are few technical publications available but popular accounts show that wolf and bear are still the most common adversaries for LGD. Wolves currently present a minor, (though locally severe) depredation problem in North America (Fritts et al. 1992). However, due to the protected status of wolves and efforts for reintroduction, their significance on livestock predation will undoubtedly increase (Cook 1993). Coppinger (1987 cited in Coppinger et al. 1988) first evaluated the effectiveness of LGD for protecting cattle from wolves in Minnesota. They documented several interactions without any injuries sustained by either the dogs or wolves, rather resembling normal dog-dog (wolf-wolf) interactions to ascertain dominance status. They concluded that LGD maintained

Table 3.7.2 Losses of sheep and lambs from predators: number of head and total value, United States, 1994 (USDA 1995).

Predator	Number of livestock killed	Percent of total predators	Value (USD)	Value (USD x 6.5) (Million NOK)
Coyotes	243,800	66.2	$11,504,900	74.8
Dogs	40,325	11.0	2,206,975	14.4
Mountain Lions	28,500	7.7	1,460,600	9.5
Eagles	15,000	4.1	641,150	4.2
Foxes	12,350	3.4	507,250	3.3
Bears	12,250	3.3	640,150	4.2
Bobcats	9,200	2.5	418,425	2.7
All others	6,625	1.8	337,450	2.2
TOTAL U.S.A.	**368,050**	**100.0**	**17,716,900**	**115.2**

their protective roles against wolves not by direct aggression but rather by disrupting the normal predatory sequence of the wolves. Wolves would either avoid the LGD territories or would be distracted into other behaviours (greeting, ritualised contests to determine status, play, etc.) thus increasing the effort needed to make a kill (Coppinger & Coppinger 1995).

Additionally they found LGD effectively prevented feeding by wolves and black bears at carrion feeding stations (Coppinger et al. 1987 cited in Andelt 1996, Coppinger & Coppinger 1995). Coppinger (1992) explains the similarities between LGD and wolves and proposes a mechanism through which LGD are successful guarding livestock against a behavioural con-specific. In general it can be said that wolves avoid the LGD initially but that over a period of weeks will come closer and closer until near contact is made.

The Coppinger group also observed wolf LGD interactions under controlled conditions within a large fenced enclosure at Wolf Park, Indiana (Coppinger & Coppinger 1995). Results of this work affirmed the con-specific nature of the wolf-dog relationship but also showed the dominance of wolves over LGD in direct confrontations. Why wolves avoid LGD in the field remains an unanswered question.

As regards reintroduction, Coppinger & Coppinger (1996a) recommend that LGD be established with livestock in possible conflict zones long prior to the wolves' arrival, giving the LGD time to establish their territories. It should also be pointed out that wolves have been documented having killed pet dogs, including Anatolian Shepherds in Minnesota and Montana (Fritts & Paul 1989, Woodruff pers. comm. 1996).

(4) Wolverines: There have been no confrontations between wolverines and LGD documented. At this point we can only speculate that wolverines would probably avoid confrontation with dogs choosing instead, the path of least resistance and simply avoid the dogs. However should wolverines choose to attack LGD then they would probably succeed in killing the dogs. We should point out that this is true with all of the large predators and that it is not the LGD's fighting ability that protects the flock but rather their interference with the normal predatory routine that inhibits depredation.

3.7.2.5 Costs

The initial costs for LGD range from 1500-6500 NOK ($240 to 1,000 USD) depending on the age and breed selected (Green et al. 1984a, Lorenz 1989b, Andelt 1996). First year costs of shipping, feed, veterinary expenses, travel, damages caused by the dogs, etc., average between 4500-5800 NOK ($700-900). Subsequent mean annual expenses ranged from 1600 to 1900 NOK ($250-290) (Green et al. 1984a, Andelt 1992). Time investment in supervision, training and feeding of LGD averaged 9 hours per month for 37 ranchers surveyed by Green et al. (1984a) and 10 hours per month for 21 Colorado ranchers (Andelt 1992).

Eleven of 44 (25%) ranchers in the Green et al. (1984a) survey reported that they owned dogs that had injured or killed livestock. Fourteen of 135 (10%) dogs killed or injured at least 1 sheep or goat in their lifetime. Of these 9 were isolated incidents in dogs less than 2 years old that later became good LGD. However, 5 (4%) of the dogs persisted in livestock killing and were culled (Green et al. 1984a).

3.7.2.6 Benefits

Green & Woodruff (1989b) report that 82% of livestock producers using dogs in the USA and Canada thought that LGD were an economic asset. Ninety-nine percent of the 360 producers using pasture grazing systems and 38 of 39 producers grazing open ranges recommended dogs. Results were varied between LGD working the open ranges and those in fenced pasture systems though both were generally good (**table 3.7.3**).

In an earlier survey Green & Woodruff (1985) found that 73% of producers reported that LGD resulted in annual savings averaging 1200 to 94.000 NOK ($180 to $14,487) (calculated by dividing the difference of [dog expenses] minus [value of sheep saved] by the number of years a dog was in use). Andelt (1992) reports on 11 Colorado producers who calculated that LGD annually saved 21.000 NOK ($3,216) worth of sheep. In Oregon Lorenz (1989b) found that small flock owners ($\bar{X}$ = 105 sheep, range 30-400) saved 3300 NOK ($501) per dog and large producers ($\bar{X}$ = 644 sheep, range 500-2600) saved 4000 NOK ($615) per dog.

Table 3.7.3 Evaluation of livestock guarding dogs effectiveness by 399 respondents to a 1986 survey of livestock producers from the US and Canada (Green & Woodruff 1989b).

Grazing system	Performance rating of dogs			Totals
	Very effective (%)	Somewhat effective (%)	Not effective (%)	
Pastures	475 (71%)	144 (21%)	52 (8%)	671
Open Range	60 (66%)	17 (19%)	14 (15%)	91

3.7.2.7 Summary

With the use of any tool there will be some situations where its use will be of limited usefulness. This is equally true of LGD. Green & Woodruff (1985) effectively summarise both the positive and negative impacts of incorporating LGD into a livestock management plan and their results are quoted below.

> In the course of our research we identified potential benefits associated with using a guard dog.
>
> **BENEFITS:**
> 1. A reduction in predation.
> 1. Reduced labour (i.e. no longer necessary for a shepherd to be present 24 hours a day).
> 1. If night confinement is discontinued, pastures can be utilised more efficiently and condition of sheep may be improved.
> 1. Increased utilisation of acres where predators made grazing prohibitive prior to use of dogs.
> 1. Increase in grazable acres may provide opportunity to increase the size of the flock.
> 1. Improved potential for profit.
> 1. Dog alerts owner to disturbance (predators) near the flock.
> 1. Increased self-reliance in managing predator problems.
> 1. Protection for family members and farm property.
> 1. Peace of mind.
>
> **PROBLEMS:**
> Although the majority of dogs that are reared to protect sheep are ultimately successful, there are potential problems during the adolescent period of the dog as well as problems that may develop with an experienced dog. Many of the problems are considered to be minor by most producers, but others are serious. We identified the following potential problems.
>
> 1. Dogs occasionally harass sheep (usually a play behaviour) resulting in injury or death.
> 1. Dog does not guard sheep.
> 1. Dog is overly aggressive to people.
> 1. Dog harasses other animals (livestock or wildlife).
> 1. Expenditure of labour to train and supervise the dog.
> 1. Dog destroys property (chewing objects, digging).
> 1. Dog is subject to illness, injury, or premature death.
> 1. Dog roams beyond farm boundaries causing problems with neighbours.
> 1. Financial expenditure with no guarantee of the dog being successful.
> 1. Dog interferes when sheep are moved or interferes with herd dog.

There have been other studies showing mixed or negative results of LGD (Lorenz et al. 1986, Timm & Schmidt 1989) but the list above adequately details the problems encountered. The end result is that is most cases LGD appear to be a cost-effective tool to help reduce the problem of predators.

3.7.3 Guard donkeys

Donkeys are descendants of the wild ass and are small sturdy animals (0.8 to 1.5 m at the shoulder) found throughout the world (Varshney & Gupta 1994). They are generally thought to be divided into two species, the African or true wild ass and the Asiatic wild ass or half ass. Donkeys were first domesticated around 2650 B.C. in the Nile Valley and have a physiological tolerance for extremes, both nutritional and climatic (Varshney & Gupta 1994). Historically donkeys have been used as draught animals, static power, cart animals, pack animals, riding animals, meat, milk, fuel and fertiliser (dung) (Varshney & Gupta 1994). A recent addition to this list is their use as a guard animals.

Apparently using donkeys as guardian animals builds upon their herding instincts and an innate dislike and aggressiveness towards canids in particular. To date there have been no controlled testing of the effectiveness of donkeys against various predators though some studies are in progress. There are numerous popular accounts of their use, but only 3 scientific publications that survey their use as livestock guardians.

The most comprehensive publication (Walton & Feild 1989) estimated that from 1,000 to 1,800 of the 11,000 active sheep and goat ranchers in Texas used donkeys as guard animals (based on a survey sent to 500 producers). Green (1989a) bases an estimate of donkey use on the percentage of donkeys being adopted from the U.S. Government's "Adopt A Burro" Program. Since 1972, 13,229 donkeys have been adopted as pets, breeding stock, or guardians, by people throughout the United States. Data from one area (South Dakota) indicate that in 1988, 62% of 50 adopted donkeys were intended for use as guard animals. This figure steadily rose with 73% of 113 donkeys in 1989 and 79% of 114 donkeys in 1990. These figures indicate an increasing tendency for using donkeys as guardians.

Low purchase price ($\bar{x}$ = 936 kr. ($144), range 422 kr.-1625 kr. ($65-$250), minimal maintenance costs ($\bar{x}$ = 430 kr. ($66), range 0-1950 kr. (0-$300), long life expectancy (10-20 years), no labour invested in training, no special feeding requirements, and compatibility with other lethal predator control techniques (specifically, M-44's and 1080 collars), are the reasons for the increasing interest in donkeys (Green 1989a, Walton & Feild 1989). However their range of usefulness appears to be more limited than dogs.

The effectiveness of donkeys as guardians is highly variable depending upon the type of predator and the temperament of the individual donkey (Green 1989a, Walton & Feild 1989). Poor husbandry practices and unrealistic expectations are cited by Walton & Feild (1989) as accounting equally for the failures of donkeys. In a survey of 17 known donkey users 59% of the donkeys were rated as good or fair. In a second survey conducted by Walton & Feild (1989) of 500 sheep and goat producers, sixty of the 275 respondents replied with ratings for their donkey's effectiveness (**table 3.7.4**).

The reactions of donkeys to larger predators such as puma and bear are not well documented but second hand reports tell of donkeys "running in terror" at their approach (Green 1989a). However Marker-Kraus et al. (1996) report that many farmers in Namibia use donkeys to successfully ward off cheetah attacks. They relate the story of another Namibian farmer who observed a mule trample a leopard to death.

In summary it appears that under relatively restricted conditions donkeys can be used to help against some predator problems. The results of donkeys as guardians are considerably more inconsistent than livestock guardian dogs and field conditions appear to be significantly more restrictive. The following list from Walton & Field (1989) outlines the husbandry conditions necessary for maximum effectiveness from donkeys as guardian animals.

Guard donkeys should be selected from medium to large size stock. Do not use extremely small or miniature donkeys.

1. Do not acquire a donkey which can not be culled or sold if it fails to perform properly.
2. Use jennies [females] and geldings. Do not use jacks [intact males] as guard animals.
3. Test a new donkey's guarding response by challenging the donkey with a dog in a corral or small pasture.
4. Use only one donkey or jenny with foal, per pasture.
5. Isolate guard donkeys from horses, mules, and other donkeys.
6. To increase probability of bonding, donkeys should be raised from birth or placed at weaning with sheep and goats.
7. Raise guard donkeys away from dogs. Avoid or limit the use of herding dogs around donkeys.
8. Monitor the use of guard donkeys at lambing or kidding as some donkeys may be aggressive to new-borns or overly possessive. Remove donkeys temporarily if necessary.
9. Use donkeys in small (< ca.240 ha.) open pastures with not more than 200 head of sheep or goats for best results. Large pastures, rough terrain, dense brush, too large a herd, and sheep or goats that are scattered all lessen effectiveness of guard donkeys.
10. Do not allow donkeys access to feed containing Rumensin, urea, or other products intended only for ruminants.

Due to the ease of management with guard donkeys, their use will likely continue to expand. With additional research better techniques and selection criteria for guarding donkeys (sex, breed line, etc.) will most likely be developed, increasing their utility in the future.

3.7.4 Guard llamas

The most complete work on guard llamas is an Iowa State University Co-operative Extension Service publication entitled "Guard Llamas" (Franklin & Powell 1993). There are several other popular publications available through local llama groups such as "Llamas for guarding livestock" (International Llama Association 1996).

Llamas are members of the South American camelid family composed of 4 groups: the llama and alpaca are domesticated and the guanaco and vicuña are wild. Llamas, guanacos, alpacas, and their hybrids are all used as guard animals but are all referred to as llamas (Franklin & Powell 1993). However Tronsen & Hansen (1995) report that alpaca producers in Israel find llamas to be more territorial and defensive than alpacas and actually use llamas to protect flocks of alpacas. Field studies in South America have reported observations of the wild species actively pursuing foxes but fleeing from pumas. Apparently these species are very territorial and even the domestic varieties will aggressively defend "their" pasture (Franklin & Powell 1993).

Franklin & Powell (1993) conducted telephone interviews with 145 sheep producers in the U.S. using 204 guard llamas. Their study revealed that 70% used gelded males costing 4500 kr.- 5200 kr. ($700-$800) with an average of one llama per 284 sheep (range 4-2150). Average pasture size was 100-120 ha. (range 2-3239 ha.) and

Table 3.7.4 Percentages of 60 Texas sheep and goat producers reporting various effectiveness ratings of guard donkeys against common mammalian predators (Walton & Feild 1989).

Species	Excellent	Good	Fair	Poor	Failure	Unknown
Coyote	3%	17%	20%	25%	17%	18%
Dog	2%	18%	22%	13%	15%	30%
Fox	0%	10%	13%	5%	8%	69%
Bobcat	0%	5%	5%	5%	13%	72%

producers had been using llamas for an average of 3 years (range <1-12 years). The average llama was 2 years old when first introduced to the sheep flock with 50% adjusting to the sheep within a few hours and 80% adjusting within a week. Producers reported that llamas can become closely bonded to sheep and show intense attachment to young lambs (Franklin & Powell 1993).

The average annual predation losses from 1972-1991 was reported by 114 producers to be 11% ($\bar{x}$ = 26 sheep and lambs). This figure dropped to 7% ($\bar{x}$ = 8 sheep and lambs) after introducing llamas. Eighty eight percent of the producers responded as satisfied (18%) or very satisfied (70%) with their guard llamas citing predator control and ease of maintenance as the top benefits. An average gross annual savings of 8150 kr ($1,253) range 0-130.000 kr. (0-$20,000) was reported among 87 producers (Franklin & Powell 1993).

Problems encountered by the producers surveyed by Franklin & Powell (1989) included attempts to breed ewes , aggressive behaviour (assumedly towards the sheep), overprotectiveness, and interference of sheep with feeding llamas.

While the Franklin and Powell survey indicates relatively good success with guard llamas there continues to be much scepticism. We have received many comments from llama breeders relaying numerous accounts of llamas themselves falling prey to not only the large predators but also to single coyotes and dogs (Chelle Rogers, Mare Jarvis, Laura Keller, Pers. Comm. 1996). Many of these breeders now use livestock guarding dogs to protect their llama flocks. It appears that more concrete studies should be conducted to more clearly identify and perhaps reinforce the guarding traits found in some llamas. Such research is underway at the United States Sheep Experiment Station and through Dr. Fred Knowlton at the USDA National Wildlife Research Centre.

3.7.5 Cattle

Some promising research has been performed on bonding sheep to cattle to decrease the risk of predation (Hulet et al. 1987, Anderson et al. 1988, Hulet et al. 1989, Anderson et al. 1994). This technique not only reduces predation but also enable better use of the grazing lands (Glimp 1988), minimise stress at weaning of sheep (Hulet 1988), and controlling the spatial distribution of sheep without fencing (Anderson et al. 1994).

The process of bonding sheep to cattle was accomplished by placing the young lambs 45-90 days old together with cattle in a small, 139 m^2 pen for 60 consecutive days (Anderson et al. 1987). After bonding the average distance between sheep and the cattle was reduced and in the presence of a emulated predator (trained border collie) the sheep responded by positioning themselves among the cattle and away from the dog (Anderson et al. 1988). Cattle aggression (kicking and charging) was observed only when the dog approached the cattle themselves indicating that the protection afforded sheep is a passive by-product of their close association with these potentially threatening animals (Anderson et al. 1988).

In 1986, Hulet et al. (1987) placed 9 cattle-bonded lambs together with 7 heifers at the Jornada Experimental Range in southwest New Mexico, USA. For comparison they placed unbonded lambs in adjacent pastures and rotated the control group with the test (bonded) group from pasture to pasture. During three trials no bonded lambs were lost during 163 days of testing, compared to 13 of 23 unbonded lambs or ewes lost over 63 days of testing (confirmed or strongly suspected to be coyote kills).

This group has also bonded goats to sheep and cattle, successfully reducing predation among those goats bonded to sheep and cattle. Five month old goats, kept together with cattle for 60 days were placed in 2 groups for an additional 14 days bonding. Group 1 was together with 2 heifers; group 2 was with together with 8 cattle-bonded sheep and a heifer; and group 3 was a control group of unbonded goats, sheep, and heifers. Comparisons among the 3 groups showed that only group 2 resulted in reduced predation. This reinforces previous observations of success with sheep bonded to cattle but indicates the necessity for goats to bond with sheep that are already bonded to cattle. Through this method they will remain near the cattle and obtain the same passive protection as sheep (Hulet et al. 1989).

Problems associated with this technique are primarily the additional costs and labour involved during the bonding period. Anderson et al. (1994) estimate that the cost for pen confinement of 42 lambs for 55 days was 3.3 kr. ($0.51) per lamb/ per day. These costs can be offset by reduced predation loss, reduced fence expenses, and reduced time spent searching for sheep (Anderson et al. 1994). At this time it is not possible to give adequate estimates for the value of these savings. Also the effectiveness of this technique in areas impacted by large, cattle killing predators is unknown, but likely to be greatly reduced and highly variable.

Further research is needed to discover the most effective herd composition for both sheep and cattle (breed, sex, age, numbers, etc.) as well as exploring less expensive bonding techniques.

3.7.6 Other species

The following animals have been briefly mentioned in the previous literature as additional guard animals, though their use is probably quite limited: Goats, Baboons, Zebras, and Stallion horses in Namibia (Marker-Kraus et al 1996); Ostriches in South Africa (Jennings Pers.Comm

1996, Franklin & Powell 1993); Kangaroos (Franklin & Powell 1993).

3.8 Carcass and carrion disposal

Main points - Carcass disposal
- *Removing carcasses and carrion from a pasture will avoid attracting scavenging carnivores from the area and will help prevent larger populations of smaller carnivores (foxes etc.) from developing.*

Carcasses which have either been killed by predators or died from other causes should generally be disposed of by burial or incineration. Leaving carcasses around on the pasture can actually increase depredation (Andelt 1996, Lehner 1976, Yom Tov et al. 1995);
- by allowing populations of generalist carnivores (foxes, jackals, eagles) and scavengers to increase.
- Conditions scavengers and carnivores to livestock as a food source
- attracts scavengers/carnivores to the area where the livestock are kept.

The success of cleaning up carcasses at reducing coyote predation on pigs and sheep was demonstrated by Robel et al. (1981), Todd & Keith (1976) and Jones & Woolf (1983). Also the general health aspects of leaving rotting meat on the range needs to be considered.

Finding a carcass that is still being fed on by the carnivore that killed it is a special case. On the one hand if it is left undisturbed the carnivore is able to eat it completely, and this will prevent the immediate killing of another animal. However, it also conditions the carnivore to eating livestock. On the whole if depredation is rare, and there are active measures taken to reduce depredation it is probably best to scare the carnivore away and dispose of the carcass. However if depredation is common and therefore most carnivores are already conditioned to eating livestock it is probably best to leave the carcass for the carnivore to completely consume, unless the economic loss can be minimised by recovering some of the meat/skin.

3.9 Fencing to restrict livestock movements

Main points - fencing to restrict animal movement
- *Fencing which only restricts livestock movement may be effective to keep livestock away from high-risk habitats and will allow animals to be more easily herded into night-time enclosures.*
- *Gaining control over flock distribution is vital for any measures to reduce depredation.*

An earlier section (**section 3.2**) has discussed predator-exclusion fencing. Fencing can also be used to control the movement of livestock. The rate at which they use different habitats or patches can be regulated and they can be more easily gathered in for the night. Livestock can also be fenced out of areas / habitats associated with high risks of predation. Fencing required to control the movements of livestock is much easier and cheaper to erect than predator-exclusion fencing, and has virtually negligible side effects on other wildlife. Both electric and wire fencing is usable under most grazing conditions, with electric fencing being most portable. While fencing livestock inside fencing that is not carnivore proof will not necessarily decrease depredation (see **section 3.17** for an exception), it does permit the herder to have better control over the flocks. This control is vital for the successful use of guarding dogs (**section 3.7**) and night-time enclosures (**3.11**) in situations where it is not economic to have a shepherd with the flock 24 hours a day.

3.10 Avoiding depredation "hot-spots"

Main points - avoiding depredation hot-spots
- *Carnivores usually show selection for certain habitats and topographical features.*
- *Keeping livestock away from such areas, through fencing or herding, may serve to reduce encounter rates between carnivores and livestock.*

Carnivores do not use their habitats at random. Certain habitats or landscape features are selected for different activities like hunting, travelling or day-lairs. Keeping sheep away from such areas will reduce encounter rates and may help reduce depredation. Sheep can be excluded through either fencing or active herding. Large felids such as cougar, snow leopard and leopard have been demonstrated to kill most livestock in steep, rocky areas, probably because these areas are associated with their day-lairs (Shaw 1988, Cunningham et al. 1995, Jackson et al. 1994, Mizutani 1993, Richard et al. 1994). Jaguar depredation on cattle occurs almost exclusively in forest, especially in riverine forests, and a ranch with a policy of excluding cattle from forest land had lower rates of depredation than neighbours which grazed animals in the forest (Hoogesteijn et al. 1993. Rabinowitz 1986). In a Belize study, jaguars never killed pigs in or near villages, yet killed any pigs left out or grazed in the forest (Rabinowitz 1986). Despite having a large lynx population, predation on unattended sheep in Switzerland was very low primarily because sheep were kept out of the forest. Lynx predation on sheep was higher in areas with forest grazing rights (Kaczensky 1996, **section 6.6**). Snow leopard and coyote predation on livestock was also associated with the availability of stalking cover (tall grass, bushes) on the pasture and coyote predation was higher in pastures that contained a stream or much brush and rough terrain (popular coyote hunting habitat) than in other pastures (Pearson & Caroline 1981, Robel et al. 1981, Jackson et al. 1994). Predation from bear, wolf and lynx is typically higher in forest than mountain areas, although wolverine and eagle predation is generally confined to mountains (Fritts 1982, Fritts et al. 1992, Wabakken & Maartman 1994, Wabakken et al. 1996).

