MESOCARNIVORES OF NORTHERN CALIFORNIA

Biology, Management, & Survey Techniques

August 12^{th} -15^{th},1997
Humboldt State University
Arcata CA

presented by

The Wildlife Society
California North Coast Chapter

This document consists of non-refereed papers submitted by the individual authors to serve as background material for the Mesocarnivores of Northern California: Biology, Management, & Survey Techniques Workshop. The included papers only received minor editorial review. The material presented herein is the opinion of the individual authors.

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Copies of this document may be obtained through The Wildlife Society, California North Coast Chapter. Requests should be mailed to:

Mesocarnivore Manual
California North Coast Chapter, TWS
PO Box 4553
Arcata, CA 95518

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MESOCARNIVORES OF NORTHERN CALIFORNIA:

Biology, Management, & Survey Techniques

Sponsored by

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MESOCARNIVORES OF NORTHERN CALIFORNIA: Biology Management, & Survey Techniques

Speakers

Dr. Steven Buskirk, Univ. of Wyoming
Dr. Reginald Barren, Univ. of Calif., Berkeley
Dr Keith Aubry, USFS, PNW, Forestry Sciences Lab
Jeff Copeland, Idaho Dept of Wildlife
Dr. Richard Golightly, Humboldt State Univ.
Armand Gonzales, Calif. Dept. Fish & Game
Dr. James Halfpenny, A Naturalist's World
Mark Higley, Hoopa Valley Tribe
Dr. Judd Howell, USGS, Golden Gate Field Station
Ron Jurek, Calif. Dept. Fish & Game
Dr. Thomas Kucera, Univ. of Calif., Berkeley
Rich Klug, Simpson Timber Company
Jeff Lewis, Washington Dept. Fish & Wildlife
Dr. Wayne Me1quist, Idaho Dept. Wildlife
Dr. William Zielinski USFS, PSW, Redwood Sciences Lab

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Sandra von Arb, AmeriCorps, Watershed Stewards Project
Dr. William Zielinski, USFS, PSW, Redwood Science Lab

Mesocarnivores of Northern California: Biology, Management, & Survey Techniques

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Program

Tuesday, August 12, 1997

09:30 am	***Registration***
INTRODUCTION	
10:00-10:15 am	***Introduction.*** Jay Harris, President, California North Coast Chapter, The Wildlife Society, California Department of Forestry & Fire Protection.
KEYNOTE SPEAKERS	
10:15-11:00 am	***Mesocarnivore communities: structure, function, and conservation.*** Dr. Steven Buskirk, Univ. of Wyoming.
11:00-11:45 am	***Perspectives on the history of mesocarnivore conservation in California.*** Dr. Reginald Barrett, Univ. of California, Berkeley.
11:45-1:00 pm	***LUNCH***
FOREST MUSTELIDS	
1:00-1:45 pm	***Fisher.*** Dr. Richard Golightly, Humboldt State Univ.
1:45-2:30 pm	***Marten.*** Dr. Steven Buskirk, Univ. of Wyoming; and Dr. William Zielinski, USFS, PSW, Redwood Sciences Laboratory.
2:30-3:15 pm	***Wolverine.*** Jeff Copeland, Idaho Dept. of Fish & Game; and Dr. Thomas Kucera, Univ. of California, Berkeley.
3:15-3:45 pm	***BREAK***
AQUATIC MUSTELIDS	
3:45-4:45 pm	***River otter and mink.*** Dr. Wayne Melquist, Idaho Department of Fish & Game.
5:00-8:00	***SOCIAL MIXER***

Wednesday, August 13, 1997

CANIDS

8:00-8:30 am	***Coyote.*** Dr. Richard Golightly, Humboldt State Univ.
8:30-9:00 am	***Gray fox.*** Dr. Judd Howell, USES, Golden Gate Field Station.

9:00-9:30 am ***Sierra Nevada red fox***. Dr. Keith Aubry, USFS, PNW, Forestry Sciences Laboratory.

9:30-9:50 am *BREAK*

MISCELLANEOUS MESOCARNIVORES
9:50-10:30 am ***Weasel, skunk, ringtail, raccoon, and badger.*** Armand Gonzales, Calif. Dept. Fish & Game, Eureka.
10:30-11:00 am ***Bobcat.*** Dr. Judd Howell, USGS, Golden Gate Field Station.

EXOTIC MESOCARNIVORES
11:00-11:30 am ***Red Fox.*** Jeffrey Lewis, Washington Dept. Fish & Wildlife.
11:30-12:00 pm **Ferrets *and feral cats*.** Ron Jurek, Calif. Dept. Fish & Game, Sacramento.

12:00-1:30 pm ***LUNCH***

SURVEY TECHNIQUES
1:30-2:00 pm ***Snow tracking***. Dr. James Halfpenny, A Naturalist's World
2:00-2:30 pm ***Track plates***. Richard Klug, Simpson Timber Company
2:30-3:00 pm ***Photography.*** Dr. Thomas Kucera, Univ. of Calif., Berkeley.

3:00-3:20 pm ***BREAK***

3:2-3:50 pm ***Videography.*** Dr. Keith Aubry, USFS, PNW, Forest Sciences Laboratory.
3:50-4:20 pm ***Monitoring mesocarnivore populations***. Dr. William Zielinski, USFS, PSW, Redwood Sciences Laboratory.

Thursday, August 14, 1997

FIELD DAY # 1
8:00 am - 5:00 pm Meet at the bus stop just north of the campus library. Transportation will be provided. Participants are responsible for their own lunch.

Friday, August 15, 1997

FIELD DAY #2
8:00 am - 5:00 pm Meet at the bus stop just north of the campus library. Transportation will be provided. Participants are responsible for their own lunch.

Table of Contents

A Short History of Mesocarnivore Management in California

Reginald H. Barrett
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In reviewing this short history of mesocarnivore, or "furbearer" management in California I have three observations. First, it is important to remind ourselves that we must take some interest in all members of the mesocarnivore community, not just the politically hot species of the moment. Second, management and research do not happen without funding, and funding is rarely available unless the resource being managed is valuable itself, or it stands in the way of developing a resource that is valuable. Mesocarnivores have generally been considered low priority in California. Third, most real advances, regardless of funding, are made by "special" individuals. They are special because they are able to persevere towards a personal goal over the long term despite numerous setbacks. By so doing, they provide leadership for others around them. This account is about some of these special people.

When humans first descended on the North American continent they may or may not have affected mesocarnivore (medium-sized mammalian carnivore) populations. Some have suggested humans did eliminate some large mammals, but we will probably never know if the earliest human immigrants had any impact on mesocarnivores. In any case, these early immigrants utilized many species, but apparently had established a relatively stable equilibrium by the time of European contact. Native Americans were likely well acquainted with mesocarnivore natural history, but it is less likely that they actively managed mesocarnivore populations. My definition of management includes the notion that humans must have an explicit management goal, the ability to manipulate the management system, and the ability to adequately monitor the results of manipulations, to qualify actions or decisions as management.

While I will focus on forest mesocarnivores here, it is impossible not to mention the role of two non-forest furbearers in the historical development of furbearer management in California. The first records of furbearer management resulted from regulations issued by the Spanish in 1785 regarding the take of sea otters. We know that Vicente Vasadre y Vega was given a monopoly on the sea otter trade by the King of Spain, and that in the five years between 1786 and 1790 he obtained 9,729 sea otter skins, which he sold for about $10 per skin (1790 dollars). Vicente became wealthy and the sea otter population began its dive towards near extinction. The Russians under the direction of Captain Kuskof assisted by legally taking 13,600 sea otters along the north coast of California between 1812 and 1841, earning $30 to $60 per skin. At this point hunting sea otters became economically infeasible because no one could find any more otters. Clearly the management system needed finer tuning if sustainability was to be a goal.

The likes of Jedediah Smith, James Pattie and Peter Ogden arrived in California by 1826 to manage the golden beaver along the lines of the then current management program for sea otters. John Suffer finally joined the action by hiring over 40 trappers to take beaver and river otter from the Sacramento delta between 1840 and 1843. He had to give up this enterprise because by 1845 beaver were economically extinct. The California legislature finally passed a law in

1911 to regulate the trapping of beaver; by 1913 the sea otter was fully protected. In 1917 a new law required all trappers to be licensed, and trapping could only occur during an open season when pelts were prime. By 1925 the legislature was debating over the advisability of closing all trapping of wolverine, fisher and marten.

One could argue that some of these developments after the turn of the century were a result of the efforts of a woman named Miss Annie Alexander. Using inherited money from Maui sugarcane, Annie Alexander established the Museum of Vertebrate Zoology (MVZ) and the Museum of Paleontology at the University of California in 1908. Throughout her life she was the MVZ's patron and benefactor. Joseph Grinnell was her hand-picked director of the MVZ, and a good choice it was. Joseph Grinnell and his students wrote profusely, including letters to newspapers and magazines attempting to stimulate notions of conservation and sustainability among Californians and their legislators. In 1919 Grinnell drew up a prospectus for his "fur book" for Annie Alexander's approval. She agreed to fund the research and the book. In addition she garnered support for the book from UC President Robert Gordon Sproul and Director of the UC Press, Samuel Farquhar.

The "fur book" is without question the cornerstone for all subsequent mesocarnivore research and management in California. Grinnell wrote the book over a 13-year period from 1922 to 1935. It was finally published in 1937. Jospeph Dixon was the field man from 1922 to 1928, when he took a job with the National Park Service. Dixon analyzed over 2,500 stomach samples to provide dietary information specific to California. Jean Linsdale took over the field assistant position in 1929 and stayed to complete the book. The research comprised 25 years of collecting by MVZ staff, interviews with numerous trappers, and official state records from 1920-1924. Some of the key players among trappers were Bruce, Gardinsky, Luscomb, Oliver, Parkinson and Wilder. Key payers from the California Fish and Game Commission (then equivalent to the Department today) included Bryant, Hunter, McLean, Moffitt, Sumner and Wilson. Clearly the information provided in this publication influenced management thinking and legislative action, not to mention improved education of new wildlifers at Berkeley and elsewhere.

Let me provide a few quotes to illustrate. Page 24: "... since the State was first occupied by white man, the major population trends of fur animals have been downward." Page 26: "California provides, at best, a poor type of habitat for most of these species. For some of them, such as the beaver, wolverine, fisher and marten, trapping by only a few men is enough to reduce the total population in California to the vanishing point, or nearly so. It is doubtful whether, in the interests of the whole State, trapping of these [four] species should have been permitted at all..." Page 25: "If the citizens of this State ever come to understand the true values of the wild life, we expect that they will no longer tolerate the killing of any form of native vertebrate animal by the use of poison in a natural habitat." Page 21: "Care should be exercised to preserve our native fur mammals, not alone that they may supply pelts of commercial value, but also--and mainly--that they may retain the important place they deserve in the makeup or `balance' of the fauna of the State."

I arrived on the scene in 1942 when the State held only 6 million people; there are now nearly seven times that many residents. There are relatively few trappers afield today in California, instead the habitat changes resulting from our rapidly increasing human population now make habitat loss the primary concern for those interested in maintaining viable mesocarnivore populations. There was a period after World War II, however, when efforts at predator and rodent control using the newly developed poison, compound 1080, along with more traditional traps, snares and poisons, made major inroads on mesocarnivore populations. In some cases local extirpation of carnivores is only now being reversed. The coyote has just recently returned to western Contra Costa County and southern Marin County, for example. Badgers have not yet returned to western Contra Costa County. Massive programs to poison porcupines (strychnine salt blocks) and ground squirrels (1080 coated grain) resulted in secondary poisoning of many mesocarnivores during the 1950's and 1960's. This era ended in 1972, when President Nixon banned the use of poisons, particularly 1080 as a predicide. Unfortunately, with no effective monitoring program in place, the exact situation in California during this period will never be known.

In 1964 I took a class in furbearer management from Charles Yocum at Humboldt State. While we covered the natural history of these species well, and were presented with enlightened views on management goals and the ecological value of mesocarnivores, it was abundantly clear that there would be few jobs waiting for any of us interested in pursuing furbearer management on a professional basis. At least in California, this area was considered a backwater to be avoided. Nevertheless, Charles Yocum attempted to keep track of the status of furbearers in northwestern California, and published some notes on the subject. There simply were no funds available for major research projects on California mesocarnivores at that time.

By 1971 I had completed my schooling at UC Berkeley, where I worked with Marshall White and Starker Leopold. Marshall White was interested in working on a revision of Grinnell's "fur book" and asked if I would join him on the project. We began attending meetings of a Carnivore Study Group established by Gordon Gould of the Department of Fish and Game. As a result of these regular meetings, and with the realization that without commercial trapping effort no data at all was available, Marshall took on Phil Schempf as a M.S. student. Schempf toured the State interviewing agency personnel and others to gather historical and recent incidental observations of mesocarnivores, especially in the Sierra Nevada. Schempfs thesis was eventually published by the Regional Office of the US Forest Service in San Francisco with the help of Dave Dunaway, another member of the Carnivore Study Group. Despite many hours of deliberation and proposal development, no funds could be found to actually proceed with a revision of the "fur book," and the Carnivore Study Group soon disbanded.

By the late 1970's the issue of clearcutting and wildlife-timber conflicts had become front page news. As a result of this, and a considerably improved public attitude towards carnivores in general, it became recognized that certain furbearers, or mesocarnivores, preferred older-aged forest habitats. The marten and fisher were of particular interest in this regard. So here was a new approach to obtaining public funds for mesocarnivore research and management. Archie Mossman and his students at Humboldt State University began a pioneering fisher study in northwestern California. My students, Bill Zielinski and Wayne Spencer, began a marten study in the Sierra Nevada. Several other students also began studies of marten with the help of US Forest Service "timber dollars." A small amount of funding has occasionally become available from "tax checkoff' and other special fund dollars administered by the Department of Fish and Game. In addition to Gordon Gould, Ron Schlorff, Ron Jurek and Esther Burkett have worked long and hard to gain support for mesocarnivore work. Given the high cost of studying mesocarnivores using modern radio-telemetry and automatic camera systems, progress will likely be slow at best. For example, Tom Kucera recently spent considerable time and effort to document the presence of wolverine anywhere in California; to date no one has succeeded in doing so.

The most exciting new development for actively managing, or at least monitoring, forest mesocarnivores is the requirement recently imposed by Congress on the Forest Service to monitor forest resources other than just timber volume. Work by Bill Zielinski, based at the Redwood Sciences Laboratory, in cooperation with many National Forests and Universities promises to provide reasonably accurate information on distribution, abundance and trend for several mesocarnivores on National Forest lands. Only time will tell if such large-scale monitoring efforts can be maintained long enough to provide useful trend data. Government programs of this type seem to have a way of fizzling out after a few years.

Of course, one solution would be for an interested citizen to endow a University research program geared towards mesocarnivores. However unlikely this possibility may seem today, it can happen. The role Annie Alexander played in promoting vertebrates in general and furbearers in particular via funding the MVZ and Grinnell's "fur book" should no be forgotten. Most major advances in our society occur because of the efforts of capable individual citizens, or "special" people.

Grinnell included 25 species of furbearers in his book; I will only touch on 12 species, those medium-sized carnivores that may be found in California's forest habitats. I will comment on these 12 species in the order they are listed in the Species Notes of the California. Wildlife Habitat Relationships System. I consider that source a good indication of our understanding of these species as of about 1990.

COYOTE

The coyote is an adaptable generalist that is capable of living with humans throughout the State as long as landscapes are not poisoned. With the loss of wolves from the State this species has expanded it's numbers to become the dominant canid. It continues to cause problems for sheep growers and therefore receives some research funding via the US Department of Agriculture and the California Agricultural Experiment Station.

RED FOX

An unusual situation occurs with the red fox in that the native subspecies prefers high mountain habitats in the Sierra Nevada. It is considered rare and threatened by genetic dilution from interbreeding with a subspecies introduced from the Midwest by fur farmers. The later prefers lowlands and is causing problems by preying on endangered birds along the coast. As a result, some public funding has been available for this species.

GRAY FOX

The gray fox is still legally trapped in good numbers, particularly from mid-elevation habitats around the State. There is some concern about the effect of competition with the introduced subspecies of red fox, but no studies are being done.

RINGTAIL

The ringtail is a fully protected furbearer that has probably increased its range and population throughout the same mid-elevation zone used by the gray fox. Ringtail now may be found in high densities along the Sacramento River where riparian forests still occur. They are also common along the riparian zones of most smaller streams up into the mixed conifer belt.

RACCOON

Raccoons, like coyotes, have been able to live well amongst humans. In fact they often become pests in urban as well as rural areas. It is still legally trapped throughout the State. It prefers riparian habitat, but may be found well away from streams in forested regions.

MARTEN

Martens are the smallest and most successful of the three mustelids considered to be "climax" species by Grinnell. Martens prefer the red fir belt and therefore have not been affected by massive logging activity until recently. Trapping has been closed since the 1950's. Recent survey efforts have confirmed that there is a fairly continuous distribution of marten throughout the Sierra Nevada. However, the Humboldt subspecies may now be extinct in the redwood region.

FISHER

The fisher prefers mixed conifer habitat, especially if large black oaks are present. Since it prefers the highly productive timberlands that have been heavily harvested throughout California, it is unclear if the low numbers and fragmented populations of this species are the result of trapping or habitat loss. No attempts to restore this species into currently uninhabited regions of the northern Sierra have been made. Such a project could test current ideas about habitat requirements. Research in progress by Rick Golightly, Bill Zielinski, and Rick Truex is funded in large part because of the current public controversy over the effects of timber management practices on wildlife, especially those species requiring large patches of old-growth forest.

WOLVERINE

The wolverine has most often been detected in the high Sierra nearby areas with nearly permanent snow packs. Incidental observations by reputable individuals continue to surface; however, no observations have been confirmed with photographs, hair samples, clear tracks or other physical evidence since 1925. Wolverine must be considered one of the rarest and most threatened mammals in California.

BADGER

Badger are intermediate in their susceptibility to human impacts. They prefer grasslands or open shrublands, but may be found in nearly any habitat throughout the State, including the red fir belt. The post-war poisoning campaigns against ground squirrels undoubtedly had *a* major impact on badger in California. Populations may increase if sufficiently unfragmented habitat remains.

SPOTTED SKUNK

The spotted skunk was commonly trapped, but it is unclear whether this species has decreased in recent years. It is an example of benign neglect as far as wildlife research and management is concerned.

STRIPED SKUNK

The striped skunk is more common than the spotted skunk; records are kept on annual take by commercial trappers. Striped skunks have adapted well to suburban situations to the extent that they are regularly hit by cars and have to be removed from under houses. It is of interest as a vector for rabies. Nevertheless, except for sporadic pest control efforts, there is little research or management effort going towards striped skunks in California.

BOBCAT

As a result of worldwide concern for spotted cats, the CITES treaty stimulated a burst of research on bobcats during the 1980's. The bobcat is still trapped commercially and good records are gathered on bobcat take. It occurs throughout the State, but is most abundant in open, rocky, chaparral habitats.

I want to end now with a comment about one of the most impressive lessons I learned from Starker Leopold. Several times he advised me that to work towards furthering wildlife conservation was like hiking up a sand dune, often it is difficult to see any progress. Therefore one must think in terms of life times not days or weeks; one must above all be persistent and look for the "windows of opportunity." In reviewing Grinnell's "fur book" for this meeting I found the following note from David Bohannon, a hunting buddy of Starker's, sent to Starker just before he died in 1983. The note was stuck at the beginning of the wolverine chapter.

COURAGE

When the last clay bird is shot at, and
you're walking from the line,
Perhaps a new born champion, or just
one more behind;
Don't take the score too serious, if
you've really done your best,
But keep your head and chin up, and
smile just like the rest.
The scores of life weren't everything,
nor the ballyhoo and such,
The way you went to battle, and your
conduct counts for much;
It's not the loot you've garnered, nor the
write-ups you have gained,
The fact you've been a sportsman, and
you've tried, that brings you fame.

The trophies soon will tarnish, and the
purse is quickly spent,
The way you waged the battle, and the
helping hand you lent -
Will count more in the reckoning, that
will come along some day,
And the memories you must live with,
will help you on your way.

So shoot each string the best you can,
and play the game full square,
Just do as you would have others do,
earn a word from those who care;
Then, whether you come out high gun,
or just an also-ran,
Your heart is light, your soul's at peace,
you've done the best you can.

[This poem was written by Henry N. Burguardt, February 11th, 1932, as he lay fatally stricken on a hospital bed, from an incurable disease.]

July 25, 1997

Fisher (*Martes pennanti*): Ecology, Conservation, and Management

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Description and Taxonomy

The fisher (*Martes pennanti*) is a forest dwelling member of the family Mustelidae. The other North American member of the genus Martes is the American marten (*M. americana*). Hall (1981) and Anderson (1994) recognized three subspecies: *M. p. pennanti* in the east and central regions of North America, *M. p. columbiana* in central and northwestern regions, and *M. p. pacifica* in the western region of North America. The legitimacy of the subspecies distinctions has been questioned (Hagmeier 1959) and may not be objectively resolved. There are some substantial ecological differences between regions occupied by the different subspecies.

Body size is sexually dimorphic; body mass is reported to be 3.5-5.5 kg for males and 2-2.5 kg for females (Powell 1982). *P. m. pacifica* may weigh less (Seglund 1995, Zielinski et al. 1996, Dark 1997, Golightly et al. 1997a) than animals in the eastern U.S. Fisher have long bodies with a well furred tail. Total length is 90-120 cm and 75-95 for males and females, respectively (Powell 1977). Their ears are rounded (as opposed to the slightly pointed ears of the marten). Mature males have considerable loose skin about the neck giving the appearance of a very thick neck. They have five toes on all feet and retractable claws. Their feet are large and their walk is digitgrade. They have four inguinal mammae. Dentition is 3/3, 1/1, 4/4, 1/2, = 38.

Distribution

Fisher are distributed across the forested region of Canada and the northern United States (Gibilisco 1994). In the West they are associated with mountain ranges. Within these mountain ranges fisher tend to be at low elevations. In the northern Coast Ranges and Klamath Province of California, Fisher are found from 25-1000 m (Beyer and Golightly 1996, Golightly et al. 1997a). In the south-central Sierra Nevada of California they are reported between 1000 and 2000 m (Golightly et al. 1997b). Although they range to higher elevations in the southern Sierra Nevada, their mean elevation for rest sites is lower than marten (Zielinski et al. 1996). Zielinski et al. (1995) show fisher to be absent north of Yosemite National Park in the Sierra Nevada range in spite of considerable survey effort and historical reports of fisher presence. If still present in the central to northern Sierra, they would be very rare compared to other regions of California where they are present.

Ecology

The attributes of the forests, the characteristics of topography, the prey and potential predators, and the anthropogenic influences vary across the range of the fisher. These considerations, in addition to the potential subspecific differences, make it very important to distinguish the geographic region and potential ecological units being discussed. This report focuses on fisher in the West, but necessarily uses research from elsewhere in the range of fisher; it is important to recognize that extrapolation of insights about fisher in the East may or may not be relevant to western fisher, and vice versa. Thus for both ecological and management discussions, it is important to identify the geographic source of the information. Even within a broad region (eg: the West) it is important to recognize that variation in geographic location may also be reflected in the fisher's ecology and management. These wide scale and regional differences have been revealed in a series of recent research reports from the western United States (Jones 1991, Seglund 1995, Zielinski et a1. 1996, Dark 1997, Golightly et al. 1997a, Klug 1997, Zielinski 1997).

Movements and Home Range

Individual fisher can travel over very large areas. Powell and Zielinski (1994) summarized several radio-telemetry studies which used somewhat different methods and generalized an average home range size for fisher as 40 and 15 km^2 for males and females respectively. In the East, Arthur et al. (1989a) reported a mean home range of 34 km^2 for males and 19 km^2 for females using a 100% minimum convex polygon method. Powell (1977) reported 35 km^2 for males and 15 km^2 for females. In Idaho, Jones (1991) reported 79 km^2 for males and 32 km^2 for females. In the southern Sierra Nevada, Zielinski et al. (1996) reported 27.5 km^2 for males and 5 km^2 for females using the minimum convex polygon method (52 km^2 for males and 8 km^2 for females when calculated using the adaptive kernel method). Golightly et al. (1997a) report a home range of 52 km^2 for males and 24 km^2 for females in the interior of northern California when calculated with a 100% minimum convex polygon method (58 km^2 for males and 16 km^2 for females with a 95% adaptive kernel method). Preliminary results from telemetry studies in coastal northern California indicate smaller home ranges than inland.

It is unknown how fisher density, habitat resources, disturbance, or topography may effect the wide variation in calculated home range size. However it is clear that individual fisher occupy very large areas. Individuals can travel long distances (5-6 km) in a single day (Kelly 1977, Arthur and Krohn 1991, Jones 1991, pers. obs.). Arthur et al. (1989a) and Kelly (1977) have reported overlap of home ranges between individuals of the opposite sex, but little overlap between individuals of the same sex.
Observations near Trinity Lake in northern California indicate some overlap between same-sex home ranges and we have observed occasional situations of multiple males in the same stand of trees at the same time (outside of the breeding season). Fisher do not uniformly utilize all the lands within the home range boundary.

Young of the year leave the maternal area in mid to late winter (Arthur et al. 1993). Male and female young disperse about the same distance (Arthur et al. 1993, Paragi 1990).

Reproduction

Fisher, like several other mustelids, utilize delayed implantation. Breeding occurs in the spring (March-April) but the blastocysts do not implant until the following February (Mead 1994). The pups are usually whelped in March (Mead 1994, Paragi et al. 1996). They produce one litter per year. Litter sizes vary from 1-4 (Mead 1994) but little is known about litter sizes in the West. The female apparently raises the young without assistance from the male. An estrous follows parturition by 6-8 days. Males increase their movements in March, apparently in response to estrous females (Arthur et al. 1989a).

Females appear capable of breeding at 1 year and producing their first litter at 2 years (Mead 1994, pers. obs.). However not all females produce litters in all years (Arthur and Krohn 1991, Paragi 1990, pers. obs.). Most males are capable of breeding at one year but their success at young ages is unknown.

Paragi et al. (1996) reported on 12 litters in Maine that were all in cavities of standing trees (94% were hardwood and all greater than 40 cm DBH). In the southern Sierra Nevada Mountains of California, Zielinski et al. (1996) found natal dens in cavities of large-diameter standing conifers and oaks. Similarly, fisher in northwestern California used cavities in standing, large-diameter hardwoods and conifers (pers. obs.). Following birth, the pups may be moved to a different den. As the pups get older, the mother may occupy a nearby rest site spending some of her time away from the den.

Mortality and Survivorship

Individuals can be relatively long-lived. Arthur et al. (1992) reported that fisher can live to ten years. In captivity, fisher can live in excess of 12 years (pers. obs.). In a harvested population, Krohn et al. (1994) reported that 94% of mortality was human related (80% from fur trapping alone); they also reported vehicle accidents as a source of mortality. Strickland et al. (1982) concluded that fisher had few non-human predators.

There is little data on survivorship of unharvested populations (Powell and Zielinski 1994). Adequate sampling, to assess mortality objectively, is only now becoming available due to radio telemetry studies. In the southern Sierra Nevada of California, Zielinski et al. (1996) reported predation of their radio collared fisher. In the long term study on the Shasta-Trinity National Forest in northern California, both predation (primarily coyotes) and auto collisions appear to be regular sources of mortality. Predation may be more common than investigators have previously reported.

Food Habits

Fisher consume a wide variety of prey. On the east coast they are reported to eat a variety of small mammals and squirrels, porcupine (*Erethizon dorsatum*), carrion, some other carnivores and plant material (see Powell and Zielinski 1994 for a summary of these results). In the west, squirrels, gophers, mice, marten, skunk, gray fox (*Urocyon cinereoargenteus*), deer, and birds are reported in the diet (Zielinski et al. 1996, Golightly and Zielinski 1997). Berries of *Arctostaphylos sp.* have also been reported (Zielinski et al. 1996) but the significance of plant material has not been determined.

It is apparent that fisher food habits differ by region. Snow shoe hare (*Lepus americanus*) has been reported in the diet in the East (Powell 1982, Arthur et al. 1989b) but not for populations in California. It has been suggested that Porcupine are essential to the diet of fisher, but this is questionable given that fisher occur in locations where porcupine do not occur. In spite of porcupine being present, Golightly and Zielinski (1997) have not found a single porcupine in the examination of several hundred scats.

Habitats

Until recently, almost all our understanding of fisher habitat requirements have come from the East or from the central regions of North America. The spatial scale of habitat use is extremely important in the consideration of the attributes of fisher habitat (Buskirk and Powell 1994). Fisher range over very large areas; different sites within a large home range could have different resources and have varied energetic costs. An attribute of the habitat (eg. forests within home ranges) may not be detectable at all scales because it has already been selected at a wider spatial scale (fisher are distributed across forests). The character of forests changes across the distribution of the species and the relative role of specific forest characteristics may also change.

In the East, fisher are reported to use mature forests with overhead cover (Arthur et al. 1989b, Thomasma et al. 1994). Fisher appear to avoid open areas (summarized in Buskirk and Powell 1994) and may use corridors with adequate overhead cover to travel between forest patches in their home ranges. Kelly (1977) reported that riparian areas were used for rest sites. Although areas with hardwoods were used by fisher, they were not used as much as available (Kelly 1977).

In the West, investigators have consistently found fisher in association with riparian areas (Buck 1983, Aubry and Houston 1992, Dark 1997, Golightly et al. 1997a) or near water (Jones 1991, Seglund 1995). It is important to note that this observation is confounded by the fact that trees along recognized streams may have been protected in some western forests (especially in California) and these trees may be larger with more closed canopies. Overhead cover has also been reported to be important at sites where fisher were found (Buck 1983, Zielinski et al. 1996, Golightly et al. 1997a, Zielinski et al. 1997). Jones and Garton (1994) noted that fisher did not use non-forested lands (< 40% canopy cover).

Depending on the forest type and geographical location, the relationship between seral, stage or forest age and canopy cover may vary. Jones and Garton (1994) reported that fisher used a variety of different seral stages, however, they were not detected as frequently in early successional forest as in late successional forests (Rosenberg and Raphael 1986, Aubry and Houston 1992). In coastal forests of California, fisher have been found in relatively young forests (Klug 1997, pers. obs.), but these young forests often include many hardwoods (some of old age), some older conifers not taken in harvests, and a closed canopy.

Rest sites for fisher are important attributes of the habitat. These rest sites are commonly determined from radio telemetry studies. Rest sites often represent the only fixed and fine scale locations for specific individuals that were identified without the use of bait (the highly mobile fisher are difficult or impossible to locate accurately by remote telemetry triangulation). These sites may or may not represent more than just habitat used for resting (Seglund 1995, Dark 1997, Golightly et al. 1997a).

In the East, rest sites are in the canopies or in cavities of standing trees (Arthur et al. 1989b). Similarly in the West, rest sites are in standing conifers or hardwoods (Jones 1991, Seglund 1995, Zielinski et al. 1996, Golightly et al. 1997a). Canopy cover, greater than generally available, surrounds the rest site (Zielinski et al. 1996; 85-94% canopy closure, Golightly et al. 1997a). Trees used as rest sites have relatively large dbh's, with an average of 58-61 cm on the Shasta Trinity National Forest (Golightly et al. 1997a), an average of 67 cm in the southern Sierra Nevada (Zielinski et al. 1996), and 56 cm in Idaho (Jones 1991). Other attributes that have been associated with rest sites include the absence of human disturbance (Seglund 1995), the presence of hardwoods, and water present within 100m at 50-60% of the sites (Golightly et al. 1997a). Zielinski et al. (1996) reported 17% reuse of rest sites in the southern Sierra Nevada; in northern California reuse of rest sites was less (Golightly et al. 1997a) and may be a result of greater fragmentation or human intrusion into the forests.

At a greater scale than that described by rest sites, forest type varies considerably between areas. Douglas fir is common in coastal California forests (Beyer and Golightly 1996, Klug 1997). Detections were most common in Sierran Mixed Conifer and Montane Hardwood Conifer (California Wildlife Habitat Relationships vegetation types, Mayer and Laudenslayer 1988) in south-central Sierra Nevada (Golightly et al. 1997b), and around rest sites in the southern Sierra Nevada (Zielinski et al. 1996). On the Shasta-Trinity National Forest fisher used Douglas fir with 50 - 75% canopy closure (Dark 1997) and mixed conifer; Fisher used areas with more contiguous blocks of habitat, but used open areas less frequently than was available (Dark 1997). Zielinski et al. (1997) reported fisher in forests with higher canopy cover, higher basal area, greater hardwood DBH, and with fewer logs.