3.11 Enclosure at night

Main points - Night-time enclosure

- *Most carnivores are night-active. Herding livestock into a solid carnivore-proof night-time enclosure is a traditional husbandry technique which has been shown to be very effective at reducing depredation. Electric or wire fencing is most practical.*
- *It requires that livestock are herded or have their movements restricted during day-time so they can be collected at night.*

Most carnivores are mainly active at night, a fact that has been well known by herders for millennia. Accordingly in almost all forms of traditional herding, livestock are kept inside pens, often close to the farm or village, at night (Kruuk 1980). Night guards are often posted to deter both wild and human predators. Simply concentrating the animals into a corral at night reduces the probability of an encounter between a hunting carnivore and livestock. This measure alone has been shown to reduce predation by coyotes on sheep (Dorrance & Roy 1976, Nass et al. 1984, Robel et al. 1981). Typically individual livestock which are left out at night suffer very high mortality (Kruuk 1980, Mizutani 1993, Saberwal et al 1993). However, if a carnivore is able to enter a night time corral the possibility for surplus killing greatly increases (Dorrance & Roy 1976, Jackson et al. 1994, Kaczensky 1996, Mizutani 1993, Wick 1995). Therefore, night time enclosures should be constructed as solid and carnivore-proof as possible (**section 3.2**). Villages with better constructed night time corrals had lower predation rates than villages with poorly constructed corrals (Karani et al. 1995, Kruuk 1980, Jackson et al. 1994). Lights at a corral can further reduce predation (Robel et al. 1981). Corrals close to human habitation are likely to be particularly effective.

When using night time corrals for any period of time, the health care of the animals becomes even more important because of the crowding. Ecto- and endo-parasites can increase in numbers and are more readily transmitted between animals. Livestock need more frequent anti-parasite treatment and the enclosure may need to be treated with chemicals that kill ecto-parastites (Wade & Connolly 1980, Kruuk 1980).

Conventional wisdom dictates that livestock that are confined at night may have reduced weight gain caused by the reduced grazing time available. Todate, two experimental studies have shown that both cattle and sheep can behaviourally compensate for lost grazing time (Bayer 1990, Iason et al. submitted). Although the generality of this remains to be seen, especially on complex and heterogeneous pastures, the problem can be reduced by providing additional feed inside the enclosure. Such a management practice also permits daily inspection of the livestock.

3.12 Shepherding

Main points - Shepherding

- *The constant presence of a shepherd with a concentrated flock of livestock is effective at reducing depredation. The shepherds presence should help deter carnivores from the immediate area, and the shepherd is able to interrupt carnivore attacks.*
- *In addition, a shepherd can hold a flock together to enable guarding dogs to function or to gather the flock into a night-time enclosure.*

The *constant* presence of a human shepherd with a *concentrated flock* of livestock can reduce predation in a number of ways;

- the shepherd can manage the herd to keep it away from certain depredation hotspots and confine it at night.
- the shepherd can interrupt carnivore attacks that are in progress, and either prevent any animals from being killed or reduce the number of livestock killed per attack. Such interruption will also provide a negative experience for the predator.
- human scent and constant presence associated with a specific area may act as a deterrent.
- depredation will be rapidly documented to aid compensation payment or to allow effective control action to occur.

Occasional human presence, especially among widely dispersed livestock is unlikely to help reduce depredation, but it may assist in the finding of kills and a better documentation of the problem.

The success of shepherds is a vital component of other husbandry practices like night time confinement, or keeping the livestock together, rather than spread. Their use throughout the world was ubiquitous, and still is in many places. Where shepherds are present and vigilant, depredation has been demonstrated to be reduced (Jackson et al. 1994, Jorgensen 1983, Karani et al. 1995, Kruuk 1980, Nass et al. 1984, Tigner & Larson 1977, Wick 1995) and some of the highest losses of livestock are reported from herds that are not herded or supervised (Boitani 1982, DeLorenzo & Howard 1976, Henne 1977, Kaczensky 1996). As many predators can also be dangerous to humans, it is not recommended that children should be responsible for guarding livestock at night. In addition it has been recommended that shepherds be armed with some form of self defence or carnivore repellent devices such as spears (Kruuk 1980), shotguns capable of firing flashes or rubber bullets (Clarkson 1989) or pepper spray (**section 3.4.3**). As well as providing protection for the herder in the rare case of an attack on a human (Swenson et al. 1996), such stimuli will reinforce the negative experience associated with interrupted depredation attempts.

Probably the biggest constraints on the use of herding are economics and the availability of competent shepherds that are prepared to accept the long hours and hard working conditions associated with the job.

3.13 Herding Dogs

Main points - Herding dogs
- *Herding dogs alone do virtually nothing to prevent depredation. However, they are vital aids to a shepherd for efficient herding of the flocks to direct their movements and gather them at night.*

The use of guarding dogs has been reviewed in **section 3.7**. They are best used in conjunction with other husbandry methods such as herding, fencing of livestock and night time confinement. Even the presence of non-guarding dogs has been shown to reduce depredation to some extent (Kruuk 1980, Robel et al. 1981), and any dogs can act as an alarm to alert a sleeping herder to the presence of a predator. While herding dogs (border collie, kelpie etc.) are not very effective at reducing depredation on their own they are a vital tool for managing herds and making their herding easier (Coppinger & Schneider 1995). Most sheep herding traditions which depend on the use of herding dogs (Australia, New Zealand, Scotland, western US etc.) would find it difficult to imagine that anyone would try to herd sheep without a dog. Although their selection and training takes time, they should be considered as an indispensable part of any herding operation.

3.14 Controlled calving/lambing

Main points - Controlled calving/lambing
- *New-born lambs and calves are much more vulnerable to a wider range of carnivores than animals older than a few months. Lambing and calving should always be under the most controlled conditions possible, on the most protected pastures.*

All livestock are most vulnerable to carnivores in the period after birth. As they grow larger they become less vulnerable to the most common predators. For examples, foxes and eagles almost exclusively kill lambs during the first month of life (Bergo 1990, Bellati & Thungen 1990, Hewson 1984, Saunders et al. 1995, Smith 1965, O'Gara 1978) and coyotes and jackals exclusively kill cattle calves during their first month (Dorrance 1982, Yom-Tov et al. 1995). With this background it makes sense to ensure that lambing / calving occurs either indoors or under very close supervision and / or in areas from which predators are excluded (Marker-Kraus et al. 1996). Husbandry techniques that involve unsupervised lambing or calving on open range are associated with generally high losses (Bjorge 1983, Shaw 1988, Tigner & Larson 1977). When the number of lambs that die from exposure or mis-mothering in free-range lambing operations are considered (e.g. Alexander 1987) this policy will also have many secondary benefits.

Even when livestock are several months old, most predators select for the smallest domestic animals on the pasture (lambs and calves). For example wolves, dingoes, black bears and cougars almost exclusively kill calves less than 6 months old (Bjorge 1983, Corbett 1995, Cunningham et al. 1995, Gunson 1983, Horstman & Gunson 1982, Jalkotzy et al. 1992, Shaw 1977, 1988) and lynx and coyotes select for lambs over ewes or rams (DeLorenzo & Howard 1976, Henne 1977, Wabakken et al. 1996). Where possible young livestock should be grazed in the safest pastures available, or grazed with the most intensive herding methods. Bears killing sheep are probably an exception in that they can select for adult ewes over lambs (Wabakken & Maartman 1994, Wabakken et al. 1996), and many smaller predators are probably able to kill adult sheep when the possibility of killing lambs is not available. Cattle reach an absolute size that confers near immunity from predation by most medium sized predators and therefore it is unlikely that predators will switch from calves to adults if calves are no longer available. However, in general anything which decreases vulnerability to predation will help increase survival.

3.15 Adjusting birth season to decrease vulnerability to predation

Main points - Adjusting birth season
- *The birth season of cattle and sheep can almost always be adjusted in modern agricultural systems.*
- *To help reduce depredation the birth season should be adjusted so that new-borns are as old as possible before release onto open pasture.*
- *In some situations it may be possible to synchronise birth with a season of high alternative prey availability.*

Apart from the extensive free-ranging cattle ranches of Australia, south America, and North America, where herders have minimal contact with their animals, most lambing and calving could be timed to any desired season. In production systems were livestock are confined during one season and released onto open range in another season lambing / calving could be timed and synchronised so that all females had given birth before being released onto open range (Bjorge 1983). This could be especially useful if enough time were allowed for lambs / calves to pass through the critical period after birth when they are most vulnerable to predation. In an extreme case in Kansas, ewes gave birth during late autumn just before winter confinement. By the time that animals were released onto pasture in spring lambs were several months old and much less vulnerable to predation (Robel et al. 1981).

In less seasonal environments lambing / calving could be timed to periods of high alternative prey abundance, or other periods when predators are less likely to kill livestock such as denning or mating (Corbett 1995, Till & Knowlton 1983).

In cases where new-born livestock are vulnerable for only a short period after birth, synchrony of birth between neighbouring farms / ranches can reduce depredation levels by swamping the resident carnivores during a short season. Staggered birth allows the carnivores to depredate on one property for the duration of the birthing season before moving onto another property (Saunders et al. 1995) and may even permit a numerical response by the carnivore population if the net effect of staggered births is a year round food supply.

3.16 Different breeds and species of livestock

Main points - Different breeds and species of livestock

- *Cattle are generally much less vulnerable to depredation than sheep and goats because of their large size and better ability at defending themselves. In areas with high numbers of carnivores, changing from sheep / goat production to beef production would be very successful at reducing depredation.*
- *Different breeds of both cattle and sheep have different characteristics such as aggression, flocking behaviour, body size and anti-predator behaviour, which may help make them more compatible with other husbandry techniques.*

There are two behavioural characteristics of livestock breeds which could be modified to help reduce carnivore-livestock conflicts;

- behavioural traits which affect the ease of herding, and
- behavioural traits which make livestock less vulnerable to attack.

In the first category, livestock breeds which stay together in a flock, and which respond well to a herder or a dog could make the process of herding easier. In the second category breeds which are larger, more aggressive, or with better anti-predator behaviours may be less vulnerable to predation. Selection for more aggressive cattle is already underway in the US and offers many good possibilities. The selection for maximal milk / meat / wool production within the last few decades has lead to the widespread use of many breeds which are totally unsuitable to free-range grazing, especially where predators occur. Fortunately most older breeds of domestic livestock still survive, albeit at low numbers, and the possibility for further breeding still exists. Among cattle, goats and sheep breeds there is still always the possibility of breeding with their wild ancestors (bison / yaks for cattle, ibex for goats, bighorn / thinhorn for sheep) to improve anti-predator behaviour if so desired.

Different species of domestic animal have different levels of vulnerability to predation. Given the ability of large carnivores to kill wild ungulates which have a complete repertoire of anti-predator behaviours it is unlikely that it will be possible to breed a sheep or goat race which is immune to depredation. It may be possible to decrease their vulnerability, although this may often be at the expense of ease of herding. In general cattle are much less vulnerable to predation than sheep / goats due to their larger size and better anti-predator behaviour. Almost universally both predation rates (Connolly 1992, Fritts 1982, Gee 1979, Kaczensky 1996, Terrill 1977) and the incidence of surplus killing (Horstman & Gunson 1982) on cattle are at least an order of magnitude lower than for sheep. The only reported case where cattle and sheep were equally likely to be killed was from north Spain (Clevanger et al. 1994, García-Gaona 1995). Cattle are more valuable than sheep, and therefore the loss of an individual will have greater economic impact, however it take less cattle to support a herder, and a smaller herd allows easier management and herding.

Data on the vulnerability of other domestic species like goats, horses, yaks, and llamas are rare, and not suited for detailed comparison. Horses, both feral and domestic, appear to be more vulnerable to large felids like cougars and snow leopards than their size would predict (Schaller et al. 1994, Turner et al. 1992).

3.17 Grouping of livestock - making use of carnivore territories

Main points - Grouping of livestock

- *Carnivores generally show some degree of spatial segregation, and most evidence todate shows that in very few cases will a carnivore actually select (kill a larger than expected proportion based on relative availability) livestock when other prey is available.*
- *Clumping livestock into concentrated patches will serve to reduce encounter rates between carnivores and livestock at both the level of the individual carnivore and the population.*
- *Having livestock spread out across large areas will maximise encounter rates.*

Populations of almost all species of carnivore have a degree of spatial structure, which limits the number of individual carnivores within an area (Sandel 1989). This can be used to reduce encounter rates between carnivores and livestock. At the level of an individual carnivores home range or territory, grouping the livestock into one or a few herds will reduce the encounter rate between the carnivore and the livestock, resulting in a higher probability of wild prey being encountered and killed first by the carnivore. Within the scale of a population, grouping of livestock into a smaller area will reduce the number of individual carnivores (or social groups) with access to the livestock at any one moment (Althoff & Gipson 1981). This strategy will be especially useful in populations with an old and stable social structure. Harvest or control activities will reduce the rigidity of social structure, and may allow more individuals into a given area (**section 2.4**).

Some carnivore species are able to cross each other's territories when hunting for migratory or mobile prey- examples include coyotes feeding on sheep (Shivik et al. 1996) and spotted hyenas hunting wildebeest (Hofer et al. 1993). Most carnivores clearly do not select for sheep or other livestock over natural prey and if natural prey is abundant, leaving the home range should not be necessary. For example, bears were not observed to follow moving sheep herds (Jorgensen 1983, Wick 1995) and the carnivore literature is full of observations of individual carnivores living close to livestock areas, and never killing livestock (Bjorge 1983, Fritts et al. 1992, Kaczensky 1996, Rabinowitz 1986).

3.18 Temporal avoidance of depredation

Main points - Temporal avoidance of depredation

- *Depredation is rarely evenly distributed throughout the year. Seasonal levels are determined by both the life cycle of the carnivore, and the life cycle of the livestock.*
- *Periods of maximum depredation can be associated with seasons with little alternative prey, bears fattening-up for winter, reproduction of carnivores etc.*
- *Depredation can be minimised by providing maximum protection for livestock during periods of greatest risk.*

Levels of depredation on livestock are rarely uniformly distributed throughout the year. In general there are distinct periods of the year during which a disproportionate amount of depredation occurs. These peaks can be explained by four separate, but not mutually exclusive, factors;

- seasonal changes in husbandry practice which alter livestock's vulnerability to depredation.
- seasonal changes in livestock's life cycle (mainly age structure) which affects vulnerability.
- seasonal changes in predator's life cycle affecting predation rates.
- seasonal changes in alternative prey availability

3.18.1 Seasonal changes in husbandry practice

Almost all regions on earth are seasonal (hot season / cold season or wet season / dry season) and husbandry practices usually vary with these seasons. Grazing patterns are dictated by the spatial and temporal distribution of good grazing, for example by its availability with respect to snow or rain. Flocks of livestock are either grazed in different areas, at different altitudes, or kept indoors depending on the season. Such changes in husbandry clearly influence the level to which livestock are exposed to predators. As animals are at most risk when grazing on open pasture, the limitation of this season is the most vital.

3.18.2 Seasonal changes in livestock's life cycle

Most depredation on livestock peaks after the birth period, or when young of the year are first released onto open pasture. The increased vulnerability of new-born lambs and calves to depredation and ways of reducing this risk have been discussed in **section 3.14**.

3.18.3 Seasonal changes in predator's life cycle

During a year carnivores go through distinct cycles of mating, birth, lactation, cub rearing, and in the case of bears, hibernation. Each phase of this cycle is associated with distinct energetic requirements that effect the probability of livestock being depredated. When bears emerge from hibernation, they are usually very low on fat reserves and need to consume high fat, high protein foods to quickly regain body condition. The killing of ungulates, both wild and domestic has often been observed to peak during this post-emergence period. During late-summer and early autumn bears are trying to accumulate fat reserves for their winter hibernation and will exploit the existing fat rich food resources. Livestock depredation by bears has been observed to peak during this period in several studies (García-Gaona 1995, Gill and Beck 1990, Horstman & Gunson 1983, Kaczensky 1996, Wabakken & Maartman 1994).

Increased coyote predation on livestock has been linked to the increased energy requirements of the pup rearing period (Till & Knowlton 1983) while increased wolf predation on cattle and sheep in late summer has been explained as being due to the increased mobility of packs with pups of the year which are just becoming active. Seasonal peaks in dingo attacks on cattle were explained as being due to displacement behaviour of sexually frustrated non-dominant males (Corbett 1995).

3.18.4 Seasonal changes in alternative prey availability

Natural prey species go through cycles of abundance, both within years and between years. For example, in the same way that domestic animals are more vulnerable in the period after birth, the young of wild ungulates are also much more vulnerable after birth. Wolves prey heavily on white-tailed fawns (Kunkel & Mech 1995) in late May and June. Depredation on livestock increases during July-August, which has been explained by the wolves switching to livestock after fawns become less vulnerable (Gunson 1983, Tompa 1983, Fritts et al. 1992). Hibernation of marmots in winter appeared to cause an increase in snow leopard depredation on livestock (Schaller et al. 1988).

3.18.5 Avoiding periods of maximum depredation

Although the seasonal cycle of depredation varies widely from area to area and from predator to predator, if the seasonal pattern of depredation is known within a given area livestock can be brought in from open pasture, or more intensive husbandry methods can be used during this period. Although there are no evaluations of the success of this measure it has been recommended (Gill & Beck 1990, Wabakken & Maartman 1994) in the context of avoiding the late summer peak in bear depredation. Increased costs may be associated with bringing livestock in from seasonal open pasture, however these will almost always be less than the costs of losing sheep to depredation. The success of the strategy depends clearly on the exact seasonal pattern existing within a given area. Where this peak is pronounced, the strategy will have best effect.

3.19 Protection collars

Main points - Protection collars

- *Strong collars have often been used to protect sheep from the throat bite of carnivores like lynx which have a site specific bite on the throat.*
- *The success of this measure has never been adequately tested, and certainly will not help against carnivores like bears or wolf.*

Protection collars (not to be confused with toxic collars which are also called Livestock Protection Collars, see **section 2.2.1.6**) are made of steel or strong nylon and placed around the neck of livestock in the area that predators bite. The principle is to physically prevent the bite from killing, and hopefully provide a negative experience for the carnivore. Protection collars have been used in several areas in Europe, although there has been little evaluation. One trial in Norway indicated that they reduced lynx and wolverine depredation on free-ranging lambs (Bø 1993) and a second trial is also underway in Norway (Wabakken pers. comm.). Further research is needed to evaluate their widespread effectivity, but they will be only effective against carnivores with very site specific bites like felids and wolverines. They are likely to be ineffective against bears and wolves.

3.20 Does compensation reduce carnivore-livestock conflicts?

Main points - Compensation

- *Payment of compensation for livestock killed by carnivores does nothing to reduce the level of depredation.*
- *It is, however, vital to increase public acceptance of depredation, and to prevent extreme economic hardship on the part of herders that are exposed to depredation.*

In many countries and states around the world monetary compensation is available for damage to private property, such as livestock or crops, which is caused by wildlife. This is not universal and among other things depends on the legal status of wildlife within the country (state-ownership vs. private ownership), and if the state is legally liable for damage caused by wildlife (Wolfe 1995). Even when the state is not legally liable for wildlife damages, it is common to compensate damage caused by endangered species to aid their conservation. Generally compensation for damage caused by endangered carnivores is available in western Europe, and parts of eastern Europe and North America, and is lacking throughout most of Africa, Asia and South America (see **section 6.10** for an exception).

However, the system by which compensation is paid and the source of the funding varies from country to country. A comprehensive review is beyond the scope of this section, but in general funds come from three sources (Kaczensky 1996);

(1) State government. The state is usually the source of compensation for species which are protected or classified as endangered.
(1) Hunters' association. For carnivores classified as game species and which are huntable, either the hunters' association or the lessee of hunting rights must pay the compensation. Generally this is through an insurance fund. Examples include Austria, Slovenia and Poland.
(1) Private organisations. In several cases where neither government or hunters are economically liable, private animal protection may pay compensation for damage caused by endangered species organisations (e.g Defenders of Wildlife have created a trust fund to pay for damage caused by the reintroduced Yellowstone wolves).

The process of validation and the proportion of loss compensated also varies, with some countries paying inspectors, and others relying on the herders' claims alone. In many cases the full value of the livestock is paid, in other cases only a proportion of the loss is compensated. The subject of animals which are missing is particularly variable. Some countries only pay compensation when husbandry methods are judged to be adequate to reduce conflicts (Gunson 1991, Gunson & Markam 1993).

The main point relevant to this review is that *compensation for killed livestock is not a cure for carnivore-livestock conflicts*. The logic is that a reduction in economic loss resulting from the physical loss of an animal will result in acceptance of the presence of carnivores. This may be true to some extent, especially in areas of the world where loss of livestock can threaten human survival, although these are generally the areas where compensation is least available (Oli et al. 1994). Compensation in no way contributes to a decrease in the number of livestock being killed. In fact the opposite may happen if owners lose motivation when they do not suffer personal economic hardship as a result of their loss. This may result in less intensive husbandry and increased losses.

The only compensation system that actually encourages conservation of carnivores *and* better husbandry practices to reduce conflicts is the system presently in use in reindeer husbandry areas of Sweden. In this system the owners of semi-domestic reindeer are compensated (at predetermined rates) for the presence of carnivores, especially breeding carnivores, on their grazing area. Nothing is provided for loss of animals. Therefore if they leave the carnivores alive, and take better care of the reindeer so that depredation is reduced, they will achieve maximum economic returns (Sametinget/Naturvårdsverket 1995).

In conclusion, compensation for losses alone achieves at best a greater acceptance of livestock depredation. While this may be enough when damage levels are low, it does nothing to prevent the problem. Based on these problems several authors (Jackson et al. 1994, Tompa 1983, Gunson 1991) recommend that compensation should only be available in cases of severe hardship or when reasonable precautions have been taken to reduce the risk of depredation. A staggered system could provide more compensation for herders that used better husbandry methods. To function, a compensation scheme should be simple, rapid, and safeguard against false claims (Nowell & Jackson 1996, Saberwal et al. 1994).

3.21 Evaluation of the ability of improved husbandry techniques to reduce depredation on livestock

Main points - Summary of the ability of improved husbandry to reduce depredation

- *Improved husbandry can decrease depredation. Few measures are enough alone, several need to be incorporated into a viable husbandry system which must obviously be adapted to local conditions.*
- *The first step is to control the movement and distribution of livestock. Only then can other measures be used.*
- *In many cases the traditional methods of shepherding combined with guarding dogs and night-time enclosure appear to be the most promising.*

The previous sections have shown that a large number of methods exist to reduce depredation on livestock through improved husbandry. The case studies reveal that levels of depredation vary widely from study site to study site depending on the carnivore species present and the husbandry techniques used. There appears to be a clear trend that more intensive husbandry reduces depredation. Additional benefits such as reducing accidents and allowing rapid diagnosis and treatment of illness are not evaluated here, but are likely to be significant.

Few of the above mentioned methods can function alone. The first step is to gain control over the distribution of vulnerable livestock using either fencing or shepherds. Only then can other depredation reduction measures come into use. For example, a combination of shepherds, guarding dogs and night-time predator-proof enclosures should allow the farming of even vulnerable livestock like sheep in proximity to carnivores. The need for shepherding may be reduced if fences can restrict livestock movements to ease gathering the sheep at night. The methods used depend on the habitat, the carnivore species and the local agricultural economics. The main point is that improved husbandry can reduce depredation, however it may be expensive and fall outside the narrow margin for profit that many herders operate under. On the other hand where subsidy and compensation are available it may make little difference to the economic well being of the herder to adopt more intensive husbandry practices. Such a movement to resurrect the lost skills of shepherds may actually create employment in rural areas. Also the cost of improved husbandry must be evaluated against the cost of lethal-control of carnivores. The main benefit of reducing depredation through improved husbandry is that it reduces the need for lethal control, and therefore may be more compatible with other management objectives such as conserving viable populations of endangered carnivore species.

We will draw conclusions about the integration of different depredation reduction strategies in the last section (**section 5**).

4 Zoning of land use for agricultural production and carnivore conservation

4.1 The principles of zoning to reduce carnivore-livestock conflicts

Main points - Principles of zoning
- *The mechanism is to spatially separate areas with sources of conflict from areas where carnivores are to be conserved.*
- *Carnivores rarely require wilderness habitats. Forestry, hunting, resource extraction and many forms of agriculture are compatible land-uses.*
- *It is only the free-range and unsupervised grazing of sheep, goats and cows with very young calves, that are incompatible land-uses.*
- *Sources of conflict should be removed from the carnivore areas, and carnivores should be controlled when they try to colonise areas with conflict potential.*
- *Carnivore areas need to be large and should be surrounded by buffer zones.*

In a situation where improved husbandry techniques are inadequate, or not cost effective, in reducing a carnivore-livestock conflict, a possible solution is to reduce the spatial and geographic overlap of carnivores and livestock. Zoning of landuse is not a new concept, and to a greater or lesser extent has formed the basis of nature conservation for decades. The principle is to spatially group compatible landuses with each other, and to ensure that incompatible landuses occur in different areas. Vulnerable livestock can be maintained in certain areas from which carnivores are excluded, whereas in other areas carnivores are allowed to remain and vulnerable livestock are removed (Clarkson 1995, Noss 1996). The system works best with a buffer zone between the two areas. This spatial separation reduces encounters and therefore the risk of depredation.

The success of such a strategy depends mainly on being able to establish a conservation zone with little conflict potential. The main decisions to be made are;
- where to place the conservation areas,
- how large to make them,
- where to place the borders,
- deciding which land uses are compatible with carnivore conservation.

Although the main problems with establishing such zones in practice are going to be political and social, the policy will only be successful when based around solid ecological and behavioural data. **Section 4.2** describes how the ranging behaviour and ecology of carnivores can be used to design conservation zones with an ecological basis.

4.1.1 Wilderness vs. multi-use landscapes

Wilderness areas (by definition) have a low conflict potential with agriculture and make the best conservation areas for carnivores. However, wilderness areas are very limited in availability and it is very doubtful that large carnivores can be conserved only inside large wilderness areas (Marker-Kraus et al. 1996, Mech 1995, Noss et al. 1996). This is true for both areas in the developed world like western Europe and eastern North America (see **section 6.11**) where little wilderness remains, and for areas of the developing world, like Africa and Asia where the remaining wilderness is being rapidly lost. The future of viable large carnivore populations depends on their integration into multi-use landscapes, either surrounding protected wilderness areas or as self-sufficient areas (Maehr 1990, Marker-Kraus et al. 1996, Noss et al. 1996, Weaver et al. 1996). This mirrors a growing realisation among managers that conservation of much biodiversity is often compatible with quite intensive human use of the landscape (Halladay & Gilmour 1995, Saberwal 1996).

The problem is that some human activities, especially unsupervised sheep grazing, have a high conflict potential with carnivore conservation. Therefore, for conservation in a multi-use landscape to be successful there need to be changes in human land use patterns. Those incompatible land uses need to be phased out through regulation or economic incentive in favour of other activities with lesser conflict potential. The result could be a complex of protected and multi-use areas much like a UNESCO biosphere reserve (IUCN 1993). Such areas have been successfully used to conserve isolated carnivore populations in multi-use areas (e.g. Riding Mountain Biosphere Reserve, Manitoba, Canada, High Carpathian Biospehere Reserve, Poland), even though carnivore conservation was not their main reason for being established (Bobek & Merta 1996).

4.1.2 Which landuses are compatible with carnivore conservation areas?

Generally, large carnivore species are habitat generalists in that they are usually only limited by the availability of their prey. As many human changes to habitats can benefit ungulate populations, large carnivores can often tolerate, and maybe benefit from a certain level of human activity as long as they are not directly persecuted. Wilderness is usually only required as a protection against persecution, rather than because of its nature as a habitat. When properly controlled and regulated, activities such as forestry, sustainable hunting, the collection of forest resources and even manufacturing industry and limited extraction industry can be compatible with carnivore conservation. For example in the most intensive study of a large carnivore species faced with human industrial extractive industries, grizzly bears in Canada were shown to be largely unaffected by the direct disturbance and habitat modification of forestry and mining activity. They were however affected by increased hunting and poaching due to the increased accessibility of the area following road construction (McLellan 1990, McLellan & Skackelton 1988, 1989a, 1989b). The same pattern holds true for most species of large carnivore for which data exist (Aanes et al. 1996).

Tourism, especially eco-tourism, is presently a huge growth industry and provides unique opportunities to transfer wealth from urban centres to rural districts. When properly controlled it can operate on a sustainable basis. Natural, or semi-natural habitats are very attractive destinations. The presence of large carnivores in an area can act as a magnet to attract people, and even if the chances of seeing a carnivore are almost zero, just knowing “it’s out there somewhere” can be enough. Remains of kills, abandoned bear dens, tracks in snow or mud, and even organised “wolf howl sessions” have proven to be popular attractions (Strickland 1983, Forbes & Theberge 1995). The natural prey species such as wild ungulates and other wildlife which benefit from wise habitat management are also a powerful attraction. Combined, such natural resources can be the basis for developing a whole range of year-round nature based tourism (Ceballos-Lascuráin & Johnsingh 1995, Ceballos-Lascuráin 1995, Johnsingh et al. 1995).

Many forms of agriculture can also be compatible with carnivore conservation. Intensive husbandry of livestock which are usually enclosed like poultry and pigs, and those which are often less vulnerable to depredation like beef cattle, is compatible with carnivore conservation. Horticulture of vegetables, flowers and mushrooms are further activities that in no way effect carnivore conservation. *In effect it is only extensive and unsupervised free-range grazing of sheep, goats, poultry and cows with very young calves that are incompatible with carnivore conservation*.

The point is that a carnivore conservation zone does not need to be a wilderness as long as enough habitat exists to support a prey base, and effective protection from direct human persecution exists. In many cases the presence of large carnivores can be a major asset, providing an attraction for tourism and other development. Studies in the US have clearly rejected the claim that environmental protection and the designation of protected areas have caused unemployment. In the fact the trend is for jobs to be created associated with environmental protection (Goodstein 1996, Rasker & Hackman 1996).

4.1.3 Placing borders on conservation zones

There are two main constraints on the size and location of carnivore conservation zones, one ecological, the other political. Suitable habitat may be limiting, and there is little point including areas of unsuitable habitat in a conservation zone. Although habitat can be restored, such exercises are very costly, and are likely to be impossible on the scale required for conserving large carnivores. Restoring a prey base is easier than restoring vegetation, and can be considered as a valid conservation measure in many circumstances. Choice of conservation area will of course be influenced by the existing distribution of the carnivores to be conserved. However, it is realistic to accept that some areas harbouring carnivores are unsuitable (too high conflict, too poor habitat) and should not be included. Other areas may offer suitable habitat, but will not contain carnivores. These could be included in the conservation zone, and recolonisation aided by reintroduction or limiting harvest in surrounding lead-in corridor areas.

When establishing a protected area for carnivores the seasonal migrations of prey populations need to be taken into account. All seasonal ranges of the prey population need to be included within the boundary. The example, of wolves being shot when on extra-territorial excursions to hunt white-tailed deer that migrated to a winter area outside Algonquin National Park in Ontario illustrates the point. The legal harvest of over 10% of the parks wolf population in one winter required a *de facto* increase in the park's border to include the deer winter areas in order to provide effective protection (Forbes & Theberge 1996). This also illustrates that some areas will only need to be zoned during certain seasons. Habitats such as ungulate winter areas, salmon streams and berry patches may only be used by carnivores during certain seasons. Outside these seasons such patches might be used with less restrictions.

Within any effective conservation zone changes in land use will be required. Clearly any change in land use, such as a reduction in sheep grazing, or a change in husbandry method will have an economic cost. While part of this may be recoverable in the long-term in terms of revenue from increased tourism, or decreased pay-outs of compensation for depredation losses, there will be a substantial short-term cost. This price alone places limits on the size of area which can be converted into a carnivore-conservation area. Additional constraints are habitat suitability and prey availability, not to mention the legal and political complexities of operating a conservation plan on private land. There will certainly be many areas that do not offer suitable habitat, where the conflict-potential is very high, and most importantly, where the cost of changing land use patterns are too high. All these factors will serve to limit the area that can be designated a conservation area. Thus there is a clear pragmatic need for zoning.

Any carnivores that expand outside the conservation zone will probably need to be lethally controlled to allow the system to work. The reduction or prevention of conflict in some areas through lethal control may allow a greater acceptance of conflict in other areas. Because different carnivores species cause different levels of damage to different livestock, it may be realistic to draw different boundaries for different species, and tolerate a greater number of some species outside the core conservation zones.

In conclusion, the drawing of borders for zones requires an application of biological and ecological knowledge, within a framework of economic and social constraints.

4.1.4 Effective conservation of carnivores in a multi-use landscape

The following points need to be considered and implemented before an effective zoning system can be implemented;

- clear statement of objectives as to desired carnivore population size and distribution,
- collection of ecological data on habitat requirements and home range size,
- deciding how much area is required to include the desired number of carnivores,
- mapping habitat availability, habitat quality and distribution and abundance of natural prey, especially migratory species,
- mapping of distribution of compatible and non-compatible land uses,
- use a GIS to analyse the mapping data and determine conservation zone and buffer zone borders,
- implement an information and education program, especially to farmers and hunters,
- provide economic incentives to change land use,
- help (economically and with advice) develop alternative land uses and improved husbandry,
- provide law enforcement,
- provide control for carnivores leaving conservation zones.

4.1.5 The functions of a buffer zone

With the exception of some African reserves fencing of large scale conservation areas for carnivore conservation is virtually impractical with today's economics and awareness of the side effects of fragmenting habitats. This means that the borders of conservation areas will be porous to the movements of carnivores. There are two different types of movement made by carnivores that may take them outside their normal home range. These are the processes of natal dispersal and extra-territorial movements (**section 4.2**) made by juvenile and adult animals respectively. A buffer zone is designed to reduce the damage caused by carnivores moving outside the conservation zone and to reduce the sink effect of the edge of the conservation zone. A possible management scenario for a buffer zone would be to discourage the most vulnerable forms of livestock herding and improve husbandry, especially closest to the border of the conservation zone. Occasional intrusions of carnivores into the buffer zone would be tolerated, especially be adult, reproductive age, individuals. Juveniles emigrating from the conservation zone would be controlled at the first available opportunity. In many cases these movements are season specific, which should allow some degree of discrimination. The improved husbandry within the buffer would minimise the damage caused if the season of emigration did not coincide with the season of most efficient control. The objective for a buffer zone in this scenario would be to contain no resident population of carnivores, but to allow animals resident within the conservation zone to enter the area occasionally without being killed. The existence of such a zone is vital to the success of a conservation area, and especially for smaller areas with relatively long edges.

4.1.6 Examples of effective zoning

Despite the logical potential of a zoning system to reduce carnivore-livestock conflicts, there are very few examples of such a system being specifically implemented. There are two main reasons for this;

– In many areas a *de facto* zoning system has operated, with most carnivores being exterminated from areas of conflict and only surviving in national parks or wilderness areas. The distribution of most large carnivores in southern Africa and that of wolf and grizzly bear in the US provide good examples (**section 6.4, 6.8, 6.9** and **section 6.2**).

– In areas where recovering or reintroduced carnivore populations are expanding from their refugal areas (usually areas with low conflict potential) the emphasis has been on protection. These populations have not yet recolonised areas of high conflict potential. Little planning for their future management is characteristic of such conservation exercises.

The national park systems of southern and eastern Africa, together with the wilderness and park areas of the US and the tiger reserves of India provide classic examples of extreme zoning. Their problem is that they are often too small or too isolated to guarantee a long term future for viable populations of some species with very large area requirements (cheetah, hunting dog).

Australia has one of the most clear-cut zoning systems in existence with the use of the dingo fence and widespread use of poisons to try and separate dingoes from sheep areas (**section 6.2**). Slovenia is one of the few countries in Europe where bears have been zoned into different regions for management (Kaczensky 1996). Management plans aimed to maintain high bear densities within core areas with the aid of feeding, and tolerated little damage outside these areas. However, recently the plans have changed to allow more bears to live outside the core areas in order to aid the natural recolonisation of the Alps in Austria. Norway has established some conservation core areas for wolverine and brown bear. However, populations are remnant and definitely not viable in isolation from Sweden. Under present management Norway is operating as a sink for dispersing animals from the larger populations in Sweden because these core areas contain high numbers of sheep and semi-domestic reindeer leading to large conflicts.

Recovery plans for wolves and grizzly bears in the US have recommended and implemented a zoning system for these species, based on habitat suitability and conflict potential. Plans for recovery aim to strictly protect breeding populations inside the suitable habitat, and allow liberal use of control in unsuitable habitat if conflicts arise (Fritts et al. 1992, Mech 1995, USF&WS 1987, 1990). The system in the US is based around conservation on federal (public) land. Plans to improve protection on private land are also coming into effect (Servheen 1989).

The need for zoning is generally accepted by most conservation biologists and carnivore scientists (Boitani 1982, Mech 1995). However, there is much opposition from almost all sides. Livestock herders inside the core areas generally object to any changes in their way of farming and resist the conservation of carnivores, while the animal-loving public generally refuses to tolerate the lethal control of individual carnivores outside conservation areas, no matter how much damage is caused. There is a long way to go in terms of providing ecological education to the public before the validity and good sense of a zoning system can be generally accepted.

4.2 Carnivore movements and conservation area size

Main points - Carnivore movements and conservation areas

- *Large carnivores have large home ranges, occur at low population densities and have long dispersal distances.*
- *Any zone designed to support viable populations will need to be measured in thousands, or tens of thousands of square kilometres.*

4.2.1 Behavioural background

The principle of zoning requires that “carnivore zones” or conservation areas (i.e those areas where the rearing of vulnerable livestock is not encouraged) be large enough to accommodate enough individual carnivores to allow the population to persist. Carnivores move over relatively large areas in pursuit of prey. There are four movement patterns and social parameters that need to be considered when calculating conservation area requirements;

- home range/territory size is the area within which an individual resident carnivore spends most of its time.
- extra-territorial movements are excursions made by a resident animal from its normal home range or territory for various purposes.
- natal dispersal occurs when independent juveniles leave the area where they were raised and try to find an own home range or territory.
- pack size or degree of overlap determines the number of individuals living within the same area.

4.2.2 Home range sizes

Most adult carnivores remain stable within a defined area for most of their lives. These animals are termed residents. A stable area of residence is called a home range, and if this area is depended against other individuals it is termed a territory. Few, if any, species of carnivore roam over large areas without any area of concentrated use. The polar bear is probably the closest thing in existence to a nomadic carnivore. There are many benefits associated with residency, including knowledge of the location of prey and suitable day lairs and denning locations. Such knowledge will improve foraging economics and therefore enhance individual fitness. Familiarity with an area is likely to decrease the risk of accidental mortality from roads, railways and drowning. Any excursions from a home range are likely to lead to aggressive encounters with other territorial individuals, and these encounters carry a significant risk of mortality (e.g. Mech 1994).

Although carnivore home range size varies with body weight, diet, prey abundance, social behaviour and geography (e.g. Gittleman & Harvey 1982, Grant et al. 1992, Litvaitis et al. 1986, Ward & Krebs 1985), they tend to have the largest home ranges of any mammalian group and therefore require the largest conservation areas. Only migratory ungulates like caribou and wildebeest have larger area requirements when their annual movements are considered. Species living in temperate and boreal regions tend to have larger area requirements than those in tropical regions. Home range sizes of some representative temperate and boreal large carnivores (brown bear, wolf, Eurasian lynx, wolverine) are presented in **appendix A**. These species typically require home ranges of 100 to >1000 km^2 in area. As most carnivores are solitary, and at best only tolerate slight overlap of neighbours of the same sex, densities can be very low. Wolves are the only temperate species that form groups of 2-15 individuals.

4.2.3 Dispersal distances

Although adults may be resident and occupy stable home ranges, juveniles generally leave their natal area after becoming independent. Male mammals tend to travel further than females (Dobson 1982). For large carnivores dispersal distances vary enormously, with distances between 5 and 800 km being reported for wolf and wolverine, although most animals will probably settle within 20-200 km (e.g. Mech 1987, Banci 1994). The linear dispersal distance is a great underestimate of the area covered by a dispersing, or transient individual, as they may cover large areas during several years before settling. The timing of dispersal is very important when considering the success of a conservation zone to maintain populations and reduce conflicts with livestock outside the zone. In temperate areas most dispersal occurs in spring, prior to, or at the start of, the grazing season (e.g. Fuller 1989, Messier 1985). As control exercises are most successful in winter this creates the possibility for conflict when a previously carnivore-free area can attract dispersers at a time of the year when control is difficult. Increased conservation zone size will increase the possibility of the disperser remaining within the zone, and increase the probability of a vacancy being discovered within the zone. A buffer zone (**section 6.2**) surrounding the conservation zone will provide the possibility for the disperser to settle on a vacant territory within an area of low conflict potential for latter control (Thomson 1984, **section 6.2**). The relationship between dispersal and population density appears to be complex, and there are many examples to indicate that dispersal may in fact show inverse density dependence (e.g Allen & Sargeant 1993).

4.2.4 Extra-territorial movements

Some resident individuals may make temporary excursions outside their normal home range or territory. These can be associated with several activities such as searching for mates or foraging. Cases exist of individuals or packs that hunt outside their territory boundaries. Wolves were occasionally found outside their territory hunting in a winter concentration of white-tailed deer (Forbes & Theberge 1995, Messier 1985) and spotted hyenas regularly made excursions beyond their territories to hunt migratory herds of wildebeest (Hofer et al. 1993). These examples are rare, and generally most carnivores will not establish territories in areas without a year round food supply. It is unlikely that resident carnivores will leave their territories specifically to depredate sheep or other livestock if normal levels of wild prey exist (Althoff & Gipson 1981). Such movements are less likely in summer (the most common grazing season) when wild prey are generally more evenly spread than in winter. The only example is of a few coyotes that followed a sheep flock's movements outside their own territory (Shivik et al. 1996), although it must be remembered that coyotes are known for their plastic behaviour. Larger conservation areas, with buffer zones, will have less problems with these excursions taking individuals outside their boundaries than smaller conservation zones. The seasonal nature of extra-territorial movements (especially by reproductive age adults) needs to be taken into account when planning control operations adjacent to conservation zones. Damage should be tolerated to a greater extent at times of year when adults make extra-territorial movements.

4.2.5 Implications for size and shape of conservation areas

There is much debate about what constitutes a viable population. Estimates of between 50 and 1000 have been quoted by various sources (Primack 1993). The differences depend on if genetic factors are taken into account as well as demographic factors, and on what probability of population persistence (90%, 95%, 99%) for a given time period (10 years, 100 year, 1000 years etc.) is considered to be acceptable. Also the degree of environmental variability effects the number, stable environments carry a lesser probability of extinction for a given population size. For populations with some degree of connection to other populations 50-100 individuals of a large mammalian species is regarded as being an acceptable *minimum* for demographic viability (Knight & Eberhardt 1985) although sub-populations as low as 20 individuals may be able to persist given the possibility for immigration from other, larger populations (Beier 1993). Based on the data on home ranges size (**Appendix A**) and population density (**Appendix B**) we present a rough calculation of the required areas for populations of 20, 50 and 100 individuals of some large carnivores in **table 4.2.1**.

Table 4.2.1 Sizes of conservation area needed to contain different population sizes of carnivores at different densities. Densities were chosen to illustrate the normal range of population density of northern temperate species (wolf, brown bear, Eurasian lynx, wolverine, **Appendix B**).

Population Density (animals/100km^2)	**Area (km^2) required to contain various numbers of individuals**		
	20	**50**	**100**
0.5	4 000	10 000	20 000
1.0	2 000	5 000	10 000
1.5	1 333	3 333	6 666
2.0	1 000	2 500	5 000

This all stresses that conservation zones should be as large as possible, and need to be larger than most existing protected areas (Thiollay 1989). This is the main reason that conservation in multi-use landscapes is so important. Large zones, with the lowest possible area to edge ratio will provide the least problems, especially if the edges conform to physical features that provide natural barriers to movement. Knick (1990) developed a spatial model for bobcat refuges which clearly illustrates the efficiency of larger units. This model could be upgraded for almost any species.

4.2.6 International co-operation

Cross border co-operation in the form of establishing adjacent conservation zones or corridors between conservation zones will increase the absolute and effective population sizes of carnivores, and therefore the population's viability. Where neighbouring countries are politically stable and share common management objectives this should function well, however if neighbours are politically unstable, or have differing management objectives, one country may end up becoming a dispersal sink for the other countries carnivores. Such cross border co-operation will be vital in Europe where conflict-free habitat is very limited. It is very unlikely that many countries will be able to support viable populations of any large carnivores entirely within their own borders. The co-operation existing among Alpine countries with respect to lynx and bear recovery is a good model.

4.3 Other factors to consider

Human and wildlife ecology are too complex to be able to consider single factors like carnivores and livestock in isolation from wider ecological processes. Changing carnivore or livestock densities and distributions can have wider ranging ecological effects. In particular the following points need to be taken into account.

(1) What is the role of livestock grazing in structuring vegetation communities? The interaction between livestock and vegetation is complex, and the effects are both beneficial (maintaining grassland biodiversity and preventing shrub encroachment) and detrimental (overgrazing and erosion). Changes in species of livestock grazed, stocking density or herding technique because of carnivore conflicts need to be considered. In particular the relationship between grazing and commercial forestry needs investigation.
(2) Competition between livestock and wild ungulates. The above mentioned livestock vegetation interactions also have implications for the forage quality available for wild ungulates.
(3) Can carnivores survive without livestock? In some areas of the world where prey bases are greatly reduced, removing livestock could lead to widespread food stress for carnivores. Clearly in these areas the natural prey base would need to be restored before drastic changes in livestock availability were made.

5 Strategies for reducing carnivore-livestock depredation

This section aims to conceptualise the ecology of depredation and the approaches that can prevent it, summarise the main conclusions of the previous sections, and develop a conceptual model for the reduction of carnivore-livestock conflicts.

5.1 Using knowledge of predation behaviour to reduce depredation

Main points - Using knowledge of predation to stop predation

- *Only by understanding the natural process of predation can effective measures be designed to stop depredation on livestock.*
- *When planning to use any husbandry or management method to reduce depredation the mechanism by which it is meant to work needs to be considered.*

Carnivores eat meat. Most species of large carnivore kill their own prey, and even many of those that normally scavenge will kill when the possibility arises. Carnivore-livestock conflicts occur when carnivores kill domestic animals instead of non-domestic, wild prey. Although domestic animals represent a relatively easy kill, the process by which they are killed is similar to carnivore predation on non-domestic prey. An understanding of this natural process of predation provides the basic principles for protecting domestic animals.