Dark (1997) reported a negative association between detections of fisher and roads. In this well-roaded study area (areas without roads did not exist) fisher were detected more frequently at sites where the roads were closed by the use of gates or otherwise designed to discourage vehicular traffic. In the south-central Sierra Nevada, Golightly et al. (1997b) reported that there was a negative association between fisher detections and traffic (secondary in the habitat model only to the effect of elevation and forest type in describing fisher detections).

CONSERVATION

Fisher have been and continue to be harvested for fur in many areas of their range. Although thought to be declining in several areas of their range in the early part of the century, fisher populations in the East are presently considered more secure than in the western United States. In the West there is continued concern about their persistence. The U.S. Fish and Wildlife Service has been petitioned twice in this decade to list *P. m. pacifica* under the Endangered

Species Act (Biodiversity Legal Foundation 1994). Their range in California is less now than described by Grinnell et al. (1937) with populations now absent from the central and northern Sierra Nevada (Zielinski et al. 1995). They have protected status in Oregon, Utah, Washington, and Wyoming. No legal trapping has occurred in California since 1946. Trapping is also closed in Idaho. Montana has a very limited trap season.

The cause(s) of problems for western fisher are uncertain. As noted by Powell and Zielinski (1994), recovery will be slow for a species that does not have large litters and where females do not produce young until their second year of life. Although harvest is not now a major source of mortality in the West, habitat alteration and intrusion into their habitats continues with increases in the human population. For these reasons many non-empirical reports have identified fisher with late seral stage forests, and some have speculated that fisher may be obligated to late seral stage forests. It is clear that this is not universally true and that the association with late seral may reflect some of the attributes correlated with late seral forest (eg: lack of roads, large blocks of closed canopy, minimized anthropogenic influences). Mortality or reduced reproduction from a loss of dens, reduced connectivity between areas of adequate cover or exposure to predation in more open habitats, or collisions with vehicular traffic may contribute to their slow recovery or potentially add to their decline. Great care is needed in the interpretation of fisher habitat problems across various areas because of the considerably different forest conditions.

Management

Even areas where fisher are protected from harvest, they are still susceptible to damage from incidental trapping (Lewis and Zielinski 1996). Any injury or mortality from trapping where the populations are considered potentially at risk will exacerbate the risk. Conversely, trappers can add considerably to our knowledge of the status and distribution of fisher.

Reintroduction has been used as a tool where historical habitat exists but where the fisher were missing. This technique was used in New England with success (Powell 1982). However, where habitat needs are unclear, or where detrimental forces are still prevalent, this technique may not have positive results.

In the West, some habitat issues have only recently been identified. The retention of hardwoods, especially older and larger trees, as rest sites, den sites, and as potential food sources for prey may be important. The closure of roads to public access, or severely controlled access in forests that are being entered for timber production, may be tools to reduce mortality. The speed with which the canopy closes after a disturbance may cause considerable variation in the assessment of connectivity and suitable habitat patches for fisher. The timing of take of large potential den trees should also be considered by those who manage lands (Paragi et al. 1996).

Because fisher have such large home ranges, management must consider large landscape approaches (Powell and Zielinski 1994). Specifically, an approach to managing forest systems and not just individual stands has been advocated (Jones and Garton 1994). Uneven aged management with good connectivity between stands has also been suggested (Jones and Garton 1994). Land managers must be judicious with applying habitat models built for one landscape or forest, because they will not be universally applicable to other forest types or conditions.

Recently, some unfortunate terminology has been associated with fisher habitats and management. Because many land-use and wildlife decisions are made by non-biologists (lawyers, judges, or politicians), it is important that imprecise terminology not confuse these decisions. The term "preferred" is indicative of an animals choice (usually demonstrated in experiments). Unfortunately, today many of our wildlife investigations assess habitat use with extremely . managed landscapes where many original elements of the forest are absent. For instance, we cannot examine how fisher might use late seral Douglas fir in coastal California because large stands (relative to fisher home range size) are so few. We do not know how fisher might have used these stands if they were still available. In the minds of the non-biologists (and perhaps some biologists) the term "preferred" is logically equated with "best". We do not know what fisher would have "preferred" in an unmanaged landscape. Consequently decisions are made or confrontations develop based on incorrect assumptions of what is the best habitat to be preserved or result from management actions. Appropriate use of this habitat terminology is very important for managers who regularly interact with non-biologists.

Monitoring and Detection

Fisher have been detected with a variety of devices including triggered cameras (Fowler and Golightly 1994, Zielinski 1995), 35-mm cameras with infrared sensors (Kucera et al. 1995), smoked track plates (Fowler and Golightly 1994), and snow tracking in some regions (Halfpenny et al. 1995). It is important to recognize that variations in technique and bait cause variations in efficiency, cost, and interpretation of results (Fowler and Golightly 1994). One of the most common techniques in use today are variations on a baited smoked-track-plate with a white contact-paper to record positive images of tracks (Fowler and Golightly 1994).

The purposes for detecting fisher have varied. A very common use is to detect presence at a project site; for these purposes all of the techniques can provide a positive detection, but do not provide certainty for determination of absence (Fowler and Golightly 1994). Given an adequate amount of time, the probability of detecting fisher can be quite good (Seglund and Golightly 1997, Zielinski et al. 1997). However, given the large home range size and low density, a lack of detection should not be considered to be a certain absence at a site.

Another use of detection devices is to use them for sampling habitats used (Dark 1997, Klug 1997). It is very important to recognize that for this task, the devices are part of a sampling scheme and a lack of detection at a single site may not mean that the site is unused through all time. Conversely, the large scale pattern emerging from a large sample of detections can represent habitats used more often than others (see Dark 1997, Golightly et al. 1997b, and Klug 1997 for assumptions).

Detection devices are also used to attempt to monitor trend or distribution of fisher. It is not possible to estimate the population size from these techniques, and the relationships between the rates of detection and the response variable (eg: detection ratio, Fowler and Golightly 1994; latency to first detection, Zielinski 1995) have not been described. For this reason, Zielinski and Stauffer (1996) have used these devices to identify changes in distribution as a method of monitoring very large scale trends in the distribution of the species.

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American marten (*Martes americana*) ecology and conservation

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Description

The American marten (*Martes americana*) is a carnivorous mammal about the size of a small house cat. Its total length is between 500 and 680 mm and it weighs 500 - 1400 g as a adult, depending on sex and geography (Buskirk and McDonald 1989). The male is 20-40% larger than the female. Both sexes are furred with glossy hair of medium length, tan to chocolate in color, and have an irregular throat patch ranging from pale cream to bright amber. Its face is fox-like in shape, its torso is slender, and its legs and tail are intermediate in length and darkly furred (Strickland et al. 1982). Of the two subspecies that occur in California, the Humboldt marten (*M. a. humboldtensis*) is reported to be darker, of richer golden tone, to have less orange and yellow in the throat patch, a smaller skull, and smaller and less crowded premolars and molars than the Sierra subspecies (*M. a. sierra*) (Grinnell and Dixon 1926).

Taxonomy

This is one of seven species in the genus Martes, within Family Mustelidae, Order Carnivora (Corbet and Hill 1986). Along with the Eurasian pine marten (*M. martes*), the sable (*M. zibellina*), and the Japanese marten (*M. melampus*), it belongs to a group of closely related and ecologically similar species called the "boreal forest martens" (Buskirk 1992). The only other *Martes* in North America is the much larger-bodied fisher (*M. pennanti*). A number of subspecies have been named (Hagmeier 1958) and the two that occur in California (*M. a. humboldtensis* and *M. a. sierrae*) are recognized in the most recent reviews of marten taxonomy (Hall 1981, Clark et al. 1987).

Range

The American marten is broadly distributed. It extends from the spruce-fir forests of northern New Mexico to the northern limit of trees in arctic Alaska and Canada, and from the southern Sierra Nevada of California to Newfoundland Island (Hall 1981). In Canada and Alaska, its distribution is vast and continuous, but in the western contiguous United States, its distribution is peninsular and fragmented. In California, marten were historically distributed throughout the Sierra Nevada, the California Cascades, and the Coast Ranges from the Oregon border south to Sonoma County. Recent summaries of track plate and camera surveys (Kucera et al. 1995, Zielinski et al. 1977) report that marten continue to be distributed throughout the Sierra Nevada and Cascades but are absent from the historic range of the Humboldt subspecies in northwestern California.

Reproductive Biology

Most females first mate at 15 months of age and produce their first litters at 24 months (Strickland et al. 1982). Even yearling females, up to 78% in some studies (Thompson and Colgan 1987), can fail to produce ova. Females

<2 years also may not ovulate, with pregnancy rates as low as 50% in years of environmental stress (Thompson and Colgan 1987). Among 136 litters reviewed by Strickland and Douglas (1987), the mean size was 2.85, and the range 1-5. There is some evidence of age-dependent litter size, with a peak at about 6 years, and senescence at >12 years (Mead 1994). A maximum of one litter is produced per year.

DEMOGRAPHY

The age structure of wild populations depends heavily on whether the population is trapped, and most data come from trapped populations. Hodgman et al. (1977) found higher adult survival for males than for females, and considered winter to be the limiting season in terms of survival. They reported annual survival rates for adult (>lyr) males of 0.87 and for females of 0.53. Sex structure likewise is difficult to infer from trapping data, because of its inherent sampling biases. Males are more likely than females to be taken by trapping (Buskirk and Lindstedt 1989), so that trapped samples show a higher proportion of males than does the population. Powell (1994) predicted that even sex ratios would be the general case for untrapped populations, but the higher survival rates for males shown be Hodgman et al. (1997) seen to contradict that prediction.

HOME RANGE

Marten home ranges are large by mammalian standards. Averaging all study site means reviewed by Buskirk and McDonald (1989), home ranges of American martens are 3-4 times larger than predicted for a 1-kg terrestrial carnivoran, and about 30 times that predicted for a herbivorous mammal of that size. Home range size of martens has been shown to vary as a function of prey abundance ((Thompson and Colgan 1987) and habitat type (Soutiere 1979; Thompson and Colgan 1987). Soutiere found home range sizes about 63% larger in clearcut forests than in selectively cut and uncut forest in Maine. Thompson and Colgan reported even more striking differences from Ontario, with home ranges in clearcut areas 1.5 - 3.1 times the size of those in uncut areas.

In the Sierra Nevada of California, marten home ranges have been reported to vary from 1.7 - 7.33 km^2 for males and from 0.7 - 5.8 km^2 for females (Simon 1980; Spencer 1981; Marten 1987; Zielinski et al. 1997).

DISPERSAL

Reports of long-distance movements, likely representing dispersal, are largely anecdotal. Archibald and Jessup (1984) reported two periods of dispersal, one from about mid-July to mid-September, and the other over winter. However, the timing of dispersal has not been consistent among studies and occurs from early August through mid-winter (Slough 1989). Clark and Campbell (1976) reported a period of home range shifting during late winter and spring.

SURVIVORSHIP

Longevity statistics depend heavily on whether the population is captive, wild and trapped, or wild and untrapped (Strickland and Douglas 1987). Captive martens as old as 15 years and a marten 14.5 years of age from a trapped wild population have been reported (Strickland and Douglas 1987). However, these figures say little about the life expectancy of newborn martens in the wild. Hodgman et al. (1994) reported that over 90% of mortality in a trapped area was the result of trapping, and Hodgman et al. (1997) reported that in an untrapped population, annual survival rates for adult males averaged 0.87 (95% CI = 0.75 - 1.00), and for adult females 0.53 (95% CI = 0.34 - 0.83).

FOOD HABITS AND PREDATOR-PREY RELATIONSHIPS

Martens kill vertebrates smaller and larger than themselves, eat carrion, and forage for bird eggs, insects, and fruits (Martin 1994). They are especially fond of human foods but seldom are implicated in depredation on domestic animals or plants (Buskirk 1994). Martens forage by walking along the ground or snow surface, investigating possible feeding sites by sight and smell. In winter they forage on the snow surface, with forays up trees, or into subnivean space (Spencer and Zielinski 1983; Zielinski et al. 1983).

Diets in summer include a wide range of food types, including. mammals, birds and their eggs, fish, insects, and carrion. The importance of soft mast, especially the berries of *Vaccinium* and *Rubus,* peaks in autumn and declines over winter. As snow covers the ground and deepens, martens turn to mostly mammalian prey, which dominate the winter diet. The most important genera at this time are *Clethrionomys, Microtus, Spermophilus, Tamiasciurus,* and *Lepus* (Martin 1994).

Conservation Status

Neither the American marten nor any of its local populations are protected under the Endangered Species Act. In most state and provincial jurisdictions in western North America where it occurs, the American marten is managed as a furbearer. In six western state jurisdictions (California, Colorado, Nevada, New Mexico, South Dakota, and Utah) martens may not be legally taken in any area at any time.

California classifies the marten as a furbearer, but has had no open season since 1946 in the northwestern counties, and since 1954 throughout the rest of the state. The marten in considered a "Species of Special Concern" by the State of California and a "Sensitive" species by the U.S. Forest Service. The Humboldt subspecies has been absent from most recent surveys and incidental sightings have been uncommon over the last 50 years, causing some to suspect that it had become extirpated or occurred only at very low densities (Zielinski and Golightly 1996). However, tracks and a photograph of a marten were collected in 1996 at a station within the historic range limit of the Humboldt subspecies (W. Zielinski pers. obs.) causing renewed interest in actions to determine its distribution and to protect its habitat in northwestern California.

Habitat Requirements

American martens associate closely with forested habitats with complex physical structure near the ground. They also use areas near these habitats. Structure can be contributed by the lower branches of living trees, tree boles in various stages of life and death, coarse woody debris in various forms, middens of red squirrels, shrubs, and rock fields. Herbaceous vegetation generally cannot serve this function. Over the long term and over large areas, complex physical structure in forests is most commonly the ultimate product of ecological succession. However, in some areas and at some times, disturbance can increase structure near the ground over the short term. This can result from windthrow, disease, fire, and timber cutting that leaves coarse woody debris. Use of nonforested habitats by martens increases in summer and includes meadows and recent clearcuts near forest edges, as well as areas above the tree line in western mountains (Buskirk and Powell; Buskirk and Ruggiero 1994).

The habitat of martens in California has been described in the Cascades (Ellis, submitted) and in the Sierra Nevada (Spencer et al. 1983; Spencer 1987; Hargis and McCullough 1984; Zielinski et al. 1997). The habitat requirements of the Humboldt marten are unknown.

Survey Techniques

Martens are easy to attract to bait and commercial lure and are readily detected at track plates and camera stations (reviewed in Zielinski and Kucera 1994). Tracks and trails made in the snow by marten have distinctive mustelid traits (Halfpenny et al. 1994) but differences between those of marten and fisher have not been quantified so care must be exercised where the two species co-occur. The tracks and trails of marten and mink may also be confused, especially when found near water. Consideration should be given to new genetic techniques that can identify the species from its scat or hair (Foran et al. in press; Foran et al. in prep.)

Management Considerations

Response to human-caused disturbance and activities. Martens make little absolute or relative use of clearcuts for several decades and marten populations decline after clearcut logging. Soutiere (1979) showed that marten densities in clearcut areas in Maine were 0.4/km^2, about 1/3 those in uncut and partially cut stands. Thompson and Harestad (1994) summarized the results of 10 studies of habitat selection in relation to successional stage. These studies showed consistent use/availability ratios <1 in shrub, sapling, and pole stages. Only when succession reached "mature" stage did use/availability ratios begin to exceed 1, and only "overmature" stands were consistently preferred. None of the studies found use/availability ratios for "overmature" stands <1 (Thompson and Harestad 1994). The effect of timber management on the Humboldt marten is unknown, but should be similar to the effects described for other subspecies.

MITIGATIONS

Impacts of timber cutting on martens can be mitigated by leaving slash and by selective cutting. If clearcutting is used, clearcuts should be small. Habitat refugia, where no timber cutting is conducted, should be considered. These refugia should be linked by areas (corridors) of mature forest with dense canopy closure and abundant quantities of large woody debris on the ground.

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Wolverine (*Gulo gulo*)

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Description

The wolverine (*Gulo gulo*) is the largest terrestrial member of the family Mustelidae. It appears somewhat bear-like, although movements and other behaviors are characteristic of the weasels. The wolverine is powerfully built and adapted for winter survival. Its plantigrade locomotion facilitates travel through deep snow. Powerful dentition and associated musculature enable wolverines to forage on frozen meat and bone. Its skull is robust, and the head is broad and rounded with small eyes and short, rounded ears. Its legs are short, with five toes on each foot. Claws are curved and semi-retractile (Banci 1994). Males are typically 30-40% larger than females; males generally weigh 11 to 18 kg and females 6 to 12 kg (Banci 1994).