Predation is the result of a series of steps. In effect there are six main steps in a successful predation sequence;

(1) Searching for prey, which results in an encounter,
(2) Identification of encountered animal as prey,
(3) Approaching the prey to within attack distance without being observed,
(4) Attacking the prey and making contact,
(5) Killing the prey
(6) Eating the prey

Protecting livestock can be viewed as trying to interrupt one or more of these steps. Interrupting the sequence before step 5 saves the life of the domestic animal, whereas interrupting before step 6 may help prevent further losses at a later date. Ideally, the process should be interrupted as early in the sequence as possible.

(1) The search phase. Traditionally, encounter rates between carnivores and livestock have been minimised by killing carnivores, or at least by reducing their population density. The same result can be achieved by removing livestock from areas where carnivores exist (spatially or temporally). The carnivore can search but will never encounter livestock. This is the ultimate protection available. However, a degree of protection may be achieved by clumping livestock into flocks within the carnivore range. This will reduce the encounter rate between carnivore and livestock and increase the probability that a carnivore will encounter a wild prey animal first. Clumping animals in areas avoided by carnivores will provide further benefits. Such clumping especially reduces the depredation on livestock by carnivores that are not motivated by hunger, but by instinct when confronted by an easily killed animal. Dispersion of livestock throughout carnivore range will increase encounter rates and therefore the risk of depredation.

(2) The identification stage. Most carnivore species carry a mental search image of what is prey, and what is non-prey. Within evolutionary limits this is determined by individual experience. Bad experiences or attack failure with certain prey animals should lead to their avoidance as prey. For example, foxes do not chase every moose they encounter as they learn that moose are non-prey because they cannot be captured. Similarly animals that use bright warning colours depend on their being recognised as non-prey. The process of aversive conditioning is a modern approach in trying to get carnivores to perceive livestock as being non-prey. It is not just the special experiments using repellent or emetic chemicals that can produce this effect. All bad experiences associated with hunting livestock should help to develop this non-prey image. On the other hand a sequence of successful hunts on livestock will produce a prey image for livestock, whereas a sequence of hunts being blocked (successful protection) will assist in developing a non-prey image. Any stimuli such as human smell, dog smell, bells, lights or a specific site that are associated with hunting failure will reinforce this non-prey image.

The principle of selective control aims to remove individual carnivores from the population, especially those that have acquired positive experiences and have made successful hunts on livestock, i.e. those which recognise livestock as prey. Selective control can only operate if only a few individuals within the carnivore population have learnt to recognise livestock as prey. If lax husbandry has allowed most individual carnivores within a population to kill livestock, selective control will not help without exterminating the carnivore population, although intensification of husbandry may require a new learning phase if the search image has been sufficiently altered.

(3) The approach stage can be stopped in several ways. A predator-proof fence either around a pasture or around a night-time enclosure provides an effective physical barrier to stop an approach. An open area or pasture with little stalking cover will also discourage most felids that depend on stealth to approach their prey. Lights may also help. A flock of livestock is more likely to detect an approaching carnivore than an individual, and having seen the carnivore will signal to each other and the carnivore. In many cases this may discourage the predator from approaching further. The use of guarding dogs or attendant shepherds that disturb the predator will also prevent the approach from progressing. Aggressive livestock that display good group defence (e.g. some cattle breeds) will also help to disrupt the predators approach.

(4 & 5)The attack and kill phases. Once an attack has been initiated against livestock, there is little that can be done to prevent a kill apart from the use of protection collars, which prevent the actual killing bite from killing. These traditional device are only presently being scientifically evaluated, although they appear to show promising ability to prevent lynx attacks from actually killing sheep and may function against other carnivores like wolverine with site-specific bites. Dogs or shepherds may also interrupt the predatory sequence during the attack phase, although it would be best if they could stop the sequence at an earlier stage.

(6) The eating phase. Anything which prevents the carnivore from eating its kill such as a shepherd or a guarding dog, will discourage the carnivore from trying again, especially if the same negative experience occurs repeatedly. **Section 3.8** discusses an exception.

In summary, the success of a predation-reduction method depends on reducing encounters, directly blocking hunting behaviour, and in creating a negative

Predation sequence	Method to protect livestock	Mechanism
Search	**Eradication of carnivores**	No encounters occur
▼	**Zoning**	No encounters occur
▼	**Clumping of sheep**	Reduced encounter rate
▼		
Identify	**Aversive conditioning**	Teaches carnivores that livestock are “not-prey”
▼	**Selective removal**	Removes individuals that prefer to kill livestock from population
▼	**Different livestock**	Larger species of livestock will not be recognised as prey
▼		
Approach	**Carnivore-proof fencing**	Places a physical barrier between livestock and carnivore
▼	**Avoid closed habitats**	Stalking carnivores less likely to approach
▼	**Lights, sirens etc.**	Scares carnivore away
▼	**Guarding dogs**	Interupt the carnivores approach
▼	**Shepherds**	Interupt the carnivores approach
▼		
Attack	**Guarding dogs**	Interupt the carnivores attack
▼	**Shepherds**	Interupt the carnivores attack
▼		
Kill	**Protective collars**	Prevents neck / throat bite of some carnivores from actually killing after contact is made
▼		
Consume	**Guarding dog**	Scare carnivore away - prevent learning that livestock are prey.
	Shepherd	Scare carnivore away - prevent learning that livestock are prey.

Figure 1 Overview of how different husbandry methods and management practices can prevent or reduce depredation on livestock in relation to the different stages of a carnivores predation sequence.

experience for the carnivore. This conceptual overview may seem like stating the obvious, but it is important to view the process of protecting livestock from the predator's point of view. An understanding of the ecology of depredation is a prerequisite for developing mechanisms to prevent it.

5.2 The value of carnivore control in modern carnivore management

Main points - The value of control
- *Control aimed at reducing or eliminating populations of carnivores can reduce depredation, but is only compatible with conservation objectives when;*
  - *large enough areas to support viable populations remain outside the area of control*
  - *problem individuals exist and can be selectively removed.*

Judging by present opinion among both the public and professional wildlife managers, the days of blanket reduction of carnivore populations are almost over. This does not mean that there is no place for control (or sustainable harvest for that matter) of large carnivores. There is, however, a requirement that an overall management strategy for large carnivores should secure viable populations at a national level where this is practical. Any control, especially lethal control, needs to be compatible with such a strategy. Where abundant species like coyote or red fox are concerned this will often allow very high levels of lethal control, and animal welfare becomes more of an issue than species conservation. There are two situations where control of endangered species is justifiable and compatible with conservation.

Firstly, when expanding populations enter an area which is unsuitable, either because of a lack of habitat and natural prey, or because of very high conflict potential, or both. In these situations control to prevent colonisation will be vital to allow acceptance of carnivores in other areas. To achieve this goal a combination of legal harvest and active control by humane and effective means should be justified. To ensure that control in this situation is compatible with conservation objectives, a clear demarcation of land areas (zones) needs to be made *before the situation arises*. Sufficient areas need to be left where control is not practised to allow viable populations to exist there (Mech 1995, Clarkson 1995).

Secondly, where carnivores and livestock co-exist and a certain level of depredation is judged to be acceptable, it may be justifiable to remove problem individuals from the population if these individuals cause disproportionate levels of damage. Before such a policy can be compatible with conservation objectives it needs to be determined if problem individuals really do exist. We recommend that strict criteria and management procedures be drawn up to define a problem individual along the lines of;

- depredation should be carefully and rapidly documented.
- a minimum number of livestock predation events should be set as an acceptable threshold for a given area in a given time span, rather than a minimum number of livestock killed. This threshold should be adjusted to the intensity of husbandry. The more intense the husbandry, the lower the threshold.
- before these events are attributed to an individual, species home range size, normal daily travel rate, season and local density need to be taken into account.
- track size, killing method, circumstances, and pattern of consumption may assist in determining the number of individuals involved
- once the threshold has been exceeded and the criteria for acceptance of a problem individual are met, control should follow rapidly after the next depredation event is recorded.
- selective control should not be carried out by trophy or sport hunters. Trained and skilled personnel should use the most effective and selective methodology available where this is practical.
- in cases of extremely rare carnivores or very small populations, live trapping may be preferable to lethal control so that adult (especially lactating) females can be released. Such animals could be radio-collared and monitored. In the event of a predetermined number of further depredation events this individual can then be tracked down and controlled.
- a quota for the number of animals (with a female sub-total) controlled which is compatible with maintaining viable populations should be set. If more "problem" animals need controlling than this quota allows, management authorities should seriously think about investing in changes in husbandry practices and other conflict reduction methods. It is vital that an area of conflict does not become a sink for a conservation area.

Translocation will only be an effective, non-lethal way of removing problem individuals when an acceptable destination exists. There is no point returning an individual to a saturated population from which it is dispersing, or move an animal to an area with high conflict potential. After release, almost all individuals will travel over large areas, and many will return to the capture point, even over distances of hundreds of kilometres. Soft-release methods may reduce these movements but such a system has never been used in connection with problem-individual management. Returning an animal to its normal home range when an excursion brings it into conflict may function in some cases, although providing a buffer zone would help prevent such problems arising in the first place. In effect translocation will only work if the animal can be released into large areas with a low conflict potential. As source populations and other suitable destinations (such as zoos or reintroduction projects) become saturated, translocation will become less and less successful. The cost will only be justifiable for highly endangered species, or important individuals like reproductive females.

The costs of all control methods are high, often both economically and ecologically. In the long term it will generally be cheaper to reduce the conflict potential through land-use zoning and husbandry and preventing the risk of depredation rather than trying to solve it after it has occurred.

5.3 The role of improved husbandry in reducing depredation

Main points - The role of improved husbandry

- *With the use of correct husbandry practices depredation can be minimised. The most successful practices involve direct protection (fences, guarding dogs, shepherds) of concentrated flocks (herded or fenced) and avoidance of certain habitat and terrain features. Details in box.*

The great decreases in carnivore density and distribution that are obvious today have largely occurred in the last one to two centuries. This implies that livestock herders have been living with carnivores for more than 10 000 years since domestication first began (Boguchi 1996, Wenke 1990). The success of agriculture during this period is a clear testimony to the success of husbandry at keeping depredation at acceptable levels. This view can be further extended to examine which methods are best at preventing depredation. The answer is those that have stood the test of time and cultural selection; shepherds, guard dogs, and night-time enclosure. The greatest sources of conflict with carnivores are unherded, free-ranging sheep and goats. No culture had a tradition of farming these small livestock in such a manner before carnivores were virtually exterminated. If it had been a viable farming technique in the past, it would have been used as it involves a minimum of labour and effort. It is no more a viable husbandry technique today when faced with recovering carnivore populations than it was in the past.

Modern methods such as aversive conditioning do not offer any miracle solutions. In some cases where negative stimuli can be directly linked with the domestic animal, individual carnivores may reduce or stop their depredation. The best hopes are for species that generally do not cause the greatest per capita damage such as lynx and wolverine (maybe jaguar?). With coyotes, wolves and bears for example, it is unlikely that aversive conditioning alone will reduce depredation. Whereas sirens and flashing lights may help deter carnivores from entering limited areas for a short period, they offer no real solutions. Predator-proof electric fencing functions and may be suitable in repelling carnivores from small areas such as lambing pastures or night enclosures, but is not practical for large, open range operations.

Almost all of the husbandry measures described in the previous sections will reduce depredation on sheep to some extent. Removing free-ranging sheep from open range in certain periods, limiting the distribution of sheep to reduce encounters, supervising lambing and adjusting birth season may provide some reduction in depredation. However, the real solutions lie in better husbandry in the traditional manner. The combination of constant shepherd presence, constant guard dog presence and night-time enclosure (in predator-proof fences) offers the best protection for livestock, short of removing them from carnivore range. If economics do not allow the use of round-the-clock shepherds, grazing the sheep in fenced pastures (forest, mountain or field) prevents their scattering, which is vital for guarding dogs to function, and to be able to gather the flock at night for enclosure. Good herding dogs make this work much faster and electric livestock fencing makes the movement of these pastures relatively easy. In some cases where sheep are only seasonally released onto open pasture (especially forest pasture) where most depredation occurs, it may be most economic to keep them in a fenced area close to the farm and provide extra winter food. This routine could be further enhanced by avoiding habitats, areas, or seasons when depredation is greatest, and by taking simple measures such as clearing away carrion and carcasses.

Cattle are a valid alternative to sheep, and because of their lower vulnerability to depredation will require less intensive husbandry depending on which carnivore species are present. Careful breeding for more aggressive breeds with better group defence will further decrease their vulnerability. In many areas cattle may be able to graze on open range without supervision, especially if calving is confined to areas with good supervision, and cows with young calves are offered more secure pasture. The transition to cattle may be a wise management step for many areas suffering high depredation on sheep. In areas where predators exist that are able to regularly kill cattle (lions, tigers, hyenas, jaguars and to a lesser extent leopards and snow leopards), the same steps mentioned above to protect sheep are required. **Box 5.1** provides a summary of measures suitable for the European situation.

Probably the greatest barrier to reducing carnivore-livestock conflicts through better husbandry in the western world today is that economics do not permit the labour-intensive husbandry methods required to prevent depredation. The paradox is that agricultural economics in the western world are relatively insulated from the market economy by subsidy. The paradox is further revealed when it is considered that in under-developed and developing countries, which often offer no subsidy for agriculture, husbandry is often more traditional and labour intensive, and therefore more compatible with large carnivores.

5.4 Zoning land use to reduce depredation

Main points - Zoning of landuse

- *Spatial separation of livestock and carnivores is practical because most adult carnivores occupy stable home ranges, where natural prey exists. Success of a zoning systems is dependent on the correct scale for conservation zone and buffer zone being chosen.*

Reducing the spatial overlap between carnivores and vulnerable livestock through land use zoning is probably the best method to prevent depredation. This is especially true for those species that cause most depredation, as the changes to husbandry required to reduce depredation may be too expensive to implement over large areas. Besides, some conservation areas may be capable of supporting such high numbers of carnivores that depredation would be almost unavoidable and the loss of livestock unacceptable.

Although carnivores move over large areas, they do not move at random and tend to be faithful to a home range or territory. If an adequately large conservation zone is demarcated, and surrounded by a buffer zone, there should be few problems with resident adult individuals. The main problem will lie with young individuals (especially males) that are dispersing from their natal ranges. There will be little alternative but to eliminate these individuals when they enter an area of high-conflict potential and cause damage, although selective harvest or culling of this age and sex class along the borders of the conservation zone may reduce emigration (Venter & Hopkins 1988).

Biologically speaking, zoning will succeed in reducing carnivore-livestock conflicts. The problems occur when political, economic and social factors make the establishment of large enough areas impossible. Although a half-way solution may function for some carnivore species and some livestock grazing traditions, there are some combinations of carnivore and livestock tradition (wolf/bear and unsupervised sheep grazing) that are totally incompatible. Generally the size of conservation area required will be the greatest barrier to its establishment. Cross border co-operation may in many cases enable larger, and therefore more viable, populations to be conserved.

Box 5.1 Husbandry methods to reduce livestock depredation : a summary for Europe and Scandinavia.

The main conflict lies with free-ranging and unattended sheep, although cattle can be at risk from wolves and bears. To reduce the risks of depredation in carnivore areas, we recommend the following steps.

- Encourage a change from free-ranging sheep to cattle when this is practical.
- Changing sheep breed may be effective in some situations.
- Ensure that lambing and calving occur under controlled conditions, as long before release onto pasture as possible.
- Construct *predator-proof* night-time enclosures for sheep and cattle with young calves.
- To enable sheep to be gathered into a night time enclosure they need to be either;
  - constantly herded during the day or,
  - fenced inside a limited area pasture. Electric fences enable this to be moved as each area is grazed.
- Encourage the use of guarding dogs by both day and night. The measures required for night time enclosure also allow guarding dogs to function.
- Remove carrion from the pasture when possible.
- Avoid grazing completely, or take most precautions in seasons, habitats or landscapes that have a high depredation risk.
- Develop aversive repellents (possibly in connection with protective collars) when lynx and wolverine are the only predators present.

5.5 An integrated strategy

Main points - An integrated strategy

- *A successful carnivore conservation strategy will almost certainly involve elements of control, improved husbandry and zoning.*
- *For example, livestock might be excluded, or kept using intensive husbandry, within conservation areas, kept with intensive husbandry inside buffer zones, and kept extensively outside the buffer zones, while carnivores might be protected, selectively controlled and totally excluded from the corresponding zones.*
- *Certainly a successful management will require integration between environmental and agricultural authorities and a clear statement of objective.*

Drawing up an all-embracing plan for reducing the carnivore-livestock conflict is difficult because the details of every case are different. However, the principles are often the same. We recommend a combination of land-use zoning and improved husbandry to achieve an optimum result. Mapping of land-use and habitat quality is a vital first approach. At the two ends of the landuse spectrum are wilderness and areas of intensive agriculture. In between are regions with habitat of varying quality and varying degrees of conflict potential. For successful management, a carnivore conservation zone needs to be defined, which will in practice represent a combination of wilderness (where it exists) and suitable habitat with varying degrees of conflict potential (livestock) (Weaver et al. 1996).

For a conservation zone to operate successfully, almost all potential for conflict must be removed from within the zone. This implies either that husbandry of vulnerable livestock must be greatly intensified, or another form of agriculture or employment is found to replace the herding of vulnerable livestock. Long-term success of the conservation zone, and maybe long term cost effectiveness, will often be best served by the latter option, with more intensive husbandry being used in the buffer zone. Outside the buffer zone and in areas of non-suitable habitat, agriculture should be able to continue unchanged.

Under this scenario control of carnivores will remove any individuals that disperse from the conservation zone and become resident within the buffer zone. The only time that individuals should be tolerated within the buffer zone is when residents of the conservation zone make extra-territorial movements. Knowledge of the seasonal nature of extra-territorial movements by residents is vital to discriminate between these two groups. Control of any animals should be automatic outside the buffer zone.

The only exception to this would be if sustainable harvest of large carnivores is also a management goal. Given the economic constraints imposed on creating an area with low conflict potential for carnivore conservation, it is very unlikely that there will be an adequate population within a conservation zone to tolerate harvest. Therefore harvest could be confined to buffer zones, where a separate cost-benefit analysis will need to be made to determine if the benefits of harvest will out-weigh the costs of maintaining higher carnivore populations inside the buffer zone. In countries with very large wilderness areas and large populations of carnivores, these “buffer areas” may actually cover larger areas than the core areas.

This system of concentric areas with different management procedures is very similar to the structure of UNESCO’s Biosphere Reserves. In view of the changes to agriculture and land-use required to allow carnivore conservation within a multi-use landscape it might be practical to designate these areas as biosphere reserves (or for example National Carnivore Refuges) to provide some identity and an independent administrative framework that could co-ordinate the various ecological/social/agricultural management strategies. If tourism is to be used to provide an economic incentive for conservation some formal structure will help to attract visitors and reduce their impact through careful planning. Marketing agricultural products produced in a manner compatible with carnivore conservation (e.g. “Bear friendly beef”) may be a successful sales strategy, and prevent consumer boycotts (as seen with tuna fishing methods which killed dolphins).

We stress that different carnivore species cause different levels of conflict and not all species will need to be so strictly zoned. Indeed many species may only require minor changes in husbandry to reduce depredation to acceptable levels. However, even the costs of minor changes in husbandry over large areas may become prohibitive, requiring that some limits be placed on distribution. The ecology of each species needs to be considered separately, although any overall management plan should integrate the separate species management plans.

The strategy can be summarised in three steps;

(1) Use wilderness and conflict-free areas as cores for conservation when available.
(2) Improve husbandry and encourage changes in landuse so as to reduce conflict-potential in areas that otherwise offer good habitat.
(3) Prevent colonisation of areas with very high conflict-potential and poor habitat quality.

Finally, we cannot state firmly enough that management goals need to be clearly stated from the outset in terms of desired numbers of carnivores, degree of population viability desired, and the borders of the conservation areas (Dorranace 1983). It is only when the carnivore management plans are in place that changes to agriculture can be made within the affected areas. The planning stage should include a multi-disciplinary approach with input from local, regional, national and international levels (Haggstrom et al. 1995, Primm 1996, Primm & Clark 1996) The management guidelines should be drawn up comprehensively such that they can be adhered to in all circumstances. The process should be simple to follow and not open to constant discussion and debate with each new depredation event or changes in the political arena. Without such clearly stated goals it will be very difficult to convince livestock owners to invest the money necessary to change livestock husbandry methods.

5.6 The need for education and information

Main points - Education and information

- ♦ *No carnivore management program will succeed without intensive education and information programs.*

Education and information at a local level are vital for any management strategy to work, especially when large carnivores are concerned (Kellet et al. 1996, Primm 1996, Primm & Clark 1996). Information should be available in the form of popular reports, newsletters, lectures, and possibly an information centre. A travelling information exhibition will often be an efficient way to reach people. The information should explain why carnivores need to be conserved, what the new management policy actually involves and as much about the ecology of carnivores as possible. Such information needs to be aimed at all segments of the community, especially those that are working outdoors in carnivore habitats like farmers, hunters and forest workers. Contact with school children is vital to help change the attitudes of the future generation of land users and managers.

In addition farmers need to receive information on ways to identify and prevent carnivore depredation (e,g. Boland et al. 1992, Marker-Kraus et al. 1996). Many of the recommended methods for reducing depredation depend on skilled shepherds, dog trainers, and fence construction. In many areas these skills have been lost or never existed.. Books and videos will help train people. However, for the theory of depredation reduction to be turned into practice, instructors and courses will be required. Large carnivores are often perceived as dangerous by people that enter carnivore habitat, and protecting livestock will bring shepherds into direct confrontation with large carnivores. Information on the actual risks, and the ways to react if a confrontation occurs, is vital to increase public acceptance and overcome fear.

5.7 Research needs

The last 30 years have seen an explosion in the bank of knowledge about carnivore ecology and livestock depredation. The problems of depredation still exist and will probably exist as conservation programs succeed in restoring large carnivore populations. Only through further research will depredation be reduced. Each country will need to adapt husbandry practices to its own individual conditions, so much research will be needed to simply work out how to put existing knowledge into practical use. Apart from this mammoth job there are still some broad areas which urgently need further work. These include;

- studies of depredation rates from the point of view of individual (radio-collared) carnivores. Only then will questions about the existence of problem individuals be answered.
- study the cognitive process through which carnivores recognise prey and non-prey. This is important to understand why in many cases some individual carnivore appear to be able to live in proximity to livestock without killing any.
- study depredation from a landscape perspective to identify depredation hot-spots and factors predisposing some flocks to higher depredation than other flocks.
- find ways to effectively target information and education programs.

6 Case studies

This section contains 11 case studies of carnivore-livestock conflicts. These examples were chosen from the many international cases to illustrate the wide variety of conflicts, the different levels of conflict that occur under different conditions and the various measures that have been taken internationally to reduce the conflicts.

6.1 Case study # 1 Coyote control in North America

Main points - Coyote control in North America

- *Despite enormous efforts and expenditure of resources, preventing depredation through complete control of coyotes has been impossible using ecologically sound methods.*
- *Emphasis has switched to a combination of improved husbandry and local control.*

No carnivore species on earth has been so intensively researched with respect to control methods as the coyote in North America. Almost all control methods in use today, especially the newer hi-tech methods, were developed or have been used against coyotes. The need for constant research on this topic provides a good indication of the ability that coyotes have shown to survive, and continue causing conflicts.