Wolverine pelage is typically a thick, glossy dark brown. A light, silvery facial mask is distinct in some individuals, as are pale buff stripes running laterally from the shoulders along the animal's sides and crossing the rump just above a long bushy tail. A white hair patch on the neck and chest is prominent in some individuals and virtually nonexistent in others. White hair on the digits, feet, and forelegs is common.

Taxonomy

Order Carnivora, Family Mustelidae. Some authors (Miller 1912, Anthony 1928, Ognev 1935, Miller and Kellogg 1955) place the wolverine into its own subfamily, Guloninae, while others (Stroganov 1969, Wilson and Reeder 1993) include it in the subfamily Mustelinae (Pasitschniak-Arts and Lariviere 1995).

The taxonomic relation of Old and New World wolverines has been debated for years. At present, most authorities consider *Gulo gulo* the only extant representative of the genus and separate the wolverine into two subspecies, the Old World *G. g. gulo* and New World *G. g. luscus* (Kurten and Rausch 1959, Krott 1960, Honacki et al. 1982, Wilson and Reeder 1993). Subspecific designation may also be warranted for the Vancouver Island wolverine (*G. g. vancouverensis)* based on differences in skull. size and shape from those on the British Columbia mainland (Banci 1982). Although ecotypic variation appears present, no further specific or subspecific separation has been proposed.

Fossil Record

The fossil history of the Mustelidae is not well documented because most members were small and forest-dwelling (Pasitschniak-Arts and Lariviere 1995). The earliest known mustelids were from late Eocene deposits, and a few marten-like animals were found in the Oligocene (Kurtén and Anderson 1980). Towards the end of the Miocene, recognizable martens were present. Quaternary mustelids survived in nearly all habitats from the arctic tundra, to tropical rainforests (Kurtén and Anderson 1980).

The largest of the Mustelinae, *Gulo*, is a holarctic genus specialized for feeding on larger vertebrate prey (Pasitschniak-Arts and Lariviere 1995). The wolverine has no exact counterpart in the tropics (Eisenberg 1981). *Gulo* is descended from Plesiogulo, a large Miocene and Pliocene form (Kurten and Anderson 1980). The genus *Plesiogulo* originated in Asia and migrated to North America between 7.0 and 6.5 million years ago (Harrison 1981). *Pleisiogulo* was apparently derived from marten-like ancestors originating from an early Miocene member of the genus *Martes* (Kurtén 1968).

Wolverines from the Old and New Worlds were formerly considered to be separate species (Cowan 1930, Miller 1912); however, Kurtén and Rausch (1959) found the two populations to be only subspecifically distinct. Bryant (1987) examined *Gulo gulo* from Pleistocene and concluded that any division of *Gulo* into two species was arbitrary. Studies of Quaternary remains indicate evolutionary progression within a single species, with differences among populations not enough to warrant separation into two species (Bryant 1987, Pasitschniak-Arts and Lariviere 1995).

DISTRIBUTION

The wolverine's distribution is circumpolar, corresponding with the boreal zone of the northern hemisphere (Pasitschniak-Arts and Lariviere 1995). It historically occurred throughout the holarctic taiga and forest tundra of higher latitudes and extended south to 37 degrees north in North America and 50 degrees north in Eurasia (Wilson and Reeder 1993). The wolverine's current distribution is much reduced, especially in the south.

The historical North American distribution of the wolverine included the northern part of the continent southward to the northernmost tier of the United States from Maine to Washington State. It extended south along the Sierra Cascade axis through Oregon into the southern Sierra Nevada in California and along the Rocky Mountains into Arizona and New Mexico (Grinnell et al. 1937, Hall 1981, Hash 1987). Records of the wolverine within the upper midwest apparently pre-date human settlement, with the animal absent most likely by the early 1900's (Banci 1994). The wolverine has been extirpated from the northern plains states east of Montana (Banci 1994).

In California, the historic range of the wolverine included much of the north coastal area and the Sierra Nevada (Grinnell et al. 1937, Schempf and White 1977). Schempf and White (1977:25) described the modern range to include a broad arc from Del Norte and Trinity counties eastward through Siskiyou and Shasta counties, and then southward through the Sierra Nevada to Tulare County. Subsequent reports have enlarged this range to include the White Mountains in eastern Mono County (Kovach 1981). Aside from these broad distributional data, largely based on early fur-trapping data and sporadic reports of unverified sightings, little is known specifically about wolverine occurrence or abundance, and nothing is known about wolverine ecology, in California (Kucera and Barrett 1993).

Wolverines likely occupied a wider variety of habitats during pre-settlement times than they currently do, as evidenced by their historical presence in upper mid-western states and fossil evidence in Great Basin habitats of southern Idaho (White et al. 1984). Human encroachment into historically occupied habitat may have forced the wolverine into its present distribution.

Present distribution of the wolverine in the western United States appears to constitute several peninsular extensions of Canadian populations (Hash 1987, Banci 1994). While reports of wolverine sightings persist in the Rocky Mountain states (Banci 1994), only Idaho and Montana report populations of known extent.

In Canada, wolverines are sparsely distributed in boreal forests, and inhabit the Arctic archipelago as far north as Ellesmere Island (Banfield 1987). Until the turn of the century, wolverines inhabited much of eastern Canada except for 'Prince Edward Island, Nova Scotia, Newfoundland, eastern New Brunswick, Gaspe Peninsula, and Anticosti Island (Peterson 1966, Banfield 1987). Presently, the wolverine is extremely rare in Quebec and Ontario, and there are no recent records from Labrador (Prescott 1983, van Zyll de Jong 1975). In Manitoba and Saskatchewan, numbers appear to have declined, the southern limits have receded to the north, and wolverines are now confined to the northern portions of the provinces (van Zyll de Jong 1975). In Alberta, the species once occurred in all coniferous forests of the province, but now is found only in remote areas in the north and in the Rocky Mountains of Alberta (Soper 1964, Pasitschniak-Arts and Lariviere 1995). Wolverines occur throughout mainland British Columbia, except for the southern agricultural areas, and throughout the Yukon Territory and mainland Northwest Territories, with an estimated 4,200 south of 66 degrees (Banci 1987). They occur continuously in mainland Alaska (LeReseche and Hinman 1973) but only on some of the southeastern islands (Banci 1994). Records from the Canadian arctic islands are spatially and temporally sporadic (Banci 1994).

In Eurasia, wolverines are found from Scandinavia eastward through eastern Europe, Siberia, and Asia (Ewer 1973, Makridin 1964, Stroganov 1969, Wilson and Reeder 1993, Pasitschniak-Arts and Larivi6re 1995). Records from Scandinavia show that wolverines occur in low population densities (Noway and Paradiso 1983). Most animals are concentrated in the mountain chain of northern Norway and Sweden, and along the south-central Norwegian mountains (Pasitschniak-Arts and Lariviere 1995). In Sweden, wolverines are restricted to remote areas in the northwest (Pasitschniak-Arts and Lariviere 1995). The numbers appear to be increasing; however, the distribution is irregular (Bjärvall 1982). In 1986, a maximum of 40 wolverines was recorded in Finland, and the species is now considered endangered (Pulliainen 1988). Wolverines are also found in the tundra and forest zones of eastern Europe, Russia, and northern Asia (Pasitschniak-Arts and Lariviere 1995). In western Siberia, wolverines are widely distributed in the tundra and taiga, and are relatively common in extreme eastern Russia (Stroganov 1969, Pasitschniak-Arts and Lariviere 1995).

Reproduction

The mating system of the wolverine appears to be polygamous (Rausch and Pearson 1972). Wolverines breed from May to August (Wright and Rausch 1955, Rausch and Pearson 1972), and are believed to be monestrous (Pasitschniak-Arts and Lariviere 1995). Recent studies of captive animals indicate that females generally come into estrus from June to early August (Mehrer 1976). Increased vaginal cornification occurs mid-June through early July and corresponds to the time when most matings occur in the wild (Mead et al. 1991).

Late-stage spermatids and spermatozoa are found in the testes as early as March (Mead et al. 1991). In adult captive wolverines, maximal size of testes and elevated testosterone levels were attained in early April and maintained through early July (Mead et al. 1991). Testicular regression began by late July and was complete by mid-August (Mead et al. 1991).

During the breeding season, males usually remain close to females, but females take the lead and initiate moves when pairs travel (Magoun 1985). Typically, males will mount females from behind, with forelegs clasping the female's sides. The scruff of the female's neck is often gasped, particularly if she attempts to move (Magoun and Valkenburg 1983). Ovulation is believed to be induced by coitus (Mead et al. 1993).

Wolverines exhibit delayed implantation. Fertilized eggs remain in the blastocyst stage until nidation, usually from November to March (Banci and Harestad 1988). Post-implantation following nidation of the blastocyst is about

30-50 days (Mead et al. 1993, Rausch and Pearson 1972).

Parturition occurs from January through April, with most females giving birth before late March (Pulliainen 1968). Litter size averages 2-3 kits. Young are born fully furred with eyes closed and teeth not erupted (Pasitschniak-Arts and Lariviere). At birth their fur is white, they weigh an average of 84 grams, and have a crown-rump length of 121 mm (Pasitschniak-Arts and Lariviere 1995). Young are weaned at 9-10 weeks and begin to travel with mothers by late-May. Adult size is often reached by early winter although young may remain associated with their mother, siblings, and the resident male until reproductive maturity (Copeland 1996). Female wolverines attain sexual maturity at about 15 months, but only 7% of 2-year-old females produced litters in a Yukon Territory study; males appear to reach sexual maturity at about 2 years of age (Banci 1987).

Limited data from Idaho suggest the male may participate in rearing of young (Copeland 1996). In Idaho wolverines, from parturition to physical maturation, the female was the primary associate of young, while from physical maturation until about 14 months of age, juveniles and subadults associated primarily with the resident male (Copeland 1996).

Denning

Fennoscandian studies provide the earliest data on winter denning habits of wolverine. Pulliainen (1968) presented the characteristics of 31 reproductive dens in Finland. Eighty-one percent of dens occurred on bare, rocky hillsides of mountain slopes near or above timberline, while 6 dens were located in lower elevation spruce and pine peat-bogs. Most of 28 dens in Norway were situated above timberline in deep snow near cliff areas (Myrberget 1968). The general structure of dens in both studies was the same; den entrances were located in soft snow near trees or rocks, with a vertical tunnel extending 1-5 meters to ground level. Lateral tunnels extended for up to 50 meters along the ground surface. In most cases, wolverine kits were found at ground level on bare soil.

Limited data are available on wolverine denning habits in North America. Rausch and Pearson (1972) described 3 dens in Alaska. Two were above timberline in snow-filled ravines; the third was in an abandoned beaver (*Castor canadensis*) house. Magoun (1985) provided data on the natal dens of 2 females in tundra habitat of northwest Alaska. She described entrance tunnels extending less than 2 meters beneath the snow surface accessing den systems of up to 50 m in length. The denning habitat used by 2 marked females and 1 unmarked female in Idaho (Copeland 1996) was specific to subalpine talus. Females selected den sites associated with large-boulder talus (individual rocks greater than .2 m diameter) in subalpine glacial cirques.

All authors agree that use of reproductive dens begins from early February to late March. In some cases, females may use multiple dens prior to weaning kits. Why dens become unsuitable is not well understood. Fennoscandian studies were based on data collected from wolverine hunters rather than radio-instrumented animals, so it was not always known if dens were birthing sites. Idaho wolverines abandoned natal dens as early as 10 March and moved kits through a series of maternal dens until . weaning at 9-10 weeks of age (Copeland 1996). Females in arctic Alaska remained at a single den until late April or early May and did not appear disturbed by the presence of humans (Magoun 1985). Magoun (1985) felt that den abandonment was probably forced by snow melt. Fennoscandian studies reported that den abandonment was a common response to human disturbance. Wolverine hunters in Finland emphasized that pursuit of a pregnant female may result in "exceptional" places as birthing sites (Pulliainen 1968). Myrberget (1968) mentioned 4 instances of den abandonment due to disturbance and suggested that secondary dens may be less suitable. Direct human contact occurred with 2 denning females in Idaho in late April and May and resulted in den abandonment in both cases (Copeland 1996). Ewer (1972) suggested that moves may occur in response to den parasites, or attempts by the female to deter predators from locating the den.

Mortality

In addition to human-caused mortality, starvation and predation appear to be primary causes of death in post-weaning age wolverines. Starvation was the suspected cause of death in 2 juvenile wolverines in Yukon (Banci 1987) and 2 in Montana (Hornocker and Hash 1981), although food resources were relatively abundant in both areas.

Predation as a cause of mortality may be exacerbated when wolverines scavenge kills in the presence of other carnivores. The role of more efficient carnivores as producers of carrion may be essential to survival in some areas, but the beneficiary may risk serious injury or death. Where they both coexist wolves (*Canis lupus*) and mountain lions (*Felis concolor*) may kill wolverines (Burkholder 1962, Boles 1977, Gill 1978, Hornocker and Hash 1981, Banci 1987, Copeland 1996).

The importance of predation on wolverine kits has not been documented (Banci 1994). Wolverine mothers go to great lengths to find secure dens for their young, suggesting that predation may be important (Banci 1994).

Density

Wolverine densities are low relative to carnivores of similar size, although they can range from 40 km^2 to 800 km^2 per wolverine (Banci 1994). Magoun (1985) in arctic Alaska and Copeland (1996) in Idaho calculated density based on reproductive potential and home-range size as 1 wolverine/48-139 km^2, and 1 wolverine/90-113 km^2, respectively. Hornocker and Hash (1981) and Quick (1953) reported density estimates of 1 wolverine/ 65 km^2 in northwest Montana and 1 wolverine/207 km^2 in British Columbia, respectively, based on capture and snow tracking data. Based on capture data, Banci (1987) estimated Yukon wolverine densities at 1/177 km^2.

Spatial Use

Home-Range Size

Six studies provide data on wolverine home ranges from radio-instrumented animals (Hornocker and Hash 1981, Gardner 1985, Magoun 1985, Whitman et al. 1986, Banci 1987, Copeland 1996). These researchers focused primarily on home-range size, stratified by sex and season. These studies also addressed home-range overlap to investigate a postulated spacing pattern of intrasexual exclusion.

Hatler (1989) noted several commonalties of reported spatial use by wolverine. Males have larger home ranges than females, females without kits have larger home ranges than accompanied females, and home range-use appears to vary with season.

In Alaska, researchers reported mean annual home-range size for male wolverines as 535 km^2 (Whitman et al. 1986), 637 km^2 (Gardner 1985) and 666 km^2 (Magoun 1985). In Montana and Yukon, male home ranges were 422 km^2 (Hornocker and Hash 1981) and 382 km^2 (Banci 1987), respectively. In Idaho, wolverines had the largest home ranges, with resident male home ranges averaging 1,522 km^2 (Copeland 1996). Female home ranges varied from 104 km^2 in Alaska (Magoun 1985) to 388 km^2 in Montana (Hornocker and Hash 1981), with 1 Montana female using a 936 km^2 home range.

Home-range size is generally presumed to be inversely correlated with the availability of resources, following the assumptions that food controls female dispersion and that the spacing of males is tied to the distribution of females (reviewed in Gittleman and Harvey 1982, Macdonald 1983, Sandell 1989). Food availability was not measured in any of the North American wolverine study areas, and the relation between resource dispersion and home-range size in wolverines is unclear. Hornocker and Hash (1981) believed that abundant and consistent ungulate prey explained the relatively high estimates of wolverine density in their study area. In Idaho, ungulates appeared to provide adequate food for wolverines, defense of feeding sites was not apparent, and sharing of resources was common within kin groups (Copeland 1996).

Gardner (1985) suggested that home-range size may be related to habitat and topography as well as food availability, and Krott (1959) believed that the availability of suitable denning habitat may influence the size of wolverine territories. Idaho wolverines appeared highly selective in choice of natal denning and kit rearing habitat (Copeland 1996).

Although studies in Alaska and Canada suggested early dispersal of offspring and limited social interaction, subadult wolverines in Idaho remained associated with their natal area until sexual maturity in their second year. Resident adults tolerated the presence of, and shared resources with subadults (Copeland 1996). The large home ranges of wolverines in Idaho may reflect the resource requirements of offspring with extended dependency in addition to the energetic requirements of the parent (Copeland 1996).