6.1.1 Life history

Coyotes are similar in appearance to a medium-sized dog, weighing between 10 and 25 kg, standing 45-60 cm high, and from 1.0-1.4 m long. Coyotes are monogamous (male and female pair for life) and have one litter of 1-12 pups each year. Most coyotes are year-round residents, though juveniles will establish their own territory anywhere from 15 to 150 km distant from the parents. Home range sizes vary from 5 km^2 in Texas to 140 km^2 in Washington (Tesky 1995). Coyotes prefer to be most active at night, but will hunt during the daylight hours.

Coyotes are omnivorous, opportunistic feeders, but about 90 percent of their diet consists of animal matter including: deer, pronghorn, elk, wild sheep, rabbits and hares, various rodents, ground-nesting birds, amphibians, lizards, snails, fish, crustaceans, and insects, however they also eat vegetable matter and nuts (Tesky 1995). And they prey on domestic sheep, goats, young calves and poultry.

Coyotes are currently found from Costa Rica to northern Alaska, and from coast to coast in the USA and Canada. Population densities are highest in the Great Plains states and in south-central USA (Tesky 1995). Coyote distribution has increased throughout this century with range expansion and introductions along eastern North America. They successfully occupy habitats varying from tropical rainforests to arctic tundra, and have been known to utilise all possible habitat types (Tesky 1995). This includes urban areas, with a pair even found in New York City in spring 1995 (Ohio Division of Wildlife 1996).

Peak breeding activity occurs from January through March and after a gestation period of approximately 63 days the female gives birth to a litter of 1-12 pups in April or May. Females will select, prepare, and maintains the natal den, and occasionally two or three females will share a large den area. Related females will sometimes act as helpers in the care of offspring of other coyotes in the den. Pups begin leaving the den with parents at 3 weeks of age. Both parents hunt for food and feed the young, however, the male takes the lead role when the pups are new-borns, obtaining enough food for both his mate and offspring. The parents will regurgitate their stomach contents for their offspring's meals. At 8 to 12 weeks of age, the pups are taught hunting skills. The coyotes stay together in a family unit throughout the summer into mid-fall when the young will break from the family unit and develop territories of their own (Ohio Division of Wildlife 1996).

6.1.2 Depredation on livestock

The National Agricultural Statistics Service (USDA 1995) estimated that coyotes were responsible for 66% of the total losses of sheep and lambs to predators in the United States during 1994. The total losses were valued at 115.2 million kroner ($17.7 million) with coyotes alone responsible for 74.8 million kroner ($11.5 million) in direct costs. Connolly (1992) estimates that inclusion of indirect costs (including intensified husbandry techniques, guardian animals or other predation controls, added costs of replacement animals, and contributions to government damage control programs (by ranchers and taxpayers), increased lamb prices to consumers because of the reduced supply, etc.) may equal or even exceed the direct value of the animals killed. He calculates that the economic impact (including direct and indirect costs) of predation on sheep in the 17 western states probably exceeds 325 million kroner ($50 million)!

Depredation on sheep, goats, new-born cattle calves, pigs and poultry are the main sources of conflict, although sheep depredation is the largest economic loss. At the level of the individual rancher, levels of depredation on sheep vary enormously depending on husbandry methods, habitat quality, coyote density and the intensity of coyote control. Typically the lowest levels of depredation occur in eastern areas such as Kansas or Pennsylvania where sheep losses are between 0.1 and 0.9% (Robel et al. 1981, Witmer & Hayden 1992). The highest depredation rates are in the order of 12 to 29% of lambs and 8% of ewes from individual ranches in Montana and New Mexico (DeLorenzo & Howard 1976, Henne 1977, Munoz 1977, O'Gara et al. 1983). Generally between 1 and 3% of ewes and between 4 and 10% of lambs are killed in more normal situations on western ranches (e.g. Nass 1977, McAdoo & Klebenow 1976, Taylor et al. 1977, Tigner & Larson 1977, Schaefer et al. 1981, Scrivner 1985).

6.1.3 Coyote control programs

Control of one sort or another has been in existence since Europeans first began to settle North America (Bourne 1989). Every management jurisdiction (Federal, State, and County) has established their own predation control regulations dependent upon local conditions and attitudes. Coyote control objectives have changed from extermination, to population reduction, to selective removal of problem individuals, reflecting changes in available control techniques and changes in our environmental awareness (Sampson & Brohn 1955, Beasom 1974, Connolly & Longhurst 1975 Evans & Pierson 1980, Phillips & Fall 1990, Miller 1995).

Early management was accomplished by paying bounties for confirmed kills, thus encouraging active hunting of coyotes, along with other species that were classified as vermin (Bourne 1989). As agricultural losses increased the federal government began a program to control coyote numbers in 1915 by establishing research facilities for developing additional control techniques and by hiring government trappers to assist farmers and ranchers with predator control on federal lands (USDA-APHIS 1994). The federal programs came under public attack in the 1960's largely because of the extensive use of toxicants (USDA-APHIS 1994). Subsequently a Presidential Order in 1973 banned the use of all poisons that remained in effect for several years. After it became clear that coyotes could not be controlled without at least limited use of toxicants permission was granted for the use of cyanide and Compound 1080 under strictly controlled conditions. Future toxicants must be thoroughly investigated prior to their application for registration by the Environmental Protection Agency (i.e. approval for use). This process is extremely rigorous with few potential substances gaining approval, and those that do often have severe restrictions placed on their use.

The federal control program in the United States comes under the jurisdiction of the United States Department of Agriculture, Animal and Plant Health Inspection Service, Animal Damage Control (USDA, APHIS, ADC). The ADC has some 900 employees spread out across the USA who conduct control operations and provide extension education for livestock producers (Andelt 1996). The emphasis of the ADC program has shifted from large-scale population reductions to non-lethal techniques (see **sections 3.4, 3.7**), selective removal of specific individuals, and local population reductions as preventative control in area with traditionally high predation rates (Andelt 1996, USDA-APHIS 1994).

6.1.4 Effectiveness control programs

To address this question adequately the objectives of the control program must be clearly defined. At the simplest level if the desired objective is the complete elimination of sheep predation by coyotes, then coyote control programs have not been effective. Coyote populations can withstand a very heavy control without substantial reductions in numbers through both behavioural adaptations and physiological compensatory mechanisms (Andelt 1996). Andelt points out that 3 coyotes would need to be killed for every 1 coyote present at breeding time to hold a coyote population at 50% of the pre-control level (Andelt 1996). Connolly & Longhurst (1975) developed a model that illustrated a coyote population subjected to various harvest levels from 0 to 75%. They found that through compensatory reproduction coyotes could withstand annual harvest rates up to 70% and that at 75% harvest rates, populations would persist for 50 years (and that only when 75% were killed in *every* year for 50 years). Their conclusion was that if less than 75% of the coyotes were killed the actual depredation rates would probably increase and that due to the difficulties in killing sufficient numbers of coyotes their populations probably could not be reduced over large areas without the use of toxicants (Connolly & Longhurst 1975).

However, extermination of the coyote population has not ever been a desired objective. What has been an actual objective is to hold the level of depredations down to some reasonable level (USDA-APHIS 1994). In testing the ability of the ADC program to accomplish this several studies have examined areas with control versus areas without control (or the same area before and after control measures were implemented). Nass (1980) reviewed a number of studies documenting sheep and goat losses with and without control measures in use. He found that average losses were 36% on areas without control and 3.4% on areas with damage control, though the exact makeup of these samples are not reported and could easily be biased. Another article reports on nation-wide loss rates in areas with predator control estimated by two independent sources as 1-2.5% for adult ewes and 4-8% for lambs and 1.2% for adults and 4.0% for lambs (Andelt 1996). Compared against this were data from 3 western ranches without predator control (reported by a number of authors, reviewed in Andelt 1996) that gave average predation rates of 4.5% for adult sheep and 17% for lambs (USDA-APHIS 1994, Andelt 1996). Clearly coyote control has an impact on depredation rates though further work is needed to more accurately document this effect.

Current research is focusing on ways to further increase the effectiveness of control actions by;

- analysing the behaviour of both coyotes and sheep in order to optimise the timing and nature of control actions
- developing more specific control techniques that will only remove the offending individual

- developing immunocontraceptive techniques to help reduce population growth
- developing control techniques that are more acceptable to the general public
- developing additional non-lethal techniques and more humane lethal techniques
- continuing to update livestock producers on the latest husbandry techniques effective in reducing predator conflicts.

6.2 Case study # 2 Dingo-livestock interactions in Australia

Main points - Dingo in Australia

- *A strict zoning system is used in Australia where dingo populations are excluded from, or maintained at very low levels in ,sheep areas.*
- *A 5600 km dingo-proof fence and the use of poison spread by aircraft make this possible.*

6.2.1 Background

Australia has an enormous cattle and sheep industry based on large scale, extensive ranching. Livestock are generally free ranging during the entire year on enormous ranges. Much calving and lambing occurs on the open range with little human monitoring. This is largely due to the unpredictable distribution of rainfall in many areas and general aridity which does not allow concentrations of livestock (Caughley et al. 1987).

6.2.2 Scientific research on dingoes in Australia

Dingoes once were distributed over all Australia but due to the conflict with livestock have been excluded from many areas after European colonisation, although the provision of water for livestock may have helped them expand in arid areas and the introduction of rabbits may have provided a valuable food source. Dingoes occupy all available habitats from arid desert through temperate rangelands to tropical forest. Dingoes have been extensively studied since the 1970's using radio-telemetry and carcass data. Field studies have been carried out in at least 11 areas which cover the diverse habitats within its range. Data on home range size, social organisation, dispersal, diet and dominance behaviour exist from multiple study sites (Corbett 1995, Harden 1985, Thomson 1992a-d). Living in packs, or as loosely organised individuals, dingoes mainly prey on mammals, from rodents up to kangaroos. Dingoes are able to kill both sheep and calves of cattle when available. Often livestock are only maimed, or killed and not eaten (Thomson 1984a), and as a result domestic species do not always appear in diet analyses even when predation occurs (Newsome et al. 1983). As livestock predation often peaked during the dingo mating season Corbett (1995) hypothesised that much livestock killing was a form of displacement activity by sexually frustrated young males.

6.2.3 The use of poison in dingo control

Because of the problems of predation on livestock dingoes are generally controlled throughout their range where it overlaps with livestock, especially sheep. Historically all possible methods have been used, from poison, snaring, trapping, shooting, aerial hunting, to chasing with dogs and horses. Bounties existed from the first years after Europeans introduced sheep (Corbett 1995, Harris & Saunders 1993, McKnight 1969, Reardon 1992). However, today the only cost-effective method for controlling dingoes over large areas is the distribution of poison baits, usually from aircraft. Trapping with legholds is used for local, concentrated control efforts. Enormous research activity has been invested in designing the most effective bait presentation (Allen et al. 1989, Kramer et al. 1987, Jolly & Jolly 1992 a, b, McIlroy et al. 1988), the best ways of distributing it (Thompsom 1990), and its effectiveness (McIlroy et al 1986a, Thomson 1986). The only poison in widespread use today is compound 1080 (Sodium fluroacetate). Similar techniques are used to control red fox populations (Saunders et al. 1995). An additional area of research has been in assessing the impact of compound 1080 on non-target species from both primary and secondary poisoning. Results indicate a surprising tolerance to 1080 among marsupials (King 1989, McIlroy 1981, 1986, McIlroy et al 1986 b) explained by the natural occurrence of sodium monoflouro acetate in some Australian plants (Saunders et al. 1995). Trapping also kills non-target species (Newsome et al. 1983).

6.2.4 Zoning: the dingo fences and the use of buffer zones

Because of the predation and maiming of sheep it is generally recognised that dingoes and sheep are incompatible on the same range (Corbett 1995, Thomson 1984a). As a result there is a policy of zoning, with intensive control of dingoes in sheep areas. To prevent or at least slow recolonisation of dingoes, two strategies have been developed. Beginning in the early 1900's dingo-proof fences were erected in various areas to prevent the movement of dingoes onto sheep pasture. This system of fences expanded and consolidated as state governments overtook or subsidised the management of the fences until by the late 1970's an 8 600 km fence ran from South Australia across Queensland, completely enclosing New South Wales and Victoria states. Even today a shorter 5 600 km dingo fence stands (Bauer 1964, McKnight 1969, Reardon 1992). The principle was that higher dingo densities would survive (or be tolerated) outside the fence where cattle were the main livestock species and that control would be easier inside without constant immigration. Dingoes were never completely exterminated inside the fence despite all the poison campaigns, although densities were kept lower, allowing economic sheep farming to continue with low intensity husbandry techniques (Corbett 1995).

In Western Australia, were dingo-fencing was never considered a viable option, a buffer zone mechanism is used to maintain dingo-free sheep pastures. A buffer zone is usually set as being at least two pack-territory diameters (15-20 km) wide. Data from radio-telemetry studies of dingoes was used to set biologically meaningful distances (Thomson 1992b-d). Within this zone, extensive poison and trapping campaigns are carried out every 2-3 years (Thomson 1986). The principle is that the buffer-zone will serve as a dispersal sink, absorbing immigrating dingoes before they reach the sheep pastures. The combination of buffer zones, and opportunistic control inside it has also allowed low-intensity sheep husbandry to persist in relatively dingo-free pastures (Corbett 1995, Thomson 1984 a, b, 1992d, Thomson et al. 1992a).

6.2.5 Dingoes and cattle

Cattle are much less affected by dingo predation than sheep, with only calves being vulnerable. The result is a greater tolerance of dingoes on cattle pasture than on sheep pasture. As cattle are more drought tolerant than sheep, this has lead to the survival of relatively higher dingo densities persisting in more arid areas. The interactions between dingoes and cattle, and the optimal solutions to the problem are more complex than with dingoes and sheep. As dingo predation on and maiming of calves increases during the dingo mating season, conflicts can be greater in areas where calving is synchronised with the dingo mating season. In such areas the recommended management solution is to shift the calving season. In times of drought natural prey populations decrease, forcing dingoes to increase the numbers of calves in their diet. Predation is further increased as drought forces both cattle and dingoes to use the few remaining waterholes, thus increasing encounter rates. At such times removal or destocking of calves is a standard husbandry technique to increase the probability of adult cattle surviving. Dingo predation is then felt to be of little consequence and may even help long term production (Corbett 1995).

Another consideration is that dingoes are considered to be valuable at helping control populations of other pests such as rabbits and mice, which compete with cattle for grazing. Dingoes are considered to be useful in slowing the eruption of such pests after post-drought rains. Therefore, cattle ranchers must balance dingo control with rabbit control, a difficult choice when the unpredictable nature of rain and drought in Australia is considered (Corbett 1995, CSIRO 1984, Newsome 1990).

6.2.6 Does the system work?

This depends on how success is judged. Low intensity husbandry of cattle and sheep is only viable in Australia due to the extensive control of dingoes. The aridity and resulting low carrying capacity of Australian rangelands makes most forms of intensive husbandry impractical. Dingoes still exist over much of the continent, so that twin goals of allowing profitable husbandry (even when agricultural subsidies are low or non-existent in Australia), and sustainable populations of dingoes have been reached. The survival of dingoes is not secure, although control is not the danger. Hybridisation from domestic dogs is regarded as the greatest threat facing dingoes today (Corbett 1995).

6.2.7 A note on red fox predation on lambs

The red fox is not native to Australia, but was introduced as a hunting quarry and to help control introduced rabbits in 1871. By the 1950’s they had colonised all of Australia apart from the tropical north. From the start red foxes were blamed for killing lambs on sheep ranches. The evidence for this is very poor. Frequent diet studies have found the presence of lamb in fox stomachs or scats at lambing time (e,g. Lugton 1993). However, none of these studies have been able to differentiate between lambs scavenged as carrion and those actually killed. As lambing often happens on open range, the farmers have poor control over mortality factors, and much information points to mortality causes such as stillbirths, abandonment, starvation and exposure being responsible for the bulk of lamb deaths (Dennis 1965). “Predation rates” are often calculated from the differences between the number of lambs ear-tagged at round-up (weeks to months after birth) and the expected production assuming total pregnancy and average litter sizes. There is no doubt that foxes are capable of, and do, kill lambs. What is not clear is if this predation has any significant effect on viable lambs. Obviously better data is required. A similar debate over the role of red fox predation on lambs is currently beginning in Scotland, with a similar lack of data (Hewson 1984, Harris 1995).

The effect of the belief in red fox predation in Australia has been the expenditure of enormous amounts of money on fox control. Shooting (with spotlights), trapping and gassing of dens have always been standard methods, but the only method that has any real impact on populations is the widespread use of poison. Strychnine was the first common poison to be used, but is being replaced by the use of 1080. Cyanide is used by government agencies and its suitability for general use is being evaluated. Poison baits are scattered from the ground or the air throughout fox habitat in the months before lambing. Densities as low as 6 baits per square kilometre achieve over 90% kill rates within 14 days (Saunders et al. 1995). Uncontrolled experiments provide some indication that this approach can increase lamb survival, although the evidence is far from concrete

(Lugton 1993). Because foxes can limit rabbit numbers when they are at low density (Pech et al. 1992), fox control needs to be followed by increased rabbit control. Fencing is also used, but is not considered viable to completely exclude foxes. Changes in husbandry are also recommended, such as lambing under more controlled conditions (Saunders et al. 1995).

6.3 Case study # 3 Western Europe - an historical example of carnivore population reduction

> ***Main points - Western Europe***
> - *The dramatic decrease in distribution and numbers of large carnivores in western Europe almost to the point of extermination is a clear example of lethal control taken to extreme lengths.*

Decreasing depredation rates on livestock through population reduction of coyotes and dingoes is difficult because of their high population densities and high reproductive rates. The previous case studies have illustrated that population reduction over large geographic areas is only possible with the widespread use of toxicants like compound 1080. In contrast the history of bear, wolf and lynx distribution in western Europe provides clear evidence of the ability of human control to effect population numbers.

Prehistorically wolves and bears were found throughout all of Europe, including Great Britain, and lynx were widespread throughout mainland Europe. Over harvest for meat and fur, conflicts with livestock and competition for wild game led to the widespread persecution of all species of large carnivore throughout Europe using hunting, trapping and poison. Although exact extinction dates are not available for all countries, the pressure on wolf, bear and lynx became so intense that by the early 20th century they only survived in remnant populations in southern and eastern Europe (Anon 1989, Boitani 1995, Breitenmoser & Breitenmoser-Würsten 1990, Promberger & Schröder 1993).

Similar patterns are evident from the US where cougars, grizzly bear and wolves were exterminated from most of their ranges by the end of the 19th century. Clearly control can have an effect on large carnivore populations and when unregulated can push them to the edge of local extinction (Kellert et al. 1996).

6.4 Case study # 4 Wolf-livestock interactions in Minnesota

> ***Main points - Minnesota***
> - *Despite having 7200 farms in an area with 1500 wolves, depredation levels have been very low.*
> - *This demonstrates that it is possible to keep livestock in areas with wolves provided correct husbandry practices are followed.*

Minnesota is a state with large areas of boreal forest, short growing seasons, and is in many ways similar to the forested parts of Scandinavia. The state contains a high wolf population, as well as a large livestock industry based on cattle, sheep and turkeys. Conflicts occur between wolves and livestock, however the scale of these conflicts is very low in relation to the number of wolves when compared to the situation in Norway today (Kaczensky 1996, Aanes et al. 1996).

6.4.1 Historical development of the wolf population in Minnesota

Bounty payments began in 1849 soon after European colonisation. These were paid up until 1965. During this period wolves were exterminated from most of the state and only survived within the remote north-eastern part of Minnesota. Population estimates from the late 1960's indicated from 700-950 wolves survived. Following partial protection in 1966, and full protection in 1974 the population rapidly expanded, both in range and density. By 1978 estimates were around 1300 wolves, and the species was reclassified as "threatened", a status which allowed more flexible management. Estimates from the late 1980's were 1500 individuals spread across an occupied range of 53 000 km^2 (density of 28 wolves/1000 km^2 (Fuller et al. 1992, Mech et al. 1988). In addition wolves had spread outside the state to neighbouring Wisconsin and Michigan (Mech 1995).

6.4.2 Scientific research on wolves and their prey in Minnesota

Wolves have been intensively studied in Minnesota since the early 1970's. Over 150 wolves have been radio-collared within the population as part of several studies (Fritts & Mech 1981, Fuller 1989, Fuller et al. 1992, Van Ballenberghe et al. 1975). Data on diet, predation rates, pack size, pack territory size, dispersal behaviour and population dynamics have been obtained. Additionally, simultaneous studies on the ecology of the wolves' main prey, white-tailed deer, have helped interpret the wolf data (Fuller 1990, Kunkel & Mech 1995, Nelson & Mech 1981, 1984, 1986, 1991, 1992). This scientific background has allowed effective population estimation, assessment of the prey base and wolf carrying capacity, and delimitation of suitable habitat.

6.4.3 Agriculture and the nature of the wolf-livestock conflict

A total of 7 200 farms were present within the wolf range (60 000 km^2) during the 1970-90 studies. The average farm size was 1.4 km^2, indicating that about 17% of the wolf range was farmland. Between 1976 and 1986 livestock numbers varied but were between 220 000-360 000 cattle, 16 000-60 000 sheep and somewhere around a million turkeys. During the 16 years 1976-91 cattle and sheep numbers declined, while turkey numbers increased. Livestock were confined indoors or close to farm buildings in winter but from May to October cattle, sheep and turkeys were grazed in open and forested pasture. Although most calving and lambing occurred before release, some calving occurred on pasture. These pastures were generally fenced (to constrain animal movement, not wolf access), even if they were quite large (Fritts 1982, Fritts et al. 1992, WJ Paul pers. comm.).

Generally, the level of predation on livestock was incredibly low when the potential for conflict is considered. For example in the worst year recorded (1989) compensation payments were made for 1 bull, 6 cows, 3 yearling cows, 52 calves, 13 ewes, 32 lambs and 1 866 turkeys. This covered the entire wolf range and compensation was paid to 76 of 77 farmers that claimed it. In the second worst year (1981) compensation was paid for 9 cows, 2 yearling cattle, 24 calves, 57 ewes, 205 lambs, 2 pigs, 582 turkeys, 43 geese, 15 ducks and 100 chickens (Fritts et al. 1992). The average annual loss from wolf predation (1979-91) was 4 adult/yearling cattle, 23 calves and 50 sheep. This represented an annual average of 0.012% of available cattle and 0.23% of available sheep (Mack et al. 1992). In general only a small proportion of farms experienced problems each year, although some individual farms consistently suffered higher livestock predation rates than others. Coyotes were also present in the area, and were responsible for much higher losses of livestock. Between 1979 and 1987 at least 24 domestic dogs were killed, and 10 wounded, by wolves. Generally small to medium sized breeds, up to the size of a Norwegian elkhound were killed, usually in farmyards, or close to houses. Most were eaten. The cases were often clustered in both space and time and may have been caused by a few individuals or packs (Fritts & Paul 1989).

Winter conditions appeared to effect the level of summer predation on livestock, with higher predation rates after mild winters. It was hypothesised that mild winters resulted in white-tailed deer (the main prey) being in better body condition during summer, and therefore harder to catch (Mech et al. 1988). However, evidence for an expansion of wolves into more agricultural areas were they have been absent has resulted in an increase in livestock predation and made this trend less apparent (Fritts et al. 1992).

6.4.4 Wolf zoning, and management techniques

Minnesota has been divided into five zones for the purposes of wolf management. Zones 1, 2, 3 and 4 cover the north-eastern corner of the state, and zone 5 covers the rest. Zone 1 is centred on Superior National Forest and represents the historical core survival area for wolf in Minnesota. The area is largely wilderness and within this area wolves receive virtually total protection. Zone 2, 3 and 4 are also regarded as critical habitat, but management is able to respond to livestock-predation problems on the farmland that occurs there. Zone 5 on the other hand is largely agricultural land, and is not considered as suitable wolf habitat. Wolves receive less protection here, and preventative control is practised in some areas with high conflict potential (e.g. near turkey or sheep farms). Compensation is paid by the state for livestock losses which are verified as being due to wolf.