Home Range Size Related to Reproductive Activity

Female wolverine accompanied by kits may display reduced home range size. Banci (1987) measured home ranges of 5 accompanied and 5 unaccompanied females and found home ranges of females with young 50% smaller than those of unaccompanied females. A single Idaho female wolverine absent of kits in 1 year displayed a March through August home range nearly 2 times the size of home ranges within the same period in the next 2 successive years when accompanied by kits (Copeland 1996).

Home Range Overlap

Intersexual overlap of home ranges is one of the few common aspects of wolverine spatial patterns reported in wolverine studies; the amounts of intrasexual overlap vary considerably. Magoun (1985) and Copeland (1996) found that most resident female home ranges were maintained exclusively of other females, with spatial separation most prominent during summer months. The other Alaska study (Gardner 1985) found home-range overlap only with a single adult and subadult male. Hornocker and Hash (1981) found no evidence of exclusive home ranges and suggested that harvest may have created social instability in the population and allowed inadequate time for establishment of site tenure. Hornocker and Hash (1981) and Banci (1987) concluded that a lack of understanding of familial relationships in their wolverine populations made assessment of spatial relationships difficult.

Within the home range of a resident male in Idaho, resident juvenile wolverines remained closely associated to their mother's home range until separation in mid- to late August of their first year. As subadults, they overlapped the home ranges of the resident male and their mother and siblings. In 2 cases subadults were found associating with a neighboring adult female and a neighboring adult male. In both instances, the adults were related to the subadults (Copeland 1996). Association at this early stage of development may suggest a familiarity between the mated wolverine pairs beyond that generally expected within a polygynous species. The dominance status of the resident male may provide him with a priority of access to resident females resulting from established pair bonding, or as Eisenberg (1981:411) suggests, some female choice may be involved. A requirement of familiarity for mate pairing might lessen the need for the resident male to defend access to females. Given the extremely large home ranges used by male wolverines in Idaho, such a mating strategy is more plausible than one based on resource defense or spatial separation of males through scent marking. Any reduction in mating opportunity may be offset by increased kit survival resulting from male parental investment.

Food Habits

Ewer (1973) described the wolverine as a polyphagous mustelid. Wolverines would probably not persist in the absence of ungulate populations, and evidence suggests at least a seasonal reliance on local rodent abundance (Magoun 1985, Gardner 1985, Banci 1987). The wolverine is capable of taking large ungulates as live prey (Myrberget 1968, Pulliainen 1968, Magoun 1985) but ungulate presence in the wolverine diet most likely results from scavenging (Hornocker and Hash 1981, Magoun 1985, Gardner 1985, Banci 1987, Copeland 1996). Ungulate use by wolverines at higher latitudes was more prevalent during months associated with migrating caribou (*Rangifer tarandus*) or local moose (*Alces alces*) populations (Magoun 1985, Gardner 1985). Alaska ground squirrels (*Spermophilus parryi*) were most prevalent in late winter and spring diets in arctic Alaska (Magoun 1985) and southcentral Alaska (Gardner 1985), and in Yukon, snowshoe hare (*Lepus americanus*) contributed the highest proportion of any species to the wolverine's diet (Banci 1987). Vegetation reported in the diet of wolverines may be consumed incidentally with rather than in lieu of prey (Banci 1987).

HABITAT USE

Hornocker and Hash (1981) found 70% of wolverine use in medium to scattered timber. Idaho research reported similar results, with montane coniferous forest types accounting for 70.2% of wolverine use (Copeland 1996). In Southcentral Alaska, wolverines preferred spruce (Picea sp.) during winter and rocky areas during summer (Gardner 1985). Results from Idaho were consistent, with wolverines preferring coniferous forest during winter months and talus during summer (Copeland 1996). Male wolverines in Yukon preferred coniferous habitats in winter and avoided alpine talus in summer (Banci 1987). Whitman et al. (1986) found that forest types were avoided by wolverines during summer in south-central Alaska.

Preference for higher-elevation habitats during summer may be related to the availability of prey (Gardner 1985, Whitman et al. 1986) or avoidance of humans (Hornocker. and Hash 1981), and lower-elevation forest types commonly associated with wild ungulates likely provide the greatest carrion during winter (Copeland 1996). Banci (1985) felt that low rodent availability in subalpine habitats in Yukon may have accounted for avoidance of these areas by male wolverines.

In Montana, wolverines were reluctant to cross openings such as clearcuts or burned areas (Hornocker and Hash 1981). However, in Idaho, wolverines commonly crossed natural openings and areas with sparse overstory such as burned areas, meadows, or open mountain-tops (Copeland 1996). Eight Idaho wolverines were located in burned areas at least once.

Extirpation of the wolverine through the eastern provinces of Canada and the midwestern U.S. most likely coincided with westward spread of European settlement (Banci 1994). Throughout its North American range, the wolverine occupies a wide variety of habitats, although the character of wolverine habitat most readily apparent is its isolation from the presence and influence of humans. Habitats used by the wolverine, such as vegetative communities that support prey and landscape features suitable for denning may be as useful for their isolation as for their other attributes.

Hatler (1989) commented that no particular habitat components can presently be specified for wolverines, and that reduction of wilderness "refugia" through access and alienation for timber and mineral extraction may be the greatest threat to local population viability. The wolverine has persisted in southwestern Alberta despite extirpation elsewhere in the province largely because of the presence of large refugia in the form of national parks (Banci 1994).

The discovery of fossil wolverine remains in habitats very much unlike the boreal communities presently used by wolverine, such as the cold desert environments of southern Idaho (White et al. 1984), may characterize the species' adaptability. Overharvest and displacement by humans may have forced the wolverine out of lowland habitats now altered by agriculture and urban development, and into the more isolated tracts of its current distribution. The absence of wolverines from their historical ranges may be related to human activity as much as from reductions in habitat. As transient wolverines, usually young dispersers, attempt to colonize or travel through areas of human habitation, their probability of survival may be low.

MANAGEMENT CONSIDERATIONS

In the United States, wolverines may be harvested only in Alaska and Montana. Outside of these areas a lack of basic information on wolverine distribution and habitat requirements has resulted in little management beyond administrative protection. Hatler (1989) suggested that appropriately responsive management will require a better knowledge of the nature, extent, and correlates of wolverine occurrence. Zielinski and Kucera (1995) argued that distributional surveys are essential to the generation of habitat-relations models and to the evaluation of land-use changes and effects of human density and disturbance. Surveys should focus on determining occurrence and may include snow tracking or remote-camera surveys (Zielinski and Kucera 1995). Aerial surveys of potential denning habitat in winter may provide an alternative to ground methods.

Protection of natal denning habitat from human disturbance may be critical for the persistence of wolverine. The clear association between wolverine presence and refugia may be strongly linked to a lack of available natal denning habitat outside protected areas. Idaho wolverines selected specific natal and kit rearing habitat and responded negatively to human disturbance near these sites. Technological advances in over-snow vehicles and increased interest in winter recreation have likely displaced wolverines from potential denning habitat and will continue to threaten what may be a limited resource.

Vegetative characteristics of the habitat appear less important to wolverines than physiographic structure. Montane coniferous forests suitable for winter foraging and summer kit-rearing may only be useful if connected to secluded glacial cirques required for natal denning, security areas, and summer foraging. In addition, these habitats must be available during proper season. Subalpine cirques important for natal denning may be made unavailable by human recreational activities in winter. Conversely, high road densities, timber sales, or housing developments on the fringes of subalpine habitats may reduce potential for winter foraging and kit rearing and increase the probability of human-caused wolverine mortality.

Management practices that reduce carrion may affect wolverine foraging success. A close relation exists between wolverine and ungulate presence. Ungulate carrion is a primary food item, and activities that decrease large mammal populations may negatively affect carrion availability. Excessive hunter harvesting and loss of ungulate wintering areas (Banci 1994) as well as displacement of ungulate populations due to excessive timber harvest and urbanization may adversely affect wolverines. Wounding mortality of ungulates from hunting and livestock losses on public grazing allotments may provide consistent carrion.

Refugia may be most important for providing reproductive denning habitat. Life history requirements of the wolverine are tied to the presence and stability of ecosystems lacking broad-scale human influence. Dispersing wolverines in Idaho traveled more than 200 km across isolated subalpine habitat. Habitat alteration may isolate subpopulations and increase their susceptibility to extinction.

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Aquatic Mustelids: Mink and River Otter

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DESCRIPTION

The mink (*Mustela vison*) and river otter (*Lutra canadensis*) are two closely related species adapted for life in and around water. Although both species are associated with aquatic habitat, the river otter is more adapted to life in the water. The long, streamlined body has a muscular, dorso-ventrally flattened flexible tail that is wide at the base and tapers towards the tip. The short, powerful hind legs, which provide the main propulsion in water, are equipped with large, fully-webbed feet; the front feet are only partially webbed. While the mink's body shape is similar to that of the otter, its toes have little webbing and it does not possess a flattened tail or other adaptations for foraging in the water.

Similar to other mustelids, mink and otter exhibit sexual size dimorphism with male mink being 40-80% larger than females, and male otters approximately 16-20% larger than females (see Eagle and Whitman 1987 and Melquist and Dronkert 1987 for detailed species accounts on mink and otter, respectively). Body size varies widely among individuals throughout each species' range. Adult mink range in size from 1.5-4.5 pounds (0.7-2 kg), while adult otter weigh 11-33 pounds (5-15 kg), a ratio of 1:10. Total length in mink ranges from 19-28 inches (49-72 cm), with otters ranging from 35-54 inches (90-139 cm).

The river otter's pelt consists of short, dense, soft underfur protected by longer, stiff, glossy guard hairs. When submerged, air trapped within the fur acts as insulation. Frequent grooming is important in retaining the insulative and waterproofing quality of the fur. Pelts range from dark brown or nearly black to a pale chestnut on the back, contrasted with a lighter brown on the belly. Mink pelts are soft and lustrous, with thick brown underfur and long glossy guard hairs, the only distinct aquatic adaptation. Color varies from dark brown to almost black, with the belly being somewhat lighter and the tail gradually blending from the brown body at the base to almost black at the tip. Unlike the otter, mink have individually unique white patterns on the chin, chest, and abdomen. For each species, both sexes and all ages are similar in color, with no seasonal variation.

TAXONOMY

Mink and river otters are the most aquatic members of the Family Mustelidae. The mink's body shape is typical of the subfamily Mustelinae. The otters make up the subfamily Lutrinae, which appears to be somewhat distinct from the other mustelids (Davis 1978). Escaping ranch mink and otter restoration projects involving the release of animals have diluted gene pools and effectively confounded the issue of subspecies.

DISTRIBUTION

Mink are distributed throughout most of North America (Fig. 1). Mink inhabit all of Canada

[1] Adapted from Melquist, W.E., J.S. Whitman and M.G. Hornocker. 1981. Resource partitioning and coexistence of sympatric mink and river otter populations. Pages 187-220 *in* J. Chapman and D. Pursley, eds. Proc. Worldwide Furbearer Conf. Vol. I. Frostburg, MD.

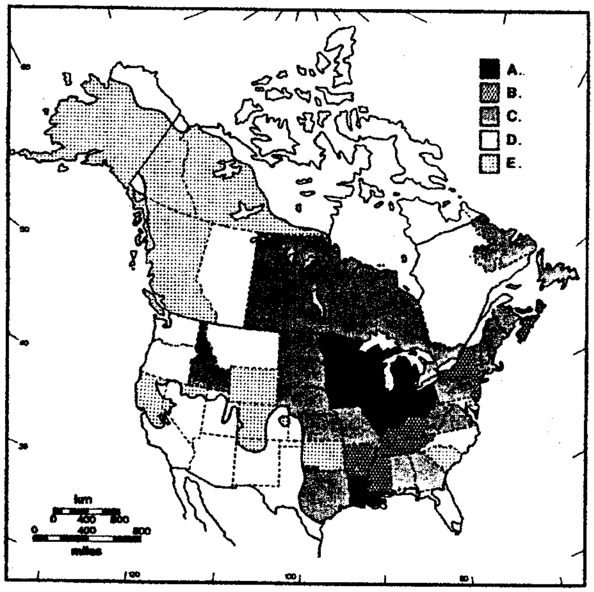

Fig. 1. Distribution and harvest density at the mink (*Mustela vison*) in Canada and the United States for the 1983-84 trapping and hunting seasons (based on a survey by M. Novak and A. J. Satterthwaite, Ont. Minist. Nat. Resour.). *Legend:* (A) 2.1-10 km^2/animal harvested (area = 992,0110 km^2): (B) 11-20 km^2/animal (659.000 km^2); (C) 21-100 km^2/animal (4,512,000 km^2); (D) 101-200 km^2/animal (2.965.000 km^2); (E) ≥201 km^2/animal (4,778,000 km^2). Total current Canadian and U.S. range is 13,906,000 km^2. (2.59 km^2 = 1 $mile^2$)

south of the treeline, except for Anticosti Island and the Queen Charlotte Islands (Linscombe et al. 1982). Insular populations have been established in several areas from escaped ranch mink and they have been introduced into Newfoundland (Banfield 1974).

River otters range widely in aquatic habitats throughout North America, using lakes, streams, freshwater and saltwater marshes, and rugged coastal areas. The species originally ranged from 25 degrees to 70 degrees N latitude and from 53 degrees to 166 degrees W longitude (Hall 1981), and could be found in most major drainages and wetlands north of the Rio Grande and Colorado river basins (Fig. 2). Since the 1800's, human encroachment, destruction of habitat, and over harvest eliminated otters from portions of their range, especially areas of marginal habitat. Increased conservation efforts, including reintroductions, have restored otters throughout a large portion of their historical range (Fig. 3).

Habitat Requirements

As their broad geographic distribution suggests, the mink and river otter are able to adapt to diverse aquatic habitats. Densities appear greatest in the least disturbed food-rich coastal regions, including estuaries, the lower portions of streams, and coastal marshes, and inland where lowland marshes and swamps interconnect with meandering streams and small lakes. Both mink and otter may be common in the tributaries of major unpolluted drainages with minimal human impact, but scarce in highly disturbed and polluted areas. Severe winter conditions probably limit densities in northern inland populations. The availability of certain key components (shelter, food, water) determine the duration and intensity of habitat use. In temperate regions of North America, otters may be forced to vacate high elevation streams and lakes during winter and move down into the valleys as the waters freeze and snow accumulates.

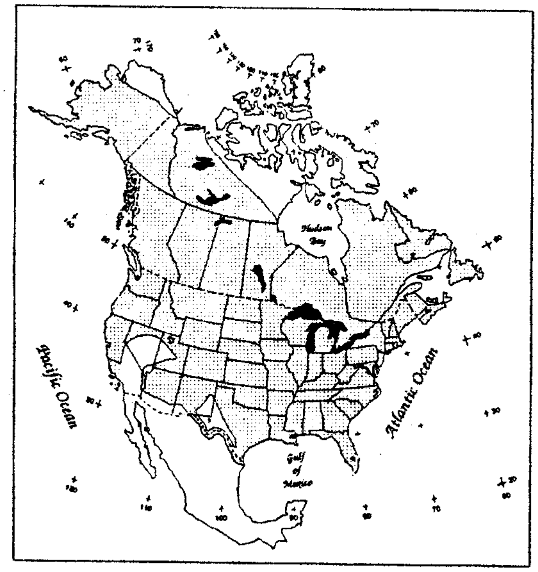

Figure 2. Original distribution of the North American river otter in the United States and Canada (from Hall 1981 and Polcchis 1988).

Riparian vegetation adjacent to lakes, streams, and other wetland areas is a key component of mink and otter habitat. Fallen or partly submerged trees, logjams created during spring runoff, and rock rip-rap provide shelter and foraging areas for both mustelids and their prey. Cavities among tree roots, dense shrubs, and tall grass provide escape cover and temporary resting sites. Beavers attracted to these areas create ponds, bank dens, and lodges that are later used by mink and otter. Melquist and Hornocker (1983) documented the importance of beavers in creating foraging and denning sites for otters, and several States have correlated good river otter habitat with the activities of beavers. In a similar manner, muskrats are important to mink, not only for food, but in creating bank burrows and lodges used by the mink.

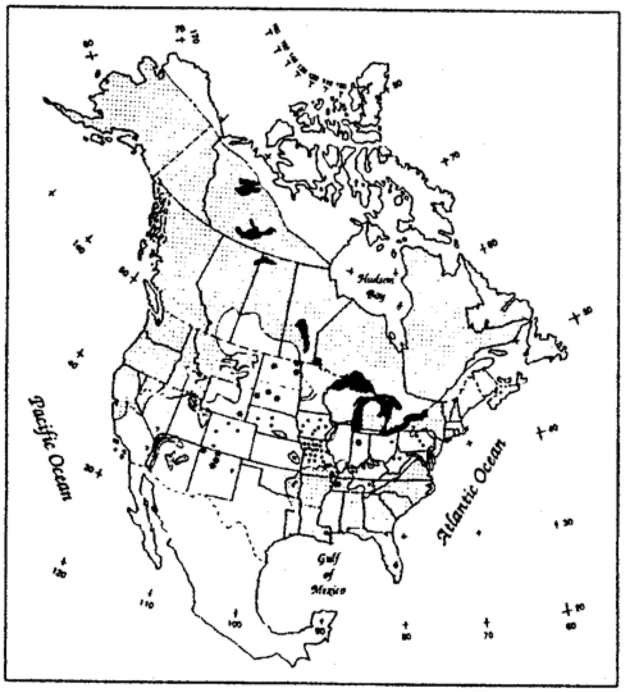

Figure 3. Distribution of the North American river otter in the United States and Canada, circa 1988. Stars represent locations of accidental deaths or reliable, recently reported sightings. Dots represent sites of reintroductions or restocking. Question marks represent locations of unverified sightings.

REPRODUCTIVE BIOLOGY

Breeding Season

Mink are generally solitary, unsociable animals, with males and females associating only for brief periods during the breeding season. River otters are much more sociable during the nonbreeding season, although males are rarely part of the family group. Similar to mink, adult male and female otters associate only briefly during the breeding season. Both mink and otter breed from late February to early April in temperate areas; earlier in more tropical environments and later farther to the north. The cue stimulating breeding in both species is an increase in daylight during spring. Mating in mink is often more violent than in otter. Otters normally copulate while in the water.

Reproduction

Female mink produce their first litters at 1 year old and reproduce once a year thereafter. Sexual maturity in river otters is generally not reached until 2 years of age, although males may not successfully breed for 2 or more years after that. As do many furbearers in the mustelid family, mink and otter have a mode of reproduction known as delayed implantation. Females breed shortly after giving birth in the spring, but the fertilized eggs do not implant into the uterus immediately. Implantation occurs sometime during fall; the exact timing depends on the health of the female. Active pregnancy in mink is approximately 28-30 days and 55-60 days in otter.

Young mink are born between April and July. Litter sizes at birth range from 1 to 8 young, with an average of 4 or 5 per female. Young mink remain with their mother until early fall, when the family separates as the young disperse.

Young otter are generally born in March or April. Prior to giving birth, the female normally retreats to a small tributary stream, pond, or lake with adequate food, shelter, and seclusion. River otters do not excavate their own dens, using instead abandoned beaver (*Castor fiber*) lodges and bank dens, the burrows of other animals, or natural shelters in close proximity to water. Litter size is generally 2 or 3. Blind, toothless, and helpless at birth, the pups grow rapidly and venture outside the den at about 2 months of age. The family group (female and her young) remains in the natal area at least until the pups are about 3 months old. There is no evidence that adult male otters participate in rearing the young. Otter pups are weaned at about 4 months of age. Young otters are able to survive on their own by the age of 6 months, but the family generally remains together for at least 7-8 months or until just prior to the birth of a new litter. Siblings may remain together until the age of 12-13 months, when dispersal occurs.

DEMOGRAPHY

Home Range

The home range of a mink or otter includes the area in which it lives, reproduces, and generally satisfies its life requirements. The size and shape of the home range is dependent on the abundance and distribution of food, the quality and quantity of habitat, and drainage patterns (Melquist and Hornocker 1983, Melquist et al. 1981). In mountainous areas it may be long, narrow, or branched, and in coastal areas it may be a narrow strip along the shoreline or may vary with the distribution of offshore islands and freshwater streams. In coastal marshes or inland areas with little relief and few interspersed lakes, streams, marshes, and swamps, home ranges may resemble a polygon. For both mink and otter, male home ranges are larger than the females.

In good quality habitat, mink densities may be high and movement restricted. Adult males generally occupy about 1.5-3.5 miles (2.5-5.5 km) of shoreline; adult females 0.3-1.9 miles (0.5-3 km) (Eagle and Whitman 1987). Areal measurements of home range size for females range from 20-50 acres (8-20 ha).

River otter home ranges vary considerably between the sexes and among the different age classes. Adult males have the largest home ranges, especially during the spring breeding season. Lactating females have the most restricted home ranges during spring. All portions of the home range are not equally used. Utters are attracted to specific sites where abundant food and ideal shelter exist. These "activity centers" often determine seasonal home range limits by virtue of where they are located. Otters will spend an inordinate amount of time at these activity centers. Home ranges may be large in areas where activity centers are widely dispersed (e.g., mountainous areas and stream habitat) and smaller in regions of low relief (inland and coastal) where food and shelter are more evenly distributed.

In the mountainous West, river otter home ranges vary in length from 5-92 miles (8-148 km) of waterway during the year (Mack et al. 1994, Melquist and Hornocker 1983). In rich coastal environments, home ranges may be as small as 0.6 miles (1 km) of shoreline (Woolington 1984). Aerial home range size in a Texas coastal marsh ranged from 455-1,139 acres (184-461 ha) (Foy 1984). Mack et al. (1994) suggest that otters in lacustrine habitats (e.g., coastal marshes and inland areas with numerous lakes) tend to move shorter daily distances within smaller home ranges.

Spacing

Mink tend to exhibit intrasexual territoriality (Powell 1979). However, the range of a single male may encompass the range of more than 1 female (Eagle and Whitnian 1987). Normal spacing may temporarily break down where an abundance of food is concentrated in a small area (e.g., fish spawning runs) (Melquist et al. 1981).

Spacing in river otter appears to be more variable than in mink. Intra- and intersexual home range overlap may be extensive, where potential confrontations appear to be resolved through mutual avoidance. Considerable mixing of sex and age groups have been reported in several studies (Mack et al. 1994, Melquist and Dronkert 1987). Based on available literature, gross habitat configuration (lakes and marshes in flatter country versus streams in more rugged topography) influences spacing patterns (Mack et al. 1994). Otters appear more prone to exhibit territoriality in the lacustrine habitat, while otters inhabiting primarily linear riverine habitats tend to have home ranges with extensive overlap and little territorial behavior. River otters along the Alaskan coast appeared more territorial (Larsen 1983, Woolington 1984), while those along the northern California coast were highly social, occurring in large groups (Shannon 1989).

Dispersal

The largest movements in both mink and otter populations involve the dispersal of young. Timing of family break-up and dispersal is variable. In mink, it may begin as early as July or as late as September. Larger males usually leave natal areas earlier than smaller mink.

Some small females may even delay dispersal until spring while others fail to disperse at all.

Break-up of river otter family groups may occur from October to March in temperate areas. Siblings may remain together until they disperse at approximately 1 year of age. In Idaho, a dispersing female otter moved extensively outside its mother's home range only to eventually establish in an adjoining, but overlapping area. Most young otter appear to disperse well outside the female's home range, however. Some of these movements take the animal over mountain ranges into different drainages, and involve exploratory trips into lakes and streams prior to settling on an area by summer.

Survival

In captivity, mink may breed annually for 7 or more years. In the wild, a mink's lifespan does not likely exceed 6 years, and they may only live an average of 3 or 4 years. The extent of natural predation is unknown. They do not appear to suffer significant mortality from predators other than humans. Mink do occasionally fall prey to large raptors and mid-sized carnivores. While populations have the potential to double each year, high annual natural mortality in some areas may result in a complete turnover of the population every 3 years. Environmental contaminants from chemical spills and factory discharge and waste material can also affect survival, with mink being extremely sensitive to polychlorinated biphenyls (PCB's).

Almost without exception, the status of otter populations is dependent on the activities of humans. Roads and railroad tracks that parallel or cross streams are probably responsible for a considerable number of otter deaths each year. Otters are often caught in traps set for beaver (*Castor fiber*), and they are occasionally shot by fishermen and waterfowl hunters. Otters frequent fish hatcheries and can become a nuisance, requiring removal. Otters have few natural enemies, but are occasionally killed by larger predators. Death due to natural causes (not human related) is difficult to assess, often going unnoticed because they often occur in remote areas. Otters in captivity have been know to live up to 25 years. However, in the wild a 15-year-old otter would be considered old.

Food and Foraging

Foraging Behavior

Mink and otter differ in their foraging behavior. Otters always forage from the water for aquatic and semi-aquatic prey. Any terrestrial prey consumed is either scavenged or caught when the animal inadvertently falls into the water. Mink, on the contrary, often forage among the riparian vegetation or investigate overhanging banks, holes, and crevices while traveling along the shore. When foraging for aquatic prey, a mink often peers from the shore or a floating log into the water for potential food. Once prey is detected, the mink will quickly dive into the water after it. Logjams in streams are excellent foraging areas for both mink and otter because they provide shelter for fish, security for the predators, and a structure from which mink can forage. In coastal areas, mink forage primarily in the intertidal zone.

Food

Mink are generalists, eating anything they can find, kill, or steal. They are not choosy in their feeding habits, preying on locally available food sources. Mammals, primarily small rodents and muskrats (*Ondatra zibethicus*) are clearly the most important class of prey for mink during most seasons (Eagle and Whitman 1987). However, depending on the area and prey availability, fish are also an important class of prey. Birds, amphibians, and invertebrates may be seasonally important. On the coast, shellfish (mainly crabs) are the most important food for mink and small fish are of secondary importance.

Otters are specialists, based on their fish-eating habits. In virtually all studies, fish dominate in the otter's diet. Otters do consume a variety of other aquatic prey, including crustaceans, reptiles, amphibians, birds, insects, and mammals. Nevertheless, these groups tend to supplement their fish diet and are only seasonally important. In coastal habitats and inland streams where they occur, shellfish (crabs and crayfish) are an important food of otters. Catchability is a key factor in the prey consumed; slow-swimming fish and any prey unable to escape detection will be selected first.

SURVEY TECHNIQUES

Because of their secretive nature, actual counts of mink and otter cannot be used as a survey technique. Distribution can be determined from sign surveys, but densities do not appear to correlate with the amount of sign observed. Changes in the amount of sign observed may be the result of variations in detectability, habitat, and the animal's behavior. Establishing scent stations for river otters is time-consuming and result in only limited success. Sex, season, habituation, and the animal's natural wariness influence response rate.

Most researchers recommend that techniques be combined, such as combining sign surveys with trapper reports or monitoring scent stations annually in the same area over the same period to obtain an index of distribution. Melquist and Hornocker (1979) used a combination of capture and telemetry data, visual observations of marked and unmarked animals, and the presence of sign to obtain population estimates. They concluded that there is no simple method for censusing river otters, although distribution and the presence of otters (and mink) in an area can easily be determined by searching for tracks, scats, and other sign. Where a network of roads intercept streams, road-bridge surveys can be a rapid and cost-efficient means of collecting distribution data for both mink and otter.

CONSERVATION STATUS AND MANAGEMENT

Conservation Status

The general status of mink appears to be secure. Mink are generally considered abundant throughout their range, which has not changed significantly in recent years. All Canadian provinces and territories and 47 American states allow at least limited harvest of mink. However, few provinces and states conduct population inventories. Given the relatively secure status of mink populations throughout their range (determined from trends indicated by fur harvest), no extensive effort to study population densities is likely to occur (Eagle and Whitman 1987).

While factors responsible for the decline of otter populations throughout North America vary considerably, habitat loss has probably contributed the most. Overharvest may have been important in reducing or eliminating otters from many areas. Recent conservation efforts have restored otters throughout a large portion of their historical range where suitable habitat remained intact. Reintroduction and augmentation programs in at least 17 sites in North America (Polechla 1990, Ralls 1990) have contributed greatly to this restoration effort. A major reintroduction effort in Missouri during the 1980's was so successful that it resulted in their first legal trapping season in decades, with more than 1,200 otters harvested in 1996-97 (Conley, pers. comm.). Today, properly controlled harvests and closed seasons have reversed the trend and allowed otter populations to slowly recover in areas where they were greatly reduced. Provided we continue to afford them with proper protection and management, these aquatic mustelids will continue to be a part of our landscape.

Management

Management options vary between mink and river otter, but may include habitat protection and enhancement, reintroductions and population augmentation, monitoring programs, and harvest regulations. These options are charted and discussed by Melquist and Dronkert (1987) for river otter, but they also apply to mink management. Nevertheless, there are some management differences between the species. Mink have much higher productivity and can withstand much greater harvest pressure than can otters. Consequently, reintroductions and population augmentation are probably not necessary tools for mink restoration and management. Because of their secretive nature, field monitoring of mink and otter is extremely difficult and unreliable, and the value of harvest data is questionable. However, a common factor to both mink and river otter is that the key to healthy populations is good, nonpolluted habitat.

Environmental legislation that controls industrial development and pollution and that is directed mainly at the protection of fish and wildlife habitat, also will protect habitat critical to the mink and otter. Riparian habitat enhancement, protection, and preservation is good business because it is so important to water quality and retention and benefits a tremendous variety of wildlife.

COEXISTENCE OF MINK AND OTTER

Niche overlap is evident in the feeding habits, habitat use, and activity patterns of mink and river otter. The degree of overlap is minimized by different foraging strategies, variability in prey selection and activity patterns, and differential habitat use enhanced by habitat diversity. Obvious differences in body size (otters weigh 8-10 times more than mink) and morphological adaptations are primarily responsible for these differences. Dissimilar body size allows coexistence between related species through resource partitioning. Intraspecific differences in body size helps to minimize competition between the sexes. Morphological variations are evolutionary adaptations that increase a species' ability to compete. Morphological differences between mink and otter provide each species with a competitive advantage. The otter is a more efficient competitor in an aquatic environment; the mink in a terrestrial environment. Consequently, these species are able to coexist.

The following is a synthesis of the important factors which permit coexistence between mink and river otter:

1. Where considerable overlap in prey (primarily fish) consumption occurs, competition is minimized by either prey abundance or the ability of each predator to exploit alternate prey.
2. Differential foraging strategies reduces the likelihood of interspecific interactions.
3. Depletion of available prey (fish) can be avoided because otters tend to move from one foraging site to another and will not stay in an area when food supplies diminish.
4. Fish can be exploited to a greater extent by both mink and otter where they coexist because the resource (fish) is partitioned in general accordance with the predator's body size (i.e., mink preyed on smaller fish, while otter selected larger fish as well).
5. Overlap in feeding habits is reduced because morphological differences permit mink to exploit both aquatic and terrestrial prey, while otter exploit a wider variety and size of fish.
6. Different foraging strategies allow mink and otter to forage at the same time, yet avoid possible aggressive interactions.
7. External factors, such as prey activity and availability, are probably responsible for differences in activity patterns, rather than competitive interference.
8. Morphological differences promote habitat segregation, confining otters primarily to aquatic habitats, while mink exploit both aquatic and terrestrial habitats.
9. Size differences allow simultaneous use of certain habitats because mink can forage and den in portions of the habitat that are inaccessible to otter.

SUMMARY

The conservation of animals considered important to man depends increasingly on our ability to intelligently manage and preserve existing populations. The economic and esthetic values of mink and otter make them important to both consumptive and nonconsumptive users. Proper management involves more than just considering the requirements of each species as separate entities, it requires an understanding of the interrelationship of mink and otter to each other and to other components of the environment.

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Coyote (*Canis latrans*): Ecology, Conservation, and Management

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Description and Taxonomy

The coyote (*Canis latrans*) is a wide-spread member of the family canidae and is found in most landscapes in North America. In visual sightings, it is often confused with wolves (*Canis lupus*) or large domestic dogs. The coyote is the oldest taxon of the genus *Canis* still living in North America (Nowak 1978). As many as 19 subspecies of coyotes have been recognized (Young and Jackson 1951).

Coyotes are considerably smaller than wolves and their body characteristics are more like their ancestral fox origins. Coyote weight varies among individuals from approximately 10 kg to more than 17 kg in some northeastern populations; there appears to be a gradient of smaller coyotes in the southwest to larger coyotes in the northeastern U.S. Coyotes have a bushy tail that generally droops behind the animal (a distinguishing character from the wolf, while running, the wolf carries the tail straight behind).