When reports are received of predation they are investigated, and usually some form of control is practised if wolves are verified as the cause of death, or if the farm has a history of predation problems. Stipulations limit control to within 0.4 km of the farm (Fritts et al. 1992). Leghold traps are used and wolves are either translocated (Fritts et al 1984, 1985) or killed. From 1976 to 1989 between 30 and 90 wolves were removed from the population annually. As wolf numbers appeared to expand during this period, the level of control had no population-level effects (Fuller 1992, Mech 1995). The success of control was difficult to evaluate, as 34% of farms that experienced a problem and had a wolf removed experienced further problems in the same year, whereas only 23% of farms that suffered one problem, but were not able to remove a wolf, had a repeat problem the same year. There was no effect caused by the number of wolves removed (Fritts et al. 1992).

Farm management and husbandry practices were considered to be important to reduce the likelihood of predation. Farmers were required to bury or burn carcasses to avoid attracting wolves as scavengers to the farm, and were encouraged to ensure that calving and lambing were carried out close to the farm under controlled conditions. Aversive conditioning and the use of flashing lights at night were not considered successful, although guarding dogs appeared promising, but were not yet in widespread use (Coppinger & Coppinger 1995). It was also recommended that the portion of pasture in dense forest should be reduced, or that the habitat should be cleared (Fritts et al. 1992). The possibility of refusing compensation payments to farmers that used bad husbandry techniques was being considered, as such a system was in use in Canada (Tompa 1983).

6.4.5 Social attitudes and public acceptance

Despite the fact that livestock predation occurred, albeit at a low level, most Minnesota residents were in favour of the presence of the wolf. Farmers were the interest group most opposed to it. There appeared to be widespread confusion between coyotes and wolves, with wolves getting much of the blame for coyote depredation. In general the impression was that people strongly supported its presence in the state (Kellert 1986, Kellert et al. 1996, Mech 1995).

Future management objectives include the encouragement of the expansion of wolf populations into neighbouring states, and into any further parts of Minnesota which offer suitable habitat, and low conflict potential. There is an acceptance among managers that control of problems (with lethal techniques) within the present range will need to continue, and that preventative control will be necessary to keep wolves out of areas with very high conflict potential (much of zone 5). Such control is not accepted by all wolf-advocate groups, but is generally considered to be vital by managers (Mech 1995, although see Haber 1996 for an alternative view).

6.4.6 Why is the conflict so low?

It is not easy to find a clear answer as to why the level of predation on livestock is so low in Minnesota. Possible reasons include (Fritts et al. 1992);

(1) the relative abundance of natural prey (white-tailed deer, moose, beaver, snowshoe hare) in all seasons.
(2) the fact that livestock were often fenced on relatively open pasture and were often close to farm houses.
(3) the fact that livestock grazed as herds, rather that scattered individuals.
(4) wolf control possibly removed individuals that specialised on livestock
(5) the stable pack territorial mosaic limited the movements of wolves.
(6) livestock were not spread throughout the whole area which led to the availability of large areas with low conflict potential within all pack ranges, and many packs had no livestock within their range.
(7) cattle were the main livestock species present rather than sheep.

6.5 Case study #5 Grizzly and black bears, wolf, cougars and livestock in Alberta

Main points - Alberta

- *Alberta demonstrates that both cattle and sheep can be grazed adjacent to large areas containing bears, wolves and cougars without suffering very high losses.*
- *Even in areas of overlap with wolf packs in unsupervised forest pasture, cattle losses are very low.*

Like Norway, Alberta has stated goals of maintaining viable populations of large carnivores within the province. The province also has a similar climate and distribution of habitats, and a large livestock industry based on sheep and cattle grazing. Unlike Norway, Alberta has relatively low losses of livestock, and large populations of large carnivores. It could therefore be instructive to see how this marriage of seemingly exclusive goals has been achieved.

6.5.1 Distribution of cattle, sheep and large carnivores in Alberta

Alberta consists of varied landscapes and vegetation communities, but in principle the northern half of the province is covered by boreal forest, the entire western edge consists of mountains and the south east corner is prairie or so-called parkland (prairie-forest mosaic). There is an enclave of parkland in the north-west corner of the province. The most intensive agriculture occurs in the prairie and parkland areas. Livestock grazing is the only practical agriculture in the forest and mountain areas.

Approximately 4 200 wolves range over approximately 400 000 km^2 (Gunson 1992). They are present throughout Alberta apart from the south east quarter (Gunson 1991, 1992). Black bears range over approximately 488 000 km^2 and are only absent from the south east corner. Present population estimates are just under 40 000 bears (Gunson 1993). Cougars are estimated to range over 90 000 km^2 in the south-west corner of the state. They are absent from the boreal forest area and south-eastern agricultural areas. The population was estimated at 685 (Jalkotzy et al. 1992). Province-wide estimates of grizzly bear, indicate 790 bears distributed over 175 000 km^2 in the western portion of the state (Nagy & Gunson 1990).

In general there is very little overlap between the intensive agricultural areas of the south-east and the areas with most

Table 6.5.1 Percentage of predation losses due to different carnivores in Alberta. This does not take into account the relative availability of different livestock and predators. Data recalculated from Dorrance & Roy (1976) and Dorrance (1982).

Livestock	% Losses to different predators			
Sheep 1974	**Coyote**	**Domestic dog**	**Bear/wolf/cougar**	
Ewe	77	15	8	
Lamb	95	3	2	
Cattle 1974-78	**Coyote**	**Black bear**	**Wolf**	**Cougar**
Calves	51	34	14	1
Yearlings/adult	13	47	39	1

large carnivores in the mountains of the west and the boreal forests of the north. The main area of conflict between carnivores and livestock lies along the interface between the forested and the agricultural areas and in the areas where livestock are grazed within the forest (Gunson 1983). In these areas cattle are the main species grazed. In many operations they are released during June and collected in September. Grazing areas close to habitation are generally well supervised, although those in remote areas are often only checked a few times a week. Many pregnant cows are released onto summer range to give birth without supervision. The forest grazing areas are generally fenced to restrict animal movements Sheep are kept on both free-range summer pasture and enclosed summer pasture (Dorrance & Roy 1976, Bjorge 1983).

6.5.2 Losses of livestock to carnivores

Alberta predation statistics have been reviewed several times by outside groups in recent years (US Fish and Wildlife Service 1987, Mack et al. 1992) and in connection with writing management plans for the large carnivore species (Nagy & Gunson 1990, Jalkotzy et al. 1992, Gunson 1991, 1993). An estimated 1500 wolves live within the area of possible conflict (139 000 km^2) along the forest-agriculture fringe. Between 1974 and 1990 cattle numbers within wolf range varied between 235 000 and 300 000. Each year an average of 235 cattle (159 calves and 76 adults) were predated by wolves. This represented 0.087% of the available cattle killed per year. The predation rate can also be expressed as the number of livestock killed per wolf (per capita). From these figures, predation averaged 0.15 cattle per wolf per year. There were no overall numbers on sheep availability for this study, although total losses to wolves throughout the state averaged 33 per year.

Grizzly bears generally did not overlap with areas of livestock grazing. During the 8 years from 1980-1987 only a total of 74 incidences of livestock being killed (number and species of livestock not given), 9 cases of mauling and 24 cases of harassment by grizzly bears were reported.

Black bear were the large carnivore responsible for most damage to livestock. During 1974-79 compensation was paid for 505 cattle, 87 sheep and 81 pigs killed by black bears. From 1982-1989 a total of 903 cases of livestock being killed by black bears were reported. The vast majority of these livestock killed were cattle as sheep were largely unavailable. During this latter period 1519 beehives were reported as being destroyed (Horstman & Gunson 1982, Gunson 1993).

From 1982 to 1987, 80 cases of livestock killed by cougars were reported, although less than half of these were compensated. 70% involved predation on cattle and 13% involved sheep (Jalkotzy et al. 1992). Cougar predation appeared to be minor compared to coyote, wolf and black bear (Dorrance 1982).

Coyote were responsible for greater losses than the larger carnivores, for both sheep and cattle. Dorrance & Roy (1976) estimated that 88% of predation losses of sheep were caused by coyote, with total predation losses of ewes ranging from 0.8-3.2% and from 0.8-6.8% for lambs in different eco-regions. New-born cattle calves were also vulnerable to coyotes during the first weeks of life when unsupervised calving occurred on open or forested range (Dorrance 1982).

6.5.3 The Simonette River Study

This study area consisted of 152 km^2 of cattle grazing lease within the boreal forest zone of central Alberta. The seven individual pastures ranged in size from 5 to 59 km^2. They were partially or totally fenced to restrict cattle movements Cattle were allowed to graze on both clear-cut, and forested areas (>90% of area was forested) between May and October. The number of cattle present in summer ranged between 1558 (1979) to 2288 (1976) giving a mean grazing density of between 12-15 cattle/ km^2. Many cows were released onto the pastures while pregnant. The cattle were supervised at irregular intervals. The pastures were typical of the low intensity grazing operations typical within the region. Wolves, black bears and coyotes were common and grizzly bears were present but rare. The natural prey-base for wolves was regarded as good, with abundant moose, white-tailed deer, mule deer and beaver.

The study ran from 1975 to 1981. From 1975 routine wolf control operations were stopped. Even when normal hunting losses and illegal poisoning were taken into account wolf numbers in the area increased from 15 in 1975/76 to 40 in 1979/80. Wolf control during winter 1979/80 using strychnine poison reduced the number to 13-16 and further control in 1980/81 reduced it to 3 wolves by summer 1981. Cattle were counted and checked for pregnancy and general condition while being released in spring, and again at autumn round-up. Wolves from four packs, plus four lone wolves, were radio-collared and their movements around the cattle pastures monitored.

Four wolf packs overlapped at least partially with the pastures, with little overlap between adjacent wolf packs. However, only one of these, the Junction pack, covered almost all of the pastures within its territory (86% of its range within the pastures). Pack territory size averaged 263 km^2 in summer and 503 km^{2}in winter. Lone wolves ranged over larger areas, averaging 911 km^2 in summer and 1130 km^2 in winter. Lone wolves were found to have a much greater association with the cattle pastures during summer than winter (46% vs. 5%) whereas the packs had an almost constant association in both summer and winter (31% vs. 22%).

Cattle remains were found in 79% of the 39 summer scats collected from the Junction pack, and only 12% of 73 scats collected from two other adjacent packs. Other prey remains found in scats were primarily wild ungulates.

The forested cover and low intensity husbandry within the pastures meant that finding carcasses of cattle was difficult. Only 49 carcasses of 327 (15%) cattle lost could be found during the six summers of study. Of 41 carcasses for which a cause of death could be identified wolves killed 17 (42%), black bears 4 (10%) and non-predation 20 (48%). In addition wolves and bears mauled 51 and 11 cattle, respectively, during the study. Wolves scavenged on at least 15 of 34 (44%) cattle carcasses that died from other causes. The predation figures were regarded as being an underestimate due to the relative difficulty of finding predator-killed and consumed carcasses. Calves and yearlings were the most frequently age classes killed, however they were also the most available. There was an especially high mortality among calves born on the range. These had a 5 times greater risk of becoming missing than calves born before release on the summer pasture.

Between 1976 and 1979 the percentage of cattle that were lost on summer pasture and the proportion of losses to known causes that were killed by wolves increased (**table 6.5.2**). Following two winters of control and a reduction in wolf numbers the percentage of animals lost and the proportion of losses to known causes that were killed by wolves decreased. In all years the losses were lower than for cattle grazing on Provincial Grazing reserves (largely deforested and intensively managed pasture with constant wolf control) north of the Simonette pastures.

The results reveal that wolf predation on cattle was in the region of 1-2% (difference between total loss before control and post control loss), and in effect doubled the loss of cattle on the range. This however represents a worse case scenario as the range was heavily forested, husbandry was of very low intensity, cows were allowed to calve on the range, and the area contained a saturated mosaic of wolf packs, including one resident almost solely on the pastures. This one pack appears to have been responsible for most of the predation as their scats contained most cattle remains and after the cattle left the pasture in one autumn, the pack immediately moved to another cattle pasture. Control using poison in winter worked relatively well, although the colonisation of the vacancy by solitary wolves implied that summer control, or repeated applications were required. Better husbandry, especially allowing cows to calve before release was expected to also have reduced mortality without control.
All data are from Bjorge (1983), Bjorge & Gunson (1983) and Bjorge & Gunson (1985).

Table 6.5.2 Numbers of cattle released and mortality rates on the Simonette River study site, Alberta before and after wolf control, and during the same period on a Provincial Grazing Reserve.

Year	Cattle	Confirmed mortality: Wolf	Bear	Other	Unknown	Missing	Loss (%)	Wolves present
Before wolf control - Simonette River								
1976	2288	1	1	12	1	50	2.9	23-25
1977	2023	1	0	1	3	65	3.5	29-33
1978	1784	3	1	1	1	58	3.6	28-31
1979	1558	8	1	2	3	43	3.7	39-40
After wolf control - Simonette River								
1980	1772	1	1	2	0	44	2.5	16-17
1981	1804	1	0	2	0	27	1.6	3
Provincial grazing reserves								
1976-79	27036	1	2	87	0	248	1.3	rare

6.5.4 Management response to depredation

Alberta was the only province in western Canada to compensate livestock herders for losses due to large carnivores. Only food-producing animals were compensated, excluding pets and horses. Compensation was adjusted to annual changes in the value of livestock. Claims are categorised as “confirmed”, “probable”, or “missing” and 80%, 50% or 30% respectively of the value of the animals is paid. The livestock owner had the responsibility for reducing losses. This compensation scheme appears to have ended in 1993.

Following an attack on livestock the owner has the right to shoot black bear or wolves, or ask for government help. Wolves may be shot at all times of the year and in some cases preventative control is practised using poison. In the latter case the offending individual will be either killed or translocated. Wolves are usually killed using poison, black bears are either shot or translocated, and cougars and grizzly bears are usually translocated unless they have shown aggression towards people or are multiple offenders.

6.5.5 Management strategies for large carnivores in Alberta

Alberta has a stated policy of both protecting viable populations of all wildlife species and minimising the impact that wildlife has on private property (i.e. livestock). The Fish and Wildlife Policy states that “ The primary consideration of the Government is to ensure that wildlife populations are protected from severe decline and that viable populations are maintained”.

Protection of viable populations is achieved by regulating harvest (of cougars, black bears and grizzly bears) and is based around their presence on the huge areas of provincially owned land, rather than integration into private land. Apart from providing assistance with control operation following damage to livestock, there is pressure to make livestock herders accept that predation is a risk associated with grazing on provincial lands. Herders in areas where problems exist are encouraged to improve husbandry techniques and dispose of carrion. Failure to take measures to reduce predation resulted in possible loss of compensation of assistance with control. Better planning and zoning of land use has been proposed in an attempt to reduce conflicts. An example has been an attempt to restrict the number of grazing leases in the forest areas. Recreational hunting and trapping of wolves close to cattle pastures has also been encouraged to reduce conflict (Gunson 1991, 1993, Jalkotzy et al 1992, Nagy & Gunson 1990).

6.5.6 Conclusions

Alberta supports large, viable populations of the larger carnivores, and despite extensive livestock grazing, has a relatively low level of conflict. This is mainly due to the low degree of overlap between the areas of intensive agriculture (south-east) and the wildland areas (rest of the province). In effect a de facto zoning system exists, which has limited the overall magnitude of any conflicts. Even in the areas of overlap, the level of conflict is low. This is probably due to two reasons. Firstly, the fact that cattle are the most commonly grazed livestock species reduces conflict as they are less vulnerable than sheep or goats. Secondly, large areas of ungrazed lands and wilderness exist between clumped grazing pastures. The territorial nature of wolves therefore limits the numbers of wolves that have access to a given number of cattle. Still this does provide evidence that carnivores and cattle can co-exist with relatively acceptable losses. Response to predation usually results in removal of the carnivore (either lethally of non-lethal). By many standards the response to carnivores, especially wolves, has been “trigger-happy” and the continued presence of these species appears to have been due to the vast areas of habitat available rather than active conservation. These control actions create sinks for dispersers from non-controlled areas. Such levels of control are only sustainable when large source populations exist.

6.6 Case study #6 Reintroduced lynx populations in Switzerland and France

Main points - Switzerland

- *Losses of unattended sheep to a large lynx population have been very low, mainly because the sheep are excluded from the forest habitats.*

6.6.1 Local extinction and reintroduction

Lynx were eradicated from Switzerland and eastern France by the end of the last century, along with most carnivore and wild ungulate species. Beginning in 1973, lynx were reintroduced into the Swiss Alps and the Swiss Jura. Although most releases were official and approved by government, a number of illegal releases have occurred making it difficult to determine the exact number released. Official estimates indicate at least 24 individuals were released from 1973 until 1989 in Switzerland. Between 1983 and 1993 a total of 21 lynx were released in the Vosges mountains of France. Most individuals were wild, captured in the Slovakian Carpathian Mountains and translocated directly. Today there are estimated to be around 110 lynx in Switzerland and about 70 in France. Although these animals are not part of one contiguous population, the French and Swiss populations are connected in the Jura mountains (Yalden 1993, Capt 1992, Kaczensky 1996).

6.6.2 Ecology of the Swiss lynx

The lynx in Switzerland are the most intensively studied Eurasian lynx population. Over 30 individuals have been radio-collared, and extensive studies of diet and social organisation have been made. The area inhabited by lynx contains abundant populations of roe deer and chamois, with ungulate population estimates being in the region of 10-30 km^2. Not surprisingly, roe deer and chamois make up the largest part of the diet of these lynx (86%). Predation rates averaged one large ungulate kill per 5.5 days, or 65 ungulates a year. Home ranges varied between 150 and 300 km^2, resulting in a general density of one lynx per 100 km^2 (Breitenmoser et al. 1993, Breitenmoser & Haller 1993, Haller & Breitenmoser 1986, **Appendix A**).

6.6.3 Levels of livestock depredation

Sheep are generally left unattended on summer pastures (mainly alpine or open grassland), and are only checked every few days. This new husbandry system has resulted from a loss of traditional guarding practices following the local extinction of large carnivores, and changes in the economics of agriculture.

From 1973 until 1988 compensation was paid by the private Swiss League for the Protection of Nature. Since 1988 the Canton and Federal government have shared the costs of compensation for lynx kills. Only those animals verified as being killed by lynx are paid for, no money is paid for missing animals (Kaczensky 1996).

From 1973 to 1994 a total of 702 domestic animals (mainly sheep) have been compensated. From 1984-94 the annual average loss was 54 sheep, valued at 88 000 NOK (13,600 US$) a year. Considering that in Switzerland 2 616 000 000 NOK (40,000,000 US$) was spent to subsidise sheep farming in 1988, the economics of this loss to lynx predation is insignificant at a national or cantonal level (Capt 1992, Capt et al. 1993, Kaczensky 1996).

Whereas a similar pattern of low predation on sheep was seen in the French Alps and Vosges, there were major problems in the French Jura in 1988-89. In 1989 389 sheep and goats were killed, mainly within a very small area. Eight lynx were shot or trapped in the area, resulting in the stabilisation of the problem. Low availability of roe deer and the unattended grazing of sheep in forest were advanced as factors causing these high losses. There is also the possibility that these lynx were the result of an illegal reintroduction of captive bred animals (Kaczensky 1996).

Livestock formed an insignificant part (6%) of the diet of radio-collared lynx. Many radio-collared lynx were followed intensively close to sheep without predation being documented. One individual that was locally regarded as a sheep-killer killed only 14 sheep within a seven month period. In all areas there appeared to be an initial peak of predation on sheep in the first years after lynx colonised the area. This was explained as being due to a period of adjustment between lynx density and prey behaviour within the area. After a few years of high losses, the depredation invariably decreased (Capt 1992, Capt et al 1993, Kaczensky 1996).

6.6.4 Are lynx and sheep farming compatible?

Apart from the 1989 experience in the French Jura, lynx recovery in the area has caused very little damage to domestic livestock Losses have been spread over the entire area, and even at the level of the individual sheep herder, few cases of depredation can be regarded as severe. Future management of lynx in central Europe plans to aid lynx population recovery in all Alpine countries by helping existing populations expand, and possibly through the use of further reintroductions. The question is “why has the process seen so little loss of livestock?” Throughout Europe, lynx have never been regarded as a major predator of livestock when compared to wolf and bear. Where alternative prey is available, lynx have been frequently demonstrated to live close to livestock with minimal losses occurring. Keeping sheep out of the forest, and any form of guarding/herding appears to keep losses at low levels. However, so far lynx have only expanded into areas with abundant non-agricultural habitat, and good natural-prey populations. What will happen if they should colonise an area with more intensive agriculture and less natural habitat remains to be seen.

6.7 Case study #7 Snow leopard conservation and depredation on livestock in central Asia

Main points - Snow leopards

- *Conservation problems can be very acute when an endangered species must share its entire range with people dependent on livestock herding.*
- *Conservation of snow leopards is completely dependent on finding solutions to depredation problems.*
- *Correct husbandry can reduce conflicts as long as a natural prey base exists.*

6.7.1 Distribution, status and conservation of snow leopards

Snow leopards have attracted more conservation interest from the public than almost any other carnivore apart from wolves, lions and tigers. Their total world range is confined to an area of 1 600 000 km^2 throughout the mountains of central Asia in ten countries (Nepal, India, China (Tibet), Bhutan, Afghanistan, Pakistan, Tajikistan, Kazakhstan, Mongolia and Russia). Although it was believed to be critically endangered in the 1970’s and early 1980’s, present estimates are between 4500 and 7350 in the wild. These are concentrated into highly fragmented clumps. This fragmentation is the main cause for concern among conservationists (Fox 1994).

Many conservation areas have been established throughout the mountain region, with a total of 140 000 km^2 of protected area containing snow leopards. However the individual areas are often small, with only 14 areas being greater than 1000 km^2 and only 3 greater than 10 000 km^2 (Green 1994). Considering that population densities vary between 0.8 and 10 snow leopards per 100 km^2, it is clear that the maintenance of viable populations is dependent on land outside protected conservation areas to contain resident individuals and to provide corridors between different conservation areas (Green 1994, Fox 1994).

The whole region, including inside the majority of protected areas, is populated by people that live more or less on the subsistence level and depend mainly on livestock (goats, sheep, yaks, horses and camels) to survive. Snow leopard depredation on domestic livestock is widespread throughout the region (Miller & Jackson 1994, Schaller et al. 1988, Oli 1994) and represents the main motivation for the illegal killing of snow leopards by local people. The demand for skins and bones for the fashion and traditional medicine markets is presently of less importance. Finding a solution to the livestock-snow leopard conflict is universally recognised as a priority.

6.7.2 Patterns and level of depredation on livestock - the case of the Anapurna Conservation Project Area

Patterns of snow leopard depredation on livestock have been best studied inside the Anapurna Conservation Area Project (ACAP) of Nepal. This conservation area is 3500 km^2 in size and is situated in central Nepal. Much of the area is high mountain above 3000 m altitude. The 40 000 people inhabiting the ACAP are mainly dependent on subsistence agriculture, with some cash income from the tourist trekking industry.

6.7.2.1 The field studies

Two studies in late 1980's and early 1990's (Oli 1994, Oli et al. 1994, Jackson et al. 1994a) combined a study of snow leopard ecology and depredation on livestock with human attitudes in the Manang district. Nine villages with a total of 975 households occurred within the study site studied by Oli (1994). Of these nine, four were studied intensively. The average household owned 26.6 animals, consisting mainly of goats, followed by yak, cattle, horses and sheep. These were grazed close to the village in winter, and further away in summer. At night small livestock were penned, although these were not predator-proof. By day they were only occasionally guarded. Larger livestock (yak, cattle, horses) were often unattended for periods of days or weeks. Based on radio-tracking and track measurements the district was estimated to support a density of 5-7 snow leopards (5-7 per 100 km^2 density) and relatively abundant natural snow leopard prey (700-1000 blue sheep).

Losses of livestock to snow leopards during 1988-89 and 1989-90 were determined by interviewing 102 households. During each year 38% and 34% of the households claimed to have lost a total of 60 and 70 head of livestock respectively. This represented between 0.6 and 0.7 animals lost per household, or 2.6% of the livestock available in 1989-90. Horses (with particularly high value) and sheep were selected greater than their availability, although goats made up the majority of the animals killed. The monetary value of these losses equalled a loss of 25% of the national average per capita income per household. Some individuals suffered even greater loss, with one family losing two horses in one attack. These had a value of five times the national average annual per capita income. In this study losses occurred mainly in winter, and always on pasture areas, never within the village. There are many reports of snow leopards entering poorly constructed night-time corrals in or close to villages. No compensation was available, and snow leopards were strictly protected. Not surprisingly, 95% of villages interviewed expressed negative attitudes towards the snow leopard and viewed extermination as the only solution (Oli 1994, Oli et al. 1994). Estimates of depredation was also available from snow leopard scat analysis. Yak, followed by horse were the most commonly found domestic species present. Livestock was most often present in winter scats, when yak had a 29% frequency of occurrence, and livestock as a whole a 39% frequency of occurrence. This indicates that livestock may have been a relatively important food source for snow leopards in winter (Oli et al. 1993).

Jackson et al. (1994a) studied the village of Khangshar (included in Oli's study) in detail for a further three years. During this period the predation rate continued to vary around a mean of 2.8% of available livestock (21% of available yaks, 20% of available horses, 7% of available sheep/goats and 1% of available cattle). Horses and yaks were the preferred livestock taken by snow leopards during this study. Jackson et al. (1994) further tried to determine the factors explaining variation in losses of livestock. They identified that predation sites were associated closeness to cliffs, rugged terrain, gullies, and areas which provided enough vegetative cover to conceal a stalking snow leopard. Herds that were allowed to wander without guarding or supervision suffered high losses than other herds. As well as snow leopard, new-born sheep and goats were vulnerable to predation from jackal and golden eagle. During this period of study they estimated that on average each snow leopard was killing 2.9 yaks, 0.1 cattle, 4.7 sheep and goats and 0.7 horses per year, despite the availability of relatively abundant natural-prey (domestic prey biomass still outnumbered wild prey biomass by a factor of 3).

As Nepal's economy changed from one based purely on subsistence agriculture to a more cash based system, people's expectations increased and so did the need for education. As a result many people left to work in the cities, and children attended school. This combined to reduce the labour pool available to guard livestock, thus increasing the potential for carnivore-livestock conflicts.

6.7.2.2 Solutions that have been advocated

In order to make the conservation objectives of the ACAP compatible with the agricultural practices of the inhabitants Jackson et al. (1994a) proposed a series of measures that could alleviate problems;

(1) ACAP should develop a system to document all cases of livestock depredation.
(2) Improve husbandry by;
    ensuring that herds are responsibly guarded, especially when grazing in predation hot-spots
    ensuring that lambing and calving occur in secure corrals
    introduce guarding dogs
    encourage stall-feeding of cash producing livestock, especially milk producing buffalo.
(3) Project staff should lethally control problem individuals when they occur, using a strict set of criteria to define a problem animal, within certain quotas. Poison, trophy hunting and translocation were rejected as management methods to remove problem animals.

(4) Encourage other forms of employment, especially within the tourist sector.
(5) Ensure protection of natural prey species.

Similar problems of carnivore-livestock conflicts exist on the rangelands of Tibet and Mongolia (Jackson et al. 1994b, Miller & Jackson 1994, Schaller et al. 1987, 1988, 1994). Suggestions to reduce the conflict have followed similar lines;
(1) Improve husbandry, especially the guarding of animals and increasing the quality of night-time corrals.
(2) Better protection of natural prey-species, especially ungulates and rodents.
(3) Discourage increases in numbers of livestock grazed, to reduce the conflict potential and the risk of overgrazing.

However, in areas with little alternative prey for snow leopards, the removal of livestock (either spatially or through husbandry) could cause nutritional problems for the resident snow leopards (Oli et al. 1993). Reducing carnivore-livestock is only one component of the ecological and sociological planning required to achieve conservation of a large carnivore.

6.8 Case study # 8 Carnivore management in southern and eastern Africa

Main points - Africa

- *Most large carnivores that are capable of killing livestock are confined to large national parks, and do not overlap with grazing areas.*
- *Carnivore-proof fencing is often used to prevent contact.*
- *Some carnivores species such as cheetah are compatible with farming as long as some basic improvements to husbandry are made.*

6.8.1 Southern and eastern Africa's carnivore fauna

Southern Africa contains at least 35 species of mammalian predators, ranging in size from the dwarf mongoose (270 g) through to lions (230 kg), and several species of eagles which are capable of killing livestock. In general, it is the carnivore species weighing more than 8-9 kg like black-backed jackal (9 kg), caracal (14 kg), African wild dog (25 kg), cheetah (50 kg), leopard (20-60 kg), spotted hyena (60 kg) and lion (230 kg) that are involved in killing livestock. Notable exceptions exist, such as the brown hyena (40 kg), serval (10 kg) and aardwolf (9 kg) which feed more or less exclusively on carrion and fruits, rodents, and termites respectively (Bowland et al. 1992).

6.8.2 National Parks as a carnivore conservation strategy

During the last 200 years livestock herding has generally been considered to be incompatible with the larger predators (Anderson 1980). Lions, wild dogs and spotted hyenas have been more or less exterminated from all private farm land throughout the region, with cheetahs and leopards also being very heavily persecuted (Hey 1964, 1985). Many other species, such as brown hyena, have also been persecuted through lack of understanding of their food habits or as a result of unselective control techniques like poison. Even within national parks carnivores were persecuted as vermin until the 1960's, although there were differences in treatment among carnivore species. Lions generally were valued far above wild dogs and hyenas (Fanshawe et al. 1991). Carnivore presence was considered to be incompatible with the effective conservation of ungulates. This situation mirrors the previous attitude towards carnivores (vermin) and ungulates (desirable animals) in American national parks (Wright 1992). The modern recognition of the importance of ecosystem preservation and the role of carnivores in these ecosystems stems from the early 1970's.

The situation as it stands today is that these larger carnivores are only present in significant numbers in the large protected areas like state-owned national parks (Myers 1986, Mills 1991, du Toit 1995), or private game reserves (Langholz 1996). These are often enormous is size (**table 6.8.1**) with a total of 16 being greater than 10 000 km^2. Many such as Kruger NP, Etosha NP and the smaller Hluhluwe-Umfolozi NP (960 km^2) have been fenced (at least partially) to ease management, although several of these fences between Kruger NP and the surrounding fenced private game reserves have been taken down to embrace a larger unit (Mills pers. comm.).
From an analysis of species/area relationships, East (1981) found that African reserves of >1250 km^2 were likely to maintain at least 25 individuals of each carnivore species, although areas of at least 10 000 km^2 would be needed to contain more than a few hundred individuals of each species. Cheetahs and wild dogs are the species most dependent on large areas by virtue of their very large home ranges and naturally low population densities (Caro 1994, Fanshawe et al. 1991, Ginsberg & Cole 1994, Mills 1991). Reserve boundaries are sharp, with livestock ranches often joining directly onto national park land. Fences are often not completely carnivore proof. When individuals of these carnivore species leave the reserves, they are usually killed after killing livestock (Stander 1990), or poached (Harvey 1992, Hofer et al. 1993).

The system has been successful in preventing extinction of carnivores during a period of massive human population growth, political instability and heavy pressure on resources and space. However cheetahs and hunting dogs do badly when facing competition and predation from larger predators (Caro 1994, Creel & Creel 1996) and both species need more space than most reserves can provide (Ginsberg & Cole 1994, Nowell & Jackson 1996). Genetic considerations are becoming a concern in view of the general lack of corridors between reserves. This is especially acute in areas such as Tanzania's Ngornogoro Crater Conservation Area, where the lion population has been severely bottle-necked. More and more emphasis is being placed on establishing conservation plans for carnivores outside reserves, to increase population sizes and allow greater genetic dispersal between populations. The conversion of many livestock ranches to private game farms or game reserves with an associated decrease in conflict potential is making this process possible.

Table 6.8.1 Areas of some of the larger National Parks and Conservation areas in southern and eastern Africa which are greater than 10 000 km^2. This is the minimum area which provides a reasonable probability of maintaining communities of large ungulates and predators. Data from IUCN (1994).

Name	IUCN Cat.	Country	Area (km^2)
Chobe NP	II	Botswana	11 700
Kgalagdi Reserve	II	Botswana	51 800
Kalahari Gemsbok NP/Gemsbok NP	II	South Africa/Botswana	36 190
Kruger NP	II	South Africa	19 485
Kafue NP	II	Zambia	22 400
Zambezi Valley NPs	II	Zimbabwe	12 791
Hwange NP/Matetsi Complex	II	Zimbabwe	22 774
Namib NP	II	Namibia	49 768
Skeleton Coast	II	Namibia	16 390
Etosha NP	II	Namibia	22 700
Serengeti NP/ecosystem	II	Tanzania	20 000
Tsavo NP	II	Kenya	21 000
Selous/Mikumi NP	IV	Tanzania	50 000
Ruaha NP	II	Tanzania	12 950

6.8.3 Carnivores outside National Parks : conflicts and possibilities

Livestock in areas around National Parks are vulnerable to depredation from carnivores that reside inside the parks. One study around Kenya's Masai Mara reserve indicated that annual losses were in the order of 0.6-1.6% of available livestock, killed by leopard, lion and hyena in decreasing order. Poorly constructed night-time enclosures and poor vigilance were found to be explain much variation in losses (Karani et al. 1995). Such figures are not available for other parks, but these are likely to represent a bad case as the Masi Mara is a relatively small reserve (1530 km^2) and therefore has a relatively high edge to area ratio.

Many of the smaller carnivores exist outside national parks. Generally they persist because they do not kill livestock, are less conspicuous, and have small area (home range) requirements. Although many have died as a result of poison campaigns directed at larger carnivores, populations are generally in good condition. As they often feed on agricultural pests like rodents, hares and termites they can often be beneficial on farmland (Bowland et al. 1992). Much effort is being spent on encouraging an acceptance of these species on private farmland. Brown hyenas are being particularly promoted as a species with high conservation priority, and which are compatible with farming (Mills 1990, 1991, Stuart et al. 1985).

Leopard, caracal and black-backed jackal are the only three habitual livestock killers that are relatively abundant outside protected areas (Grobler 1986, Hamilton 1986, Norton 1986, Rowe-Rowe 1986). Generally these carnivores kill sheep and goats, although leopards will also take cattle less frequently. As there is no system of compensation, individuals are killed after incidences of livestock predation, and many farmers practice preventative control (Esterhuizen & Norton 1985, Norton 1986). However, because jackal populations are large and difficult to control, fencing is often used to keep them out of lambing pastures. In several cases these fences have been successfully enlarged and electrified to keep out caracal and leopard (Norton 1986). Farming techniques often involve herding livestock into enclosures (bomas) at night. This method generally holds losses to predators at a minimum (Karani et al. 1995, Kruuk 1980, Mizutani 1993).

In one study on a Kenyan ranch, where sheep and cattle were kept, annual losses to predators (leopard, lion, hyena, cheetah, jackal and wild dog) averaged 2% of sheep and 0.7% of cattle. Predator estimates included 15 resident leopards on the 200 km^2 ranch. Most livestock were guarded in bomas at night (Mizutani 1993).

6.8.4 Cheetah conservation in the Namibian farmlands

Cheetahs are among the most endangered of African carnivores. From a total population estimate of 9 000 in the wild in Africa, 2 500 live in Namibia. Of these 90% live outside reserves on private farmland, which is usually used for livestock ranching. This land belongs to about 1 000 landowners. As cheetahs occasionally kill livestock, they are controlled by the farmers either after predation occurs, or as a preventative measure before calving or lambing. This situation results in the future of the largest wild population of cheetahs in Africa being in the hands of a very small number of individuals. The habitat quality is good, with plenty of wild prey and fewer large predators such as lion of spotted hyena which is good for the survival of cheetah cubs (Marker-Kraus & Kraus 1993).

Since 1990 a private charity, the Cheetah Conservation Fund (CCF) has been studying the cheetahs on these farmlands to develop ways to reduce the cheetah livestock conflict and convince landowners to accept cheetahs on their land. This effort has largely been a success. Better control of calving and lambing has helped reduce predation during the most vulnerable period. Electric fences have been widely used to protect especially valuable livestock or game. The use of guarding animals such as dogs, donkeys or baboons has also provided relief from predation. The future looks good for cheetahs in the area, and the project must be regarded as one of the most successful attempts to integrate carnivores and livestock on private land anywhere in the world (Marker-Kraus et al. 1996). Their attempts to instil a sense of pride in biodiversity (including cheetahs) among farmers and enlisting the co-operation, rather than the animosity, of farmers, should be considered as a model for future conservation endeavours.

6.8.5 Carnivore-livestock and other wildlife conflicts

The problems of carnivore depredation on livestock must be seen in a larger context. General losses of livestock are high to almost all causes, such as disease, accidents and theft. In the two Kenya studies, disease killed between 2% and 10% of the livestock, between 3 and 10 times more than were killed by carnivores (Karani et al. 1995, Mizutani 1993). In addition the damages caused by ungulates (elephant, antelope) to crops far exceed, both in extent and economic loss, the damage done by carnivores (Bell 1980, Happold 1995, Newmark et al. 1994, Thouless 1994).

6.9 Case study # 9 Case Study: The Greater Yellowstone Ecosystem

Main points - Yellowstone

- *Sheep, accompanied by a shepherd and sometimes guarding dogs, are grazed around the edges of the Yellowstone ecosystem in an area with very high densities of large carnivores. Losses are very low because of the effective husbandry.*

6.9.1 Description of area

The Greater Yellowstone Ecosystem is an area of about 73,000 km^2 that includes and surrounds Yellowstone National Park (Craighead et al. 1995). It is located in the north-western United States, occupying the north-western corner of the state of Wyoming and adjacent areas of Montana and Idaho. About 20,000 km^2 is available to the Yellowstone grizzly bear (Blanchard & Knight 1991).

This description is condensed from Blanchard & Knight (1991). The Greater Yellowstone Ecosystem consists of a high-elevation basin surrounded by mountains. Most of the area is between 2135 and 2440 m in elevation, with extremes of 1620 and 4197 m. Winters are long and cold and summers are short and cool. The mean annual temperature varies from 4^o to -9^o, with low temperatures down to -40^o. Average monthly temperatures at Mammoth, Wyoming are -8^o in January and 17^o in July. Average precipitation varies greatly, from 36 to 97 cm, with most falling as snow.

About 75% of the area is closed-canopy coniferous forest, mostly dominated by lodgepole pine (*Pinus contorta)*. Other important trees were Douglas-fir (*Pseudotsuga menziesii*) and Engelmann spruce (*Picia engelmannii*) at low elevations and subalpine fir (*Abies lasiocarpa*) and whitebark pine (*Pinus albicaulis*) at timberline. Extensive nonforested areas are found below 2125 m in warm and more xeric areas, and above 2275. Rock and tundra dominated above 3000 m. Small meadows occur in the forest where soil conditions are too wet or too dry for trees to grow.

The Greater Yellowstone Ecosystem has a diverse wildlife fauna. The following larger predators occur: grizzly bear, black bear, mountain lion, bobcat, lynx, wolverine, and coyote. Golden eagles and bald eagles are also common. The only large predator that has been exterminated from the area is the wolf, but this species was reintroduced in 1995, when 14 individuals were released in Yellowstone National Park (Fischer 1995). Population estimates are only available for the grizzly bear, and they vary from ca. 250-350 and increasing (Eberhardt et al. 1996). There are many times more black bears than grizzly bears (pers. obs.).

Grazing by sheep and cattle has a very long history in this area since European man began to settle there in the late 1800's. The livestock industry is still very important to the local economy. Today there are more cattle than sheep in the area, but more sheep in the high mountains. Sheep grazing has declined greatly during the past 50 years because of decreased profitability in the sheep industry generally. This trend has occurred over the entire western United States and is not unique to the Yellowstone area (pers. obs.).

Economic compensation is not provided from public funds to livestock owners for depredations caused by predators. In an effort to reduce the livestock-predator conflict, some private conservation organisations have established funds to compensate livestock owners for losses caused by grizzly bears, and especially for losses caused by the recently introduced wolves. The national and state governments provide assistance to livestock owners in the form of publicly employed hunters, which trap and shoot predators in areas with especially high losses. On public land, livestock owners must generally tolerate an "acceptable loss" due to predators before predators are killed. Based on my personal observations, this amount of loss that justifies killing predators seems to be in the range of 5-10%.

The Greater Yellowstone Ecosystem is a complicated mixture of land ownership units. The core is Yellowstone and Grand Teton National Parks. Surrounding these are 6 national forests, 3 national wildlife refuges, as well as land administered by the national Bureau of Land Management, by the three states, and private lands. Wilderness zones (where no motorised access is allowed) comprises about 25,000 km^2 of national park and national forest lands. Nonwilderness park and national forest lands is about the same size (Craighead et al. 1995).

Landowners have exclusive rights to graze on their private lands. There is no grazing allowed in either of the national parks, which were created in 1872 (Yellowstone) and 1918 (Grand Teton). Grazing is permitted on national forest lands, even within the wilderness areas, and the rights are governed in a contract between the permittee and the national government. Many of these permits go back to the time the national forest was established. Grazing privileges are guaranteed as long as the permittee abides by the permit; they can not be cancelled unless the permittee violates the conditions.

There have always been controversies about managing wildlife in such a large area with such a number and diversity of wildlife and land ownership units. However, in regards to large carnivores, two issues are most important. The first is the conservation of the grizzly bear, which was listed as a threatened species by the national government in 1972. At that time, the population of grizzly bears was declining (Knight & Eberhardt 1985, Craighead et al. 1995). However, this decline has been changed to an increase of 2-5% annually since the mid-1980's, when the policy of preventing adult female moralities whenever possible became effective (Eberhardt & Knight 1996). It is important to mention that the Endangered Species Act in the United States places important restrictions on all activities of the federal government and requires that federal actions, such as permitting grazing, do not have negative consequences for threatened or endangered species. Fortunately, the research generated from the management goal to save the grizzly bear in the Greater Yellowstone Ecosystem has provided results that are important to understand the interactions between bears and livestock grazing on open range.

The second important wildlife conservation question regarding large predators is the reintroduction of wolves. However, the first release has occurred so recently, 1995, that it is too early to document any effects on the livestock industry. This question will not be examined further here.

6.9.2 Bear biology

The Greater Yellowstone Ecosystem is not generally a productive area, because of the high elevation, cold temperatures, and nutritionally poor rhyolitically-derived soils. Berries , which provide the most important source of carbohydrates for fattening in the autumn prior to the winter hibernation in most brown bear populations, are sporadic and of limited species diversity in the Yellowstone area (Mattson et al. 1991). The seeds of white-bark pine are the most food during the autumn fattening period. Although they are a high-quality food, the production of seeds varies from year to year, and less digestible roots and vegetation are substituted in years with poor seed crops (Mealy 1980, Mattson et al. 1991, Blanchard & Knight 1991). This variation in climate and resulting food production has dramatic consequences for the grizzly bears. Home ranges are generally large in the Yellowstone Ecosystem, average annual ranges are 281 km^2 for adult females and 874 km^2 for adult males, but they are significantly larger during years with little precipitation (Blanchard & Knight 1991). When the whitebark pine crop fails, bears use lower elevation areas and more often came into conflict with humans (Blanchard 1990, Mattson et al. 1987). Total home ranges (over 4-8 years) averaged 884 km^2 for females and 3,757 km^2 for males, but it is entirely possible that some individual females never reach a maximum home range size, given the unpredictable food sources (Blanchard & Knight 1991). Climate also influences reproduction in this population (Picton 1978).

In summary, the variable and unpredictable climate in a generally unproductive environment results in variable use of the area. Bears come into conflict with humans more often during years with little natural food available. Total home ranges, 884 km^2 for females and 3,757 km^2 for males, are large in relation to the size of the totally protected and sheep-free Yellowstone National Park (9,000 km^2), which means that many bears that are mostly in the park can also be found outside, especially in poor years.

6.9.3 Bear-livestock conflicts

6.9.3.1 Livestock management systems

In the grass-dominated areas below the timber line, mostly cattle are grazed. Some sheep are found, but they are mostly kept within fenced pastures near the farms and are taken in at night as protection against loose dogs, coyotes, black bears, etc. (pers. obs.). Here we will discuss only management systems in the forest and alpine areas, where conflicts with predators are greatest.

Cattle graze for about 92 days on open range, from early July to early October (Orme & Williams 1986). Cattle are mostly left to themselves and are checked only periodically, but graze within large pastures that are at least partially fenced, to allow a more even grazing pressure (Knight & Judd 1983, Orme & Williams 1986).

Sheep graze for 72 days, from early July to early September in lowland forested ranges (Orme & Williams 1986), to about 60 days in high alpine ranges (Wick 1995). Everywhere on open range sheep are tended continuously by shepherds that herd the sheep while grazing and gather them to bedgrounds at night, often using dogs (Johnson & Griffel 1982, Jorgensen 1983, Knight & Judd 1983, Orme & Williams 1986, Wick 1995). On public lands, the grazing pattern, area, number of animals, and even bedgrounds are stipulated in the grazing permits (Orme & Williams 1986, Wick 1995). Herds are usually in the order of 1,500 to 2,500 sheep (Johnson & Griffel 1982, Wick 1995).

6.9.3.2 The level of conflict

There are some conflicts between grizzly bears and cattle, but they are not large (Knight & Judd 1983, Orme & Williams 1986). Occasionally a horse is also killed by grizzly bears (Knight & Judd 1983). These conflicts are very minor in comparison with conflicts with sheep raising.

Knight & Judd (1983:189) concluded that “grizzly bears and sheep are not compatible”, but Wick (1995) has disagreed. It is important to understand that Knight & Judd (1983) concluded that they were incompatible because the shepherds were killing too many grizzly bears illegally, as many as 5-12 in only 2 years. They had the bear’s viewpoint. Wick (1995) had the shepherd’s viewpoint. Actually, in spite of the large numbers of two species of bears, the loss of sheep to bear predation is low in this area: 1.9% and 1.8%, as are total losses, 3.4% and 3.7%, as reported in two studies in the Targhee National Forest in Idaho (Johnson & Griffel 1982, Jorgensen 1983), and 0.6% in the Gallatin National Forest in Montana (Wick 1995). Also, only 3% of 238 bear scats from both species contained sheep or unidentified meat (Jorgensen 1983). Johnson & Griffel (1982) estimated that 28% of the bear-caused predation was due to grizzly bears; the rest was black bears.