Distribution

Today, coyotes are found in most regions of North America. When Europeans first arrived in North America, coyotes occurred only in the western part of the continent. However, over the past 100 years they have spread east to the Atlantic and as far north as Maine (Nowak 1978). About 10,000 years ago, coyotes had occupied all of North America, as they do today (Nowak 1978); thus, some confusion arises in discussions about the "historic" range of coyotes depending on the nature of the discussion (legal, ecological, management, or taxonomic).

In California, coyotes are found in almost all wildland habitats and are significant components of some urban ecosystems that contain adequate open space (see Romsos 1997). Their historical distribution and abundance in California is unclear. Early conflicts with human interests resulted in the implementation of vigorous eradication programs. Consequently, assessments of distribution that have been based on history as recalled by human memory may be inaccurate. In northern California, coyotes occupy almost all landscapes and are abundant in most areas.

Ecology

Coyotes are very adaptable in their behavior, food habits, habitats they occupy, reproduction, and adjustments to humans. The plasticity appears both to be prevalent in the variation at a population level as well as in an individuals repertoire of behaviors. It is important to recognize that modern selective forces often have anthropogenic origins; humans are reported to be the primary causative mortality factor in many populations. Coyotes evoke strong responses by people and have been, like many other predators, the object of human persecution because of fear or their competition with humans for resources, which causes economic problems for some people.

Movements and Home Range

Home range size varies with habitat, population size, prey availability, and numerous other factors. The home range sizes of urban or suburban coyotes range from 1.1 to 15.7 km^2 (Bounds 1993, Romsos 1997). In wildlands, home range sizes are extremely variable, ranging from 9 to 92 km^2 (Andelt and Gipson 1979, Bekoff and Wells 1980, Springer 1982, Bowen 1982, Pyrah 1984, Roy and Dorrance 1985, Gese et al. 1988, Harrison et al. 1989, Holzman et a1. 1992).

Juveniles disperse October to March of their first year (Harrison 1992). Minimum dispersal movements of juveniles in Maine was 94km and 113km for females and males respectively (Harrison 1992). Movements as great as 323 km have been reported (Andrews and Boggess 1978).

Reproduction
Coyotes produce only one litter per year. Females that are not successfully bred in their first estrus of the breeding season may recycle to a second estrus. Breeding generally occurs in January (Gier 1968) and February, but can vary from one region to another and between years. Gestation is 60-63 days (Young and Jackson 1951).

The estimated litter size varies by method of calculation but probably averages 5.6 to 6.3. This average can vary with nutrition (Gier 1975) and individual age (Kennelly 1978). The greatest reported litter size was 17. Age of first reproduction also varies with environmental conditions and control efforts (tier 1968, Knowlton 1972). Males and females are both capable of breeding their first year. However, the proportion of one-year old females that actually breed ranges from none to 80% Gier 1968, Gipson et al. 1975, Nellis and Keith 1976, Crabtree 1989). Consequently, the overall variation in production of young in a population can be great and is responsive to environmental conditions (including those conditions created by humans).

Hybridization between coyotes and other canids have been reported. Coyote-dog crosses are reported (Gipson 1978) as well as wolf crosses (Kolenosky 1971). Hybridization between coyotes and the red wolf (*Canis rufus*) has been a major consideration in the conservation of that endangered species (Wayne and Jenks 1991).

Mortality and Survivorship
Mortality sources include disease, predation (including interactions with dogs), intraspecific interactions, automobile collisions, control programs (shooting, trapping, poisons, snares, aerial gunnery, and "denning"), and in some locations a legal fur harvest. Populations from wildlands seem to incur most mortality from anthropogenic sources such as control programs; in Iowa, Andrews and Boggess (1978) reported that more than 90% of tagged coyote deaths were directly related to human activities. Mortality in populations in urban settings are dominated by auto collisions (Romsos 1997).

In Texas, 70-80% of the population was reported to be under 3 years old (Knowlton 1972). In New Mexico, juveniles were 53% of the population in the fall (Rodgers 1965). The greatest mortality probably occurs in the first year of life, with dispersers having lower survival than residents (Harrison 1992). Knowlton (1972) reported one coyote that was 14.5 years old.

Food Habits
Coyotes consume a large range of food types (Bowyer et al. 1983, Andelt et al. 1987, Steinberg 1991, Cypher et al. 1996). Carrion is commonly consumed (although probably underestimated in most food habits studies because of a bias against detection of soft tissues). They will take small ungulates (deer, pronghorn) or young of larger ungulates (elk). They will also take small domestic stock including goats and sheep, or young of larger stock. However, some caution is necessary in interpretation of livestock in fecal remains since considerable stock is available as carrion on some rangelands (Cypher et al. 1996). Rodents and other small mammals are frequent in the diet (Linsdale and Tevis 1951, Windberg and Mitchell 1990), as are rabbits and hares (Andelt et al. 1987,. Cypher et al. 1996). Most birds taken are ground dwelling or ground nesting (Cypher et al. 1996).

Plant material is also consumed. Berries, fruits, and seeds are common in the diet. In urban settings, coyotes may ingest figs and other non-native fruits found in abundance on golf courses or other "green" areas. Coyotes are also known to take commercial fruits and melons, sometimes causing economic damage. The role of vegetative matter in the diet is unclear. In arid regions, succulent plant matter may be essential in obtaining adequate water (Golightly and Ohmart 1983). Coyotes may obtain all their water from their prey (about 2kg per day of mammalian prey to meet water requirements in summer), but meet their caloric need much quicker (about 0.5kg per day of mammalian prey). Therefore, fruits may be important in areas without free drinking water.

Habitats

Coyotes use a variety of habitats across their range. In northern California, coyotes are found in most available habitats. They have been found in Redwood and Douglas-fir forests, both older forests and cut-over lands (Steinberg 1991). They are also reported in oak woodlands, marshes, wetlands, agricultural lands, desert, and open prairies. Vegetative or other forms of hiding or escape cover is required. Andelt and Andelt (1981) reported that coyotes in Nebraska used open areas (pastures) at night only. They also reported that coyotes were not using otherwise good cover habitats during time with people in close proximity. Rest sites were characterized by tall vegetative cover.

Lands that provide adequate food resources are required. Defendable sources, of carrion will result in concentrations of coyotes or distinct coyote groups (Bekoff and Wells 1980).

Den sites are usually dug into stream banks or other exposed soil sites. However, coyotes have also used hollow logs and brush piles as dens. Even in desert regions dens may be difficult to see because they are usually associated with dense cover.

In urban areas, coyotes can be common. Romsos (1997) reported coyotes using most landscapes in urban Orange County, California; however open spaces (parks, golf courses, flood control channels, and wildlife refuges) and industrial areas received the most use. Industrial sites are generally secure with considerable anthropogenic sources of cover and lack human activity at night. Further, urban coyotes avoid people by timing their activity to the night. Corridors are essential to connect small patches of open space or industrial lands; these corridors can include "green belts", flood control channels, railroad right-of-ways, and even freeways.

Conservation

This adaptable animal has generally been considered a pest and management has been directed at its control rather than conservation. Because it is so widespread and numerous, its conservation has not generally been considered. However, control programs or indiscriminant take have limited populations in some areas and raised concerns about the health of local biotic communities.

Further, the coyote has been recognized as useful in the conservation of some threatened or endangered species. For example, coyotes are known to suppress red fox (*Vulpes vulpes*; Sargeant et al. 1987, Harrison et al. 1989) and are important in control of introduced red fox in California (Lewis et al. 1993, Romsos 1997). Several ground nesting and marsh birds are adversely affected by the introduced red fox (U.S. Fish and Wildlife Service and U.S. Navy 1990). Because coyotes were previously removed from several of the open spaces in urban areas of California, red fox flourished at these sites. Now coyotes have returned, however, and biologists hope they will begin to control red fox numbers. Therefore, managers are. making efforts to protect corridors (Romsos 1997) and den sites for coyotes. Because of their relatively large home ranges and because open spaces with adequate cover are highly fragmented in urban areas, coyote densities are low.

Management

In California, the management of coyotes today generally includes control programs to protect livestock or agriculture, control programs to manage coyotes on the suburban edges, control programs to protect favored wildlife, and conservation at sites where their usefulness in the conservation of endangered species has been recognized. Historically, control of coyotes has been the most significant management activity. In California, the Animal Damage Control (ADC) unit of the U.S. Department of Agriculture reported an average annual take of 8,274 coyotes between 1971 and 1976 (Evans and Pearson 1980). In 1988, the combined harvest plus ADC activity in California resulted in a take of 76,229 coyotes; this is approximately 20% of the estimated population (USDA 1993). The ADC works in partnership with counties requesting assistance (and sharing costs; Evans and Pearson 1980); thus their activities are primarily in the more rural counties. Occasionally, coyotes are also controlled at the suburban/wildlands interface in response to peoples fears about coyotes or because the coyotes are preying upon pets.

Techniques for controlling coyote damage can generally be categorized as lethal or non-lethal measures. Although leg-hold traps are not themselves lethal, captured animal are euthanized in control programs; thus all traps and snares are considered as lethal. The leg-hold trap has a poor image with the general public. It is however one of the most selective devices available to control programs. If set properly it *is* effective at selectively removing the offending individual and usually selective to the target species. In recent years a more humane version has become available (known as the "soft-catch") and has been the subject of investigation for effectiveness and humaneness (Linhart et al. 1986, Onderka et al. 1990). Poisons are still used in restricted situations, but seldom in association with urban or suburban sites. A technique called "denning" is sometimes used to reduce coyote reproduction. This technique requires locating a den and removing the pups. Lastly, lethal collars have been used on livestock to kill an attacking coyote. These devices are relatively expensive and most effective in corral or pen situations.

Non-lethal techniques are generally proactive methods to discourage interaction between coyotes and their potential prey. The simplest is a good fence. Electric fences have been shown to be effective, but expensive to build and maintain. It is also important to discourage coyotes from the food reward of livestock. The removal of livestock-carcasses slows the association by naive coyotes of the livestock and food. Recently, guard dogs and other more exotic guard animals have been effectively used in some situations. Although effective, these guard animals require planning and can be expensive. Electronic scare crows are common, but coyotes will usually habituate to these sound devices. Consequently, they are used mostly when the newborn lambs are present and vulnerable. Aversive chemicals have not been very successful nor are they widely used.

Estimates of actual damages from coyotes can be difficult to assess. Like most economic analyses, these require honest and accurate assessment of the number of livestock killed by coyotes and the dollar value of the net loss (an individual animal is not 100% profit). Missing animals in open range are especially difficult to assign to an accurate cause. Good field experience can generally provide discrimination between a kill and the use of a carcass as carrion. Sterner and Shumake (1978) summarized sheep losses from coyotes to range from 1 to 16% in several different regions, with most losses less than 5%. In Kansas, Robe] et al. (1981) estimated that coyotes were responsible for less than 1% of the sheep losses across a 9-county area.

Fear of coyotes or loss of pets has also resulted in coyote control at the wildland/suburban interface. Although coyotes certainly take pets (especially cats), the number of people actually attacked by coyotes are few (Carbyn 1989). Most control techniques are poorly suited to this environment. Large cage-type traps are very ineffective for catching coyotes, although they work well on dogs.

Coyotes can be positive tools for the management of other species. In California, coyotes are important in the control of introduced red fox. They may also influence feral cats. Therefore, land-use planning in urban areas needs to consider connecting corridors for coyotes between patches of open space and natural areas such as wetlands. Protection of coyote dens in urban areas may also be an important consideration to maintain coyote populations. Additionally, coyotes may serve a useful anthropocentric function by controlling rats, ground squirrels, or other rodent and lagomorph populations that are in conflict with human interests.

MONITORING AND DETECTION

For many years the federal government has monitored coyote populations by use of a scent station survey (Linhart and Knowlton 1975). These surveys use a standardized bait and protocol. Although probably not very useful for comparisons across states or regions, these surveys may have some utility in tracking populations at a site.

Siren surveys (Wolfe 1974; at fixed stations a siren is played and the number of coyote vocalizations heard in a period after the siren are recorded) and scat surveys (fecal droppings counted along fixed routes) have also been used to monitor coyotes. These techniques are probably useful for site specific monitoring through time. The siren surveys are most effective pre-breeding and are subject to habituation if used too often (Steinberg 1991). The scat droppings are useful all year, but require very consistent methodology and are subject to nonrandom distribution of individuals (Steinberg 1991).

Coyotes may be detected using 35mm infrared cameras (eg: trailmasters; Steinberg 1991). They are occasionally detected at smoked track plates (Fowler and Golightly 1994), but in general these plate are ineffective for coyote. Most detection's by cameras or smoke-plates vary in their effectiveness across habitats.

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Gray Fox (*Urocyon cinereoargenteus*) Ecology and Management

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DESCRIPTION

The gray fox (*Urocyon cinereoargenteus*) is a petite member of the family Canidae in the order Carnivora with a long muzzle and pointed ears (Samuel and Nelson 1982). The coat of the gray fox is silver gray across the back with significant amounts of rufus along the sides. This characteristic is often confused by people who see the flash of red and assume that the fox is a red fox (*Vulpes vulpes*). The gray fox has a black tipped tail with a dorsal black stripe that differentiates this species from the kit fox (*Vulpes macrotis*). The red fox has a white tipped tail. The gray fox weighs between 3-5 kg, occasionally to 7 kg. TL 800-1125, T 275-443, HF 100-150. (Jameson and Peeters 1988).

Taxonomy

Gray fox fossils were found in Pennsylvania from the late Post-Wisconsin period (Samuel and Nelson 1982). Wayne et al. (1989) reported that the gray fox was a distinct lineage from five other canid groups and was not directly related to the Vulpes-like foxes. This result was based upon isozyme genetic distances among 18 species from 13 genera (Wayne et al. 1989). The island gray fox (*Urocyon littoralis*) is a related, somewhat smaller species restricted to the six largest of the California Channel Islands (Fritzell 1987).

DISTRIBUTION

The gray fox is distributed across the southern half of North America and is not found in New England and the northern Rocky Mountains of the United States (Samuel and Nelson 1982). Presumably, extreme cold limits the northern distribution of this species. In California, gray fox are common to uncommon residents throughout the state except the extreme north east (Figure 1) (Zeiner et al. 1990).

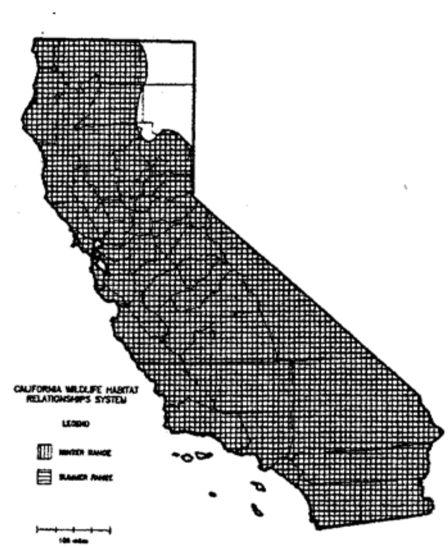

Figure 1. Distribution of grey fox in California (from Zeiner et al. 1990)

REPRODUCTIVE BIOLOGY

Breeding Season

Mating occurs in late winter with the birth of the young in April or May (Jameson and Peeters 1986). Litter size is from three to five. Females reach sexual maturity at 10 months and breed each year (Fritzell 1987). Gerhardt and Gerhardt (1995) reported one den being shared by two gray fox litters suggesting the monogamy may not be a strict mating system among gray foxes.

Jameson and Peeters (1988) make a similar statement about shared dens.

DEMOGRAPHY

Home Range

Home range estimates vary from approximately 20 to 30 ha with an extreme value of over 2,700 ha for a barren female in Alabama (Fritzell 1987). Home ranges of four females near Davis, California averaged 1,200 ha (Ahlborn et al. 1982).

Dispersal

Little is known about gray fox dispersal but varies considerably . In one study of a group of 10 radio collared foxes in Alabama the males dispersed and the females made excursions of up to 3 km but returned while in another study 75% of the males and 63% of the females dispersed (Fritzell 1987).

Survivorship

In two studies adult mortality varied between 50% and 61-64% annually, but an individual may live from 4-5 years and even up to 14-15 years of age (Fritzell 1987).

Distemper seems to be a major cause of mortality among gray fox with localized outbreaks occurring frequently (Fritzell 1987). In 1996, we observed an outbreak of distemper among gray fox in coastal scrub of southern Marin County, California that decimated the local population. Of 30 plus gray fox captured in the same area between 1992 and 1995 none tested positive for canine distemper (Seth Riley, University of California, Davis, pers. comm.)