6.9.3.3 Bear depredation behaviour

Knight & Judd (1983) studied the depredation activity of 37 grizzly bears in the Greater Yellowstone Ecosystem. Nine trapped in Yellowstone National Park were never on livestock grazing allotments. Of the remaining 28, 24 visited allotments and 10 killed livestock divided as follows: 5 killed sheep, 3 killed cattle, 1 killed sheep and cattle, and one killed sheep and a horse. Of 5 grizzly bears that had killed sheep and were captured at the kill site, marked and released, none killed sheep again that same year, but did later. The bears that killed cattle were all adults. Two males killed adult cattle, and two females killed calves.

Although no grizzly bears were exclusive livestock killers, all instumented bears that came into contact with sheep killed them (Knight & Judd 1983). However, Wick (1995) pointed out that the presence of sheep and bears in an area does not always result in depredation. Of 81 conflict situations in the Greater Yellowstone Ecosystem where grizzly bears were trapped and relocated, 10% involved livestock depredations (Blanchard & Knight 1995). Jorgensen (1983) found that only 1 of 8 radio-marked black bears was a verified sheep-killer. She found that 2 subadults were neutral to sheep, 2 subadult females avoided sheep, and 3 males were interested in sheep. She found that no black bears left their established home ranges to approach or avoid sheep. In fact, several researchers in this area have found that the problems end when sheep are moved; the bear apparently does not follow the herd (Johnson & Griffel 1982, Jorgensen 1983, Wick 1995).

Bears did not kill large numbers of sheep. Black bears killed 1-7 sheep at a time, and grizzly bears killed 1-3 sheep every few days (Johnson & Griffel 1982). Wick (1995) found that on average 2 sheep were killed per incident and only once were more than 3 killed (17 were killed). Grizzly bears killed sheep at night, but black bears killed during both day and night (Jorgensen 1983), and 90-100% of the predation occurs at the bedgrounds, either at night or early in the morning (Johnson & Griffel 1982, Wick 1995). Wick (1995) noticed that bear-sheep problems peaked when the general weather changed from dry-sunny to overcast-rainy.

6.9.3.4 Management of the conflict

To repeat, all sheep on open range are tended continuously by shepherds that herd the sheep while grazing and gather them to bedgrounds at night, often using dogs, and losses to bears are low (Johnson & Griffel 1982, Jorgensen 1983, Knight & Judd 1983, Orme

& Williams 1986, Wick 1995). Herders chose to concentrate sheep on meadows because quality forage was abundant and surveillance was easier (Jorgensen 1983). Also, loss of straying sheep was relatively higher (1.5%) in heavily forested allotments (Johnson & Griffel 1982).

Herders were with the sheep while they grazed, but it was especially important to be with the sheep at night, when depredation occurred. Wick (1995) recommended an open area for a bedground, free of trees and with an area of at least 1.6 ha for 2,000 sheep. It is important that, if attacked, the sheep can move away in all directions simultaneously without piling up. All herders slept out with the herd or bedded the herd up next to the base camp and woke up regularly, dressed, and walked out at night to check the herd. Most had prevented predation by bears in this manner. Wick (1995) used 2 Akbash guard dogs in 1992-93, and had 7 sheep killed in 22 encounters with bears (0.2% loss to bears total), compared with 29 sheep killed in 18 encounters (1.0% loss) in 1990-91, when he did not have guard dogs. Although he recommended guard dogs as effective, he pointed out that not all guard dogs are good guard dogs.

Management of sheep grazing to conserve the grizzly bear. Grizzly bear habitat and potential habitat is divided into 5 zones with guidelines that state how government lands will be managed (IGBC 1986). The 3 zones that are most important in the Greater Yellowstone Ecosystem are summarised here:

Management Situation 1. This area contains grizzly bear population centres and habitat components needed for the survival and recovery of the species or a segment of its population. Management decisions will favour the needs of the bear and land uses that can affect the bear and/or its habitat will be made compatible with grizzly bear needs or be disallowed or eliminated.

Management Situation 2. This area lacks distinct population centres, highly suitable habitat does not generally occur, and grizzly bears may be present occasionally. Habitat resources are unnecessary for survival and recovery of the species. When grizzly needs and other land uses are mutually exclusive, the other land use needs will prevail.

Management Situation 3. Grizzly bear presence is possible but infrequent. Grizzly bear presence and factors contributing to their presence will be actively discouraged.

This means that grizzly bears have first priority in *Management Situation 1* areas. Orme & Williams (1986) documented the change in sheep use in *Management Situation 1* areas on the Targhee National Forest from 1975 to 1985. The number of sheep declined 72%, but the number of cattle stayed the same. This was due to converting sheep allotments to cattle allotments, moving allotments *from Management Situation 1* areas, and because some sheep raisers quit due to the generally poor economic return from sheep farming. It is the policy of the Targhee National Forest to not reissue sheep grazing permits in *Management Situation 1* areas when they are terminated. These measures were primarily the result of the continued illegal killing of grizzly bears by sheepherders, and not because of excessive losses of sheep due to bears.

6.10 Case study #10 Conflicts between humans and Asiatic lions in the Gir Forest

Main points - Gir forest

- *The last population of Asiatic lions share their small forest reserve with a very high density of people and livestock. Livestock are an important part of the lions diet, and people are regularly attacked and killed. Problems will increase as both lion and human population density increase.*

Although carnivore depredation on livestock is by far the most common cause of conflict between large carnivores and humans, it is important to remember that carnivores can also kill people. Although not widespread, tigers and lions are the most common man-killers. Nowell & Jackson (1996) and Beier (1991) provide a comprehensive overview of the subject. Here we shall illustrate the problem with the example of the Gir Forest Sanctuary in India

6.10.1 The decline of the Asiatic lion

Once distributed from North Africa and Greece, across the middle east to India the Asiatic subspecies of the lion declined during the 18th and 19th centuries, until by the early 20th century only 20 individuals remained in the wild, confined to the Gir Forest in western India. A national park (259 km^2) and a wildlife sanctuary (1153 km^2) were established after 1965. The population has increased to about 280 individuals living at a very high density of almost 20 lions per km^2 (Ravi Chellam & Johnsingh 1993). The sanctuary is now believed to be saturated with lions (Saberwal et al. 1994). The sanctuary contains 2 172 people belonging to the Maldhari ethnic group and their 13 755 livestock divided among 74 villages, and a further 14 settlements with 3000 livestock belonging to people from other ethnic groups. Cattle and buffalo are the dominant species kept, followed by sheep and goats (Khan 1995). In addition four Hindu temples within the sanctuary attract over 70 000 pilgrims each year (Ravi Chellam & Johnsingh 1993). The sanctuary also has a complex border and is surrounded by villages, many of which illegally graze livestock within the sanctuary. Clearly the potential for conflict is high.

6.10.2 Livestock depredation and man-killing

Livestock is an important component of the diet of lions within the sanctuary, although its importance appears to be declining. In the early 1970's livestock remains were found in 75% of scats collected, whereas by the early 1980's this proportion had decreased to 48%. Studies in the late 1980's found livestock only represented a maximum of 45% of kills found. During this 20 year period populations of wild ungulates had increased dramatically from 6 000 in 1972 to 54 000 in 1989 (Khan 1995).

Livestock are usually kept within corrals, pens or houses at night. And lions killed livestock by both day and night. Accurate estimates of the numbers of livestock killed were not available. Despite the existence of a compensation scheme, 81% of villagers interviewed did not avail of it because of its bureaucratic complexity. Interviews indicated that each village was loosing at least 5 livestock animals per year. The problem was not confined to the sanctuary, as lions (especially males) sometimes foraged outside the reserve.

Attacks on humans occurred mainly outside the sanctuary. During the 13 year period from 1978 to 1991, a total of 193 attacks were recorded, resulting in 165 people injured and 28 killed. The rate of attacks increased dramatically during and after a drought, which killed many of the livestock available. The surviving animals were kept closer to, or inside houses. This resulted in lions coming into ever closer contact with humans when attacking livestock, increasing the risk of injury or death (Saberwal et al. 1994). Although high the average of 2.2 deaths/year is low compared to the number of people killed by tigers (≈ 40 per year) in the Sundarbans area of eastern India (Nowell & Jackson 1996, Sanyal 1987).

6.10.3 Solutions?

The Gir Forest lions obviously have a very high conservation priority because they represent the last population of Asiatic lions in existence. Just one captive population of pure Asiatic lions exists, descended from only nine founders. However the conflicts appear to be very high, in terms of livestock and human lives. As the sanctuary becomes saturated with lions, the problems will only increase as young lions are forced out of the territorial mosaic. Because of this the present management method of translocating problem lions back into the sanctuary is likely to be virtually useless (Saberwal et al. 1994). Although there are possibilities of reshaping the sanctuary border to reduce the edges, such a measure will only provide temporary relief. Whereas man-killing can be reduced by using certain measures, such as moving in groups, better quality livestock protection shelters at night, and the use of human masks on the backs of heads to prevent attacks from behind (Nowell & Jackson 1996), it is unlikely that conflicts can be totally eliminated. It is hardly surprising that such conflicts provoke discussions about the basic human rights of people affected by wildlife conservation in the third world (Kothari et al. 1995). However the problem must be seen in perspective of the cycles of over-population and poverty that are endemic to these regions of Asia (e.g. Mishra 1982). Solutions will need to involve a major change in management, where local people are involved to a greater extent in the planning, and where management procedures take their requirements into account (Saberwal et al 1994, Ravi Chellam & Johnsingh 1993).

6.11 Case study # 11 European protected areas and recovering carnivore populations

Main points - Europe's protected areas

- *European national parks are much too small to preserve more than a few individual carnivores each, let alone viable populations.*
- *Therefore, conservation is dependent upon integrating carnivores into multi-use landscapes, where conflicts will occur.*
- *Effective ways of reducing depredation through husbandry need to be put into use.*

When searching for areas to conserve large carnivores that offer suitable habitat and a relatively low conflict potential, national parks and other protected areas are often advocated as suitable alternatives. Yet are they suitable in size for the purpose of maintaining viable populations of carnivores?

If we assume a density of 2 resident individuals per 100 km^2 which would be typical for many saturated wolf and lynx populations then an area of 1000 km^2 would be needed to maintain 20 individuals, 2500 km^2 for a population of 50 and 5000 km^2 for 100 individuals. This assumes that all of a protected area is suitable habitat free from conflict potential. Many national parks are located in mountain habitat which is not good habitat for forest carnivores (lynx, bear, wolf), and in many areas of Scandinavia national parks are heavily grazed by sheep and semi-domestic reindeer which are the main source of conflicts.

From this it is clear that in continental Europe there is no possibility to maintain anything approaching a viable carnivore population within the limits of an existing protected area. Even within Scandinavia there is only one protected area larger than 5000 km^2. Clearly the future of carnivore populations will be on private lands where the potential for conflict with livestock is high. Large carnivores (especially wolf and bear) cause levels of damage to livestock that are generally regarded as being unacceptable. Improved husbandry or changes in the form of landuse can prevent many of the losses, however the required changes will have an associated once-off cost and possible increased running costs. This reality limits the number of areas where carnivores will be socially accepted and limits the size of the area that governments can afford to convert to a carnivore friendly pattern of land use. Therefore a zoning system, even on non-protected land is required.

Within such carnivore zones any conflict resolution will cost money, if it involves more intensive husbandry or changing livestock or land use. Such measures will not be economically possible for farmers trying to make profits. Fortunately within Europe agriculture does not follow patterns of real economics. Heavy subsidy maintains many areas of non-economic food production for reasons of maintaining strategic food supplies or aiding rural districts. There is increasing pressure to attach environmental conditions to these subsidies (e.g. avoiding pollution), and most farmers are accustomed to conforming to environmental regulations. Thus carnivore-friendly food production techniques could be regarded as just another requirement to earn subsidy. As the tax-paying public may be even more willing to support the paying of farm subsidies if it brings about the conservation of charismatic species like large carnivores there should be a good possibility within existing frameworks to pay the cost of reducing many carnivore-livestock conflicts. With an increasing public desire for environmentally friendly food, the presence of carnivores within a food production region could be used as a symbol for the environmental quality of the food produced.

Finally, huge sums of money are spent annually on regional development initiatives to aid and attract development in rural areas. Through careful planning these funds should be channelled into development which is compatible with carnivores and other conservation objectives. The presence of large carnivores could also be used as a set of symbols to advertise products or to attract interest in the region. The future of large carnivores in a changing and crowded Europe is dependent on such new thinking. The possibility for conserving exists, the public will appears to exist, it is just a question of taking the steps required to make it happen. Conservation does not have to imply the loss of jobs (Goodstein 1996, Rasker & Hackman 1996), and may even create employment.

Table 6.11.1 presents a summary of the number of protected areas of different sizes occurring in Europe, and for comparison, Russia. The areas are those in IUCN category 1, 2 and 4 (Strict nature reserve, national park and managed nature reserve) listed in the 1993 United Nations list of National Parks and Protected Areas (IUCN 1994).

Region	**Number of protected areas within each size (km^2) range**				
	100-499	**500-999**	**1000-4999**	**5000-9999**	**>10 000**
Scandinavia	39	13	19	1	
Europe	136	38	2	1	0
Russia	53	41	66	14	13

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Appendix A

Home range sizes for some selected large carnivores

Table A1 Territory sizes of wolves from North America and Europe.

Site	Home range (km2) Min	Max	Mean	N	Ref
N. Alberta	220	2730	795	22 wolves	1
NE Alberta	95	1779	498	17 pack years	2
Central Alberta	297	878	505	7 pack winters	13
Kenai, Alaska	177	1556	638	18 pack winters	3
S. Alaska	782	2541	1645	11 pack years	4
Manitoba			253	2 packs	5
S. Quebec	85	324	199	21 wolves	6
SW Quebec	130	625	311	30 pack years	7
E. Ontario			175	4 wolves	8
NE Minnesota			243	11 wolves	8
NE Minnesota			110	5 woves	8
N Minesota	50	223	116	33 pack year	9
NW Minnesota	195	555	344	16 packs	10
Isle Royale	246	327	282	7 pack years	11
Romania			≈ 100	1 pack	12
Slovakia	160	250	205	2 packs	12
Italy	120	400	≈ 200	12 wolves	15
India	130	180	153	3 packs	14
Mean			405	16 studies *	

* mean does not include the two studies for which no specific mean was available.
1. Carbyn et al, 1993, 2. Fuller & Keith 1980, 3. Peterson et al. 1984, 4. Ballard et al. 1987, 5. Carbyn 1983, 6. Potvin 1987, 7. Messier 1985, 8. Table 2 from Fuller 1989, 9. Fuller 1989, 10. Fritts and Mech 1981, 11. Peterson 1977, 12 Preliminary data from Kaczensky 1996, 13. Bjorge &Gunson 1983, 14. Jhala & Giles 1991, 15. Boitani 1982, 1992.

Tabell A2 Home range sizes (km2) for Eurasian lynx.

	Sex	Season	Min.	Max	Mean	N	Ref.
Sweden							
	Female	Summer	59,9	277,5	158,1	6	1
	Female	Winter	70,8	1024,1	432,8	6	
	Male	Summer	218,9	581,5	443,3	4	
	Male	Winter	173,9	293,1	241,0	5	
Swiss Jura							
	Female	Annual	71,0	243,0	157,5	8	2
	Male	Annual	237,0	281,0	286,7	3	
Swiss Alps							
	Female	Annual	39,0	425,0	168,2	5	3
	Male	Annual	135,0	450,0	263,7	3	
Poland							
	Female	Winter	39	108	74.6	7	4
	Male	Winter	55	148	96.2	4	
	Female	Annual	49.7	158	83.1	6	
	Male	Annual	76.3	245.9	193.9	5	
Slovakia							
	Female		132,0	222,0		2	5
	Male		156,0	200,0		2	

1. Lindén et al. 1995, 1996, 2. Breitenmoser et al. 1993, 3. Haller & Breitenmoser 1986, 4. Jedrzejewski et al. 1996, 5. Huber et al. 1995.

Table A3 Home range sizes (km2) for male, barren female (-) and reproductive female (+) wolverines in Europe and North America.

Site	Sex	Home range (km2)			N	Ref
		Min	Max	Mean		
NW Alaska	Male	488	917	666	4	1
	Female +	55	99	73	3	
	Female -	56	232	126	6	
S Alaska	Male			555	5	2
	Female +			105	3	
SW Yukon	Male			238	1	3
	Female +			47	1	
	Female -	153	157	155	2	
Montana	Male			422	9	4
	Female +			100	2	
	Female -			388	11	
Idaho	Female -			338	1	5
Sweden						6
- summer	Male			356	11	
	Female +			63	11	
	Female -			821	2	
- winter	Male			526	6	
	Female +			120	11	
	Female -			196	2	
Norway	Male					7
	Female +					
	Female -					

1. Magoun 1985, 2. Whitman et al. 1986, 3. Banci 1987, 4. Hornocker & Hash 1981, 5. Copeland 1993 in Banci 1994, 6. Lindén et al. 1996, 7. Landa unpublished.

Table A4 Annual home range sizes (km2) of brown bears in Europe and North America.

Site	Sex	Home range (km2)			N	Ref
		Min	Max	Mean		
N Yukon,	Male			645	6	6
	Female			210	8	
Arctic Alaska	Male	746	1927	776	4	1
	Female	80	873	220	37	
South Alaska	Male	100	2135	1014	10	1
	Female	110	536	294	15	
Kodiak, Alaska	Male			133	Many	9
	Female			28	Many	
Alaska Penninsula	Male	62	749	262	4	1
	Female	26	1098	293	30	
Jasper, Alberta	Male	189	1628	916	11	1
	Female	89	358	224	2	
NW Montana	Male			1185	2	4
	Female			642	8	
Yellowstone	Male			874	28	2
	Female			281	48	
Japan	Male			41.4	2	3
	Female			41.1	3	
Croatia	Male			50	1	8
	Female			85	1	
Spain	Male			1272	1	5
Sweden South	Male	476	27737	5430	26	7
	Female c	98	594	252	8	
	Female s	123	1485	428	9	
Sweden North	Male	726	2660	1444	7	7
	Female c	210	877	393	6	
	Female s	157	1277	463	11	

1. LeFranc et al. 1987, 2. Blanchard & Knight 1991, 3. Mano 1994, 4. Aune 1994, 5. Clevanger et al. 1990, 6. Nagy & Haroldson 1990, 7. Wabakken et al. 1992, 8. Huber & Roth 1986, 9. Smith & Van Daele 1990.

Appendix B

Population densities of some carnivore species

Table B1 Density estimates of wolves from different areas of North America and Europe.

Site	Density range (wolves per 100 km^2)	Main prey	Reference
N. Alberta	0.8-3.0	Bison	1
Denali, Alaska	0.7	Caribou	2
British Columbia	0.5-1.1	Caribou	3
S. Quebec	0.2-0.4	Moose	4
S Quebec	2.8	White-tailed deer	5
Kenai, Alaska	1.1-2.0	Moose	6
S Alaska	0.2-1.0	Moose/caribou	7
NE Alberta	0.6-1.1	Moose	8
Central Alberta	1.4-2.1	Moose /white-tailed	15
NW Minnesota	0.7-3.0	White-tailed deer	9
N Minnesota	3.5-5.0	White-tailed deer	10
NE Minnesota	4.2	White-tailed deer	11
Slovakia	0.6-3.5	Roe deer	12
Italy	1.3	Garbage	13
Spain	0.5-5.0	Garbage/red deer	14
India	1.5-6.0	Blackbuck/livestock	16

1. Carbyn et al. 1993, 2. Dale et al. 1994, 3. Bergerud & Elliot 1986, 4. Messier & Crête 1985, 5. Potvin 1987, 6. Paterson et al. 1984, 7. Ballard et al. 1987, 8. Fuller & Keith 1980, 9.Fritts & Mech 1981, 10. Fuller 1989, 11. Nelson & Mech 1981, 12. Hell 1993, 13. Boitani & Ciucci 1993, 14. Vila et al. 1993, 15. Bjorge & Gunson 1983, 16. Jhala & Giles 1991.

Table B2 Population densities of Eurasian lynx from Europe.

Site	Density range (lynx per 100 km^2)	Main prey	Reference
Swiss Jura	1.0-adults	Roe deer/chamois	1
E. Poland	1.9-3.2-adults 2.8-5.2-total	Roe deer	2
S Sweden	0.3-1.0-total	Roe deer	3
SE Norway	0.3-total	Roe deer/hares	4

1. Breitenmoser et al. 1993, 2. Jedrzejewski et al. 1996, 3. Liberg & Glöersen 1995, 4. Linnell et al. 1996

Table B3 Population density estimates for wolverine from North America

Site	Density range (wolverines per 100 km^2)	Reference
NW Alaska	0.7-2.1	1
N Yukon	0.13-0.25	2
SW Yukon	0.6	2
S Alaska	0.5	3
NE British Columbia	0.5	4
NW Montana	1.5	5

1. Magoun 1985, 2. Banci 1987, 3. Whitman & Ballard 1983, 4. Quick 1953 in Banci 1994, 5. Hornocker & Hash 1981.

Table B4 Population density estimates for brown bear from Europe and North America.

Site	Density range (bears per 100 km^2)	Reference
NW Alaska	1.9	Ballard et al 1990
Denali, Alaska	2.2	Dean 1987
NW Territory, Canada	0.9	Clarkson & Liepins 1994
Kodiak, Alaska	35	Smith and Van Daele 1990
Jasper NP, Canada	1.0	Nagy and Haroldson 1990
North Yukon	2.8	Nagy and Haroldson 1990
W. Alberta	0.4	Nagy and Haroldson 1990
NW Territory, Canada	0.4	Nagy and Haroldson 1990
Yellowstone	1.0-2.1	Mattson and Reid 1991, Eberhardt and Knight 1996
Sweden South	1.6	Swenson and Sandegren 1996
Sweden North	0.9	Swenson and Sandegren 1996

Appendix C

Latin names of animals metioned in text

Carnivores

domestic dog (*Canis familiaris)*
coyote *(Canis latrans)*
wolf (*Canis lupus*)
grizzly bear (*Ursus arctos)*
black bear *(U. Americanus)*
polar bear *(U. Maritimus)*
mountain lion / cougar (*Felis concolor*)
bobcat (*Lynx rufus*)
Eurasian lynx *(Lynx lynx*)
Canadian lynx *(Lynx canadensis)*
dingo (*Canis familiaris dingo*)
fox (*Vulpes* spp.)
jackals (*Canis mesomelas*, *C*. *adustus*)
spotted hyaena (*Crocuta crocuta*)
striped hyaena (*Hyaena hyaena*)
wild dog (*Lycaon pictus*)
caracal (*Lynx caracal*)
lion (*Panthera leo*)
leopard (*P. pardus*)
jaguar (*P.onca*)
tiger *(P. Tigris)*
snow leopard (*P. uncia*)
cheetah (*Acinonyx jubatus*)
wolverine *(Gulo gulo)*
marten *(Martes americana)*
fisher *(M. pennanti)*
sea otter *(Enhydra lutris)*

Ungulates

donkeys (*Equus asinus*)
llamas (*Lama glama*)
white-tailed deer (*Odocoileus virginianus*)
pronghorn (*Antilocapra americana*)
bighorn sheep (*Ovis canadensis*)
bison (*Bison bison*)
elephant (*Loxodonta africanus*)

Other

ostriches (*Struthio camelus)*