Black et al. (1996) reported a gray fox with canine distemper virus encephalitis as also infected with listeriosis (*Listeria monocytogenes*) and yersiniosis (*Yersinia pseudotuberculosis*). Both diseases can be transmitted to wild or domestic animals and to humans causing visceral and hepatic lesions in the case of yersiniosis, and abortion and encephalitis in the case of listeriosis. Davidson et al. (1992) reported 15 of 18 gray foxes with distemper at necropsy and stated the transport of wild foxes was biologically hazardous to wildlife, domestic animals, and humans.

Survival of Young

Reports to juvenile mortality varied from 43-47% in one study and 50-90% in an other study (Fritzell 1987).

FOOD HABITS - PREDATOR/PREY RELATIONSHIPS

The gray fox is omnivorous eating rabbits, mice, gophers, woodrats, squirrels, fruit, grain, and insects (Ahlborn 1982, Samuel and Nelson 1982, and Fritzell 1987). Gray fox may also be prayed upon by golden eagles (*Aquila chrysaetos*), bobcat (*Fells rufus*), and possibly coyote (*Canis latrans*) (Fritzell 1987).

HABITAT REQUIREMENTS

The gray fox is a habitat generalist and is found in most habitats across California (Samuel and Nelson 1982, Fritzell 1987, Jameson and Peeters 1988). Dark (1997) reported that gray fox were not detected in habitats where black bear (*Ursus americanus*) were detected, indicating potential exclusion or avoidance of areas occupied by bear.

Effects of Forest Structure, Use Openings or Non-forested Habitat

Rosenberg and Raphael (1986) found that gray fox were sensitive to forest fragmentation and had negative correlations with the amount of area clear cut and edge. Hallberg and Trapp (1984) reported that riparian corridors were important in areas were agricultural development limited habitat (in: Dark 1997).

SURVEY TECHNIQUES

Presence of gray fox can be determined by tracks, scat, or visual observation (Spowart and Samson 1986). Smoked track plates are an excellent tool for determining presence and relative abundance of gray fox (Barrett 1983, Howell and Barrett 1997 (in press)). Radio telemetry and capture-recapture techniques are necessary for home range and population size estimates. Seth Riley (University of California, Davis, pers. comm.) had success capturing gray fox with box traps baited with raisins or fruit.

Paxinos et al. (1997) developed a method to distinguish among five canid species using enzyme restriction of mitochondrial cytochrome-b DNA found in canid feces. This technique was effective in differentiating from among sympatric gray fox, red fox, kit fox, coyote, and dog (*Canis familiaris*).

CONSERVATION STATUS

The gray fox is protected as a furbearer under California Department of Fish and Game (CDFG) Code, and harvest by trapping and hunting is regulated. In 1996, 851 gray fox were hunted in California (Bill Grenfell, CDFG, pers. comm.) This contrasts markedly with the thousands of pelts sold in the mid-1970's and reflects the reduced demand for animal furs in the United States.

Population Trends

The population of gray fox in California is probably quite stable for the habitat available. Episodic outbreaks of canine distemper or rabies occur locally to decimate a population. Recovery may or may not occur. After an outbreak of rabies in the North Coast of California that decimated the local gray fox population, the Virginia opossum (*Didelphis virginiana*) population increased, and the gray fox population has not recovered (Richard Golightly, Humboldt State University, pers. comm.). Our work along the Central Coast of California suggests a similar occurrence of a gray fox population not recovering from a distemper outbreak in the face of coyote recolonization.

MANAGEMENT CONSIDERATIONS

Response to Human-caused Disturbance

Harrison (1993) surveyed rural residential areas in New Mexico to determine potential factors affecting gray fox distribution by the presence of unrestrained dogs during the day. He found that gray fox density was related to the extent of original habitat. He also found that people had high regard for gray fox. In a subsequent study Harrison (1997) reported that gray fox avoided high-density residential subdivisions (> 128 residences/km^2) but in lower density subdivisions gray fox home range structure was more complex requiring . corridors, foraging peninsulas, and large blocks of natural habitat.

Mitigations

In the southeastern United States foxhunters have managed gray fox habitat by providing areas of dense cover and planting of fruit trees and shrubs. Also, the pine forests were prescribed burned on a three year rotation, but hardwood fruit trees needed protection (Fritzell 1987). Harrison (1997) reported gray fox using culverts under highways as a means of getting to foraging areas. From the above descriptions of human impacts, maintaining large areas of habitat with dispersal corridors is essential for maintaining gray fox.

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The Sierra Nevada Red Fox (*Vulpes vulpes necator*)

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Description

The following description has been modified from the account given in Lariviére and Pashitschniak-Arts (1996): The red fox (*Vulpes vulpes*) is a relatively small, slender canid with an elongated muzzle, large pointed ears, and round bushy tail, usually as long as the head and body. There are 3 color phases: red, silver or black, and cross. In the typical red phase, yellow to reddish-brown fur predominates in the upper body; the cheeks, chin, throat, and abdomen are white; the face and rump are rusty; legs and ear tips are black; and the tail, with its distinctive white tip, is mixed generously with black. In the silver phase, coat color varies from silver to nearly black with a variable amount of frosting resulting from silver tips on the guard hairs. The cross phase is predominantly grayish-brown, and gets its name from the long black guard hairs that form one line down the back and another across the shoulders. Both the silver and cross phases are rare, but their prevalence varies geographically. In some areas, especially those having relatively cold climates, 10-25% of the population may be in the dark phases.

Taxonomy

Variation in the North American red fox was first investigated by Merriam (1900), who recognized ten species and two subspecies, all of which were later given subspecific status under *Vulpes fulva* by Bailey (1936a). Churcher (1959) conducted an extensive re-evaluation of cranial and dental variation in North American and Eurasian red foxes, and concluded that red foxes worldwide were members of a single species, *Vulpes vulpes.* Churcher (1957) revised the North American subspecies, eliminating three previously recognized forms and redrawing the distributional boundaries of others: *V. v. harrimani* is found on Kodiak Island in southwest Alaska; *V. v. alascensis* occupies Alaska, the Yukon and the western Northwest Territories; *V. v. abietorum,* the northern regions of British Columbia, Alberta, Saskatchewan, Manitoba and the southeastern Northwest Territories; *V. v. rubricosa,* the James Bay region of Ontario, northern Quebec, Newfoundland, Nova Scotia, Prince Edward Island and New Brunswick; *V. v. fulva,* the eastern United States east of the Mississippi River; *V. v. regalis,* the eastern United States west of the Great Lakes and the Mississippi River; *V. v. necator, V. v. cascadensis,* and *V. v. macroura,* are restricted to the upper elevations of the Sierra Nevada, Cascade Range, and Rocky Mountains, respectively. The latter 3 subspecies are high-elevation, montane forms with a unique evolutionary history (Aubry 1983); these three forms are sometimes referred to as the "mountain foxes".

Geographic Distribution

The Sierra Nevada red fox is one of California's rarest and least known mammals (Schempf and White 1977). Only 18 museum specimens from 8 localities are known, the most recent of which was collected in 1934 (Grinnell, et al. 1937, Lewis, et al. 1995). Grinnell, et al. (1937) described the distribution of the Sierra Nevada red fox as continuous at high elevations of the Sierra Nevada from Tulare County north to Sierra County, and in the vicinity of Mt. Shasta and Lassen Peak westward to the Trinity Mountains in Trinity County (Fig. 1). The records they obtained occurred from 4,500 to

11,500 ft. in elevation, but most were 'above 7,000 ft. Schempf and White (1977) gathered 62 additional sighting records which showed a similar but more continuous distribution than that of Grinnell, et al. (1937) (Fig. 2). The mean elevation of records from the northern Sierra was 6,400 ft. (range 4,300-8,500 ft.), whereas in the southern Sierra, the mean was 6,900 ft. (range 3,900-11,900 ft.).Over 1/3 of their records were from the vicinity of Lassen Volcanic National Park, which they believed supported the densest population of Sierra Nevada red fox in California. Interestingly, the only verifiable records of Sierra Nevada red fox since 1937 are several photos taken at a remote camera station in 1993, 20 mi. east northeast of Lassen Peak, at an elevation of about 6,200 ft. (Kucera 1993, 1995), and a series of photos of two individuals

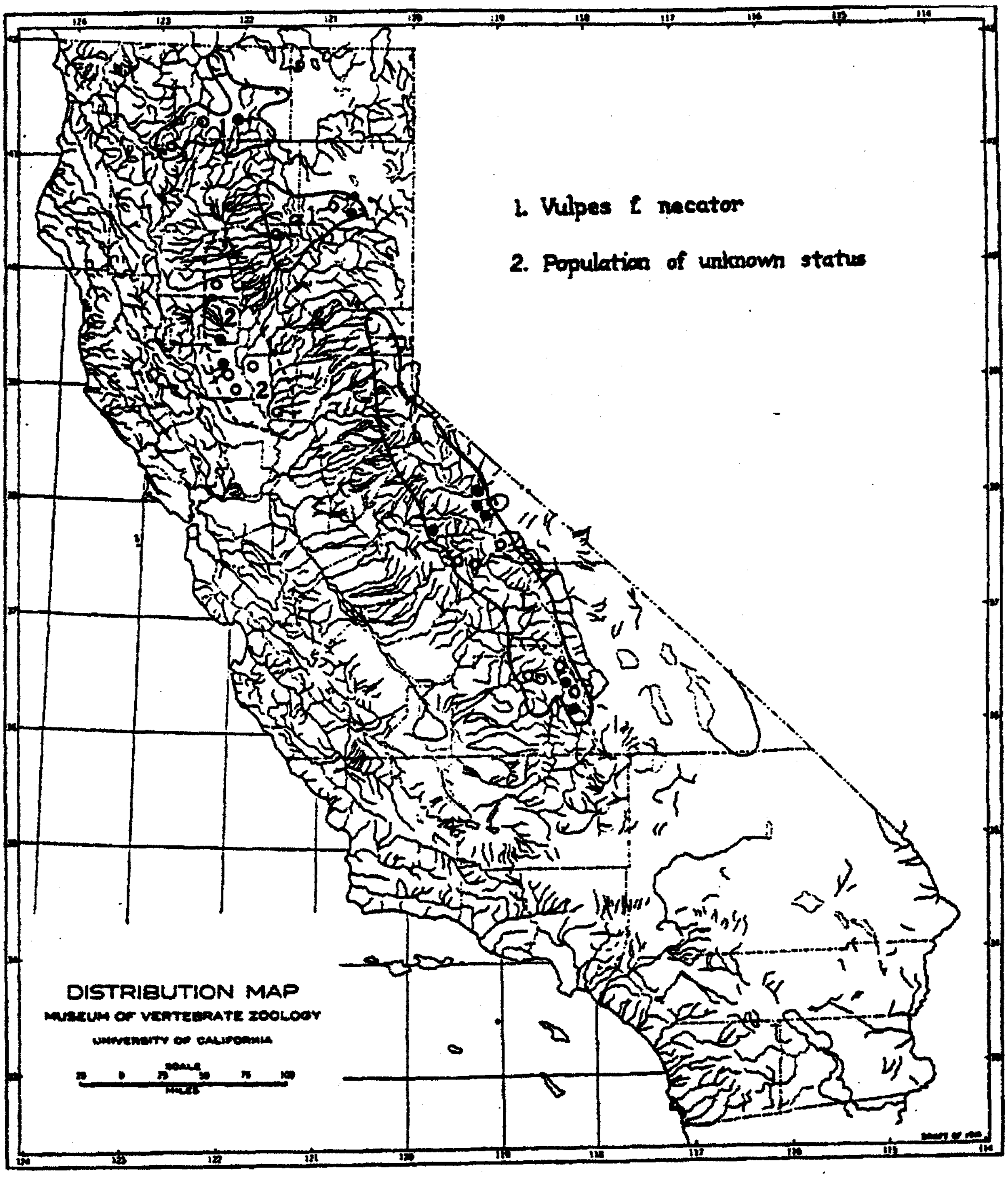

Figure 1. Red fox distribution in California, Grinnell, et al. (1937).

taken in 1997, 8 mi. south of Lassen Peak at an elevation of about 5,800 ft. (Tom Rickman, pers. comm.). Although the photos were taken within the known range of the Sierra Nevada red fox, the taxonomic status of the animal in the pictures remains somewhat uncertain (Kucera 1995). Non-native red foxes may have escaped from local fur farms, which were present in that area from the 1920's to 1940's (Lewis, et a1. 1995), or invaded from the Sacramento Valley where they have occurred since the late 1800's (Grinnell, et al. 1937; see also Gould 1980; Gray 1975, 1977; Lewis, et al. 1993; Roest 1977; and Schempf and White 1977).

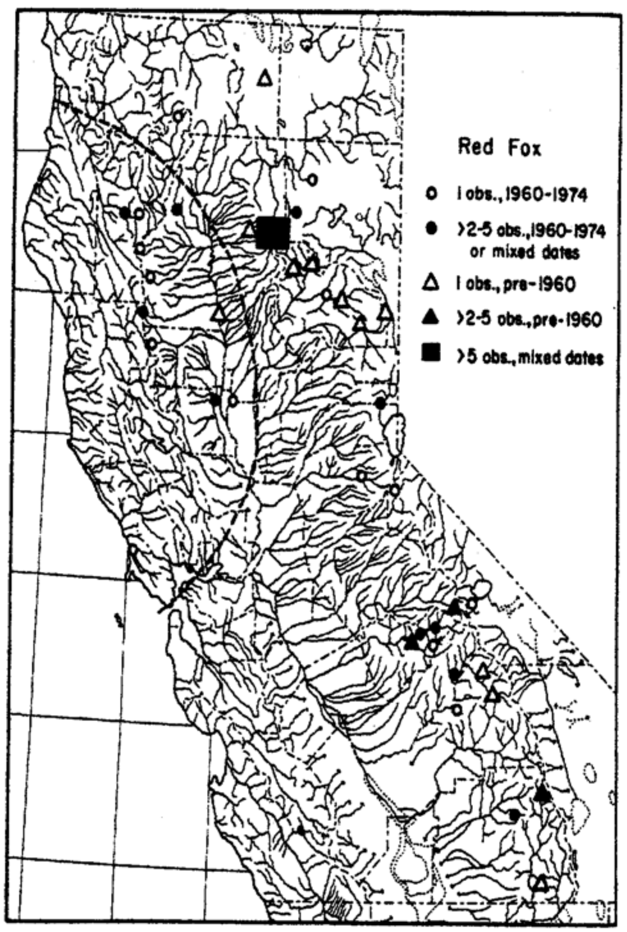

Figure 2. Distribution of red fox reports, Schempf and White (1977).

Biology and Ecological Relationships

Information on the biology and ecology of Sierra Nevada red foxes is extremely limited, and comes almost entirely from information obtained by Grinnell, et al. (1937). The information they presented came from carcasses they examined, their own field observations, and anecdotal reports from trappers who had trapped red foxes in the high Sierra. The Cascade red fox, which occurs at high elevations near tree line in the Cascade Range of Oregon and Washington, has habitat associations that are very similar to those of the Sierra Nevada red fox. Furthermore, these two subspecies are so similar morphologically, that Roest (1979) once proposed lumping them (along with the Rocky Mountain red fox) into a single subspecies. The only intensive field study of mountain foxes was research that I conducted on the Cascade red fox at elevations ranging from 5,000 to 7,000 ft. near Mt. Rainier in south-central Washington (Aubry 1983). Bailey (1936b) and Taylor and Shaw (1927) also present information on the life history characteristics of the Cascade red fox. As appropriate, I will also include information from these sources in the following sections.

Reproductive Biology

Although the Sierra Nevada red fox occurs in extremely harsh environments with a relatively short growing season, there is no evidence to suggest that mountain foxes have markedly different reproductive characteristics than red foxes occurring elsewhere in North America. Unlike many mustelids, such as the American marten (*Martes americana*) and fisher (*M. pennanti*), implantation of the blastocyst is not delayed in red foxes. According to Ables (1975), red foxes typically mate sometime between December and April, but most matings occur during January and February. Both male and female red foxes are capable of breeding during their first winter. Gestation lasts for just over 50 days, at which time red foxes give birth to an average of 4.5 to 5.5 pups, with a range of about 1 to 10 per litter.

Available data indicate that mountain foxes breed at about the same time of year as red foxes in other regions of North America. Based on pairs of tracks found together in the snow on about February 15 in California, Grinnell, et a1. (1937) concluded that Sierra Nevada red fox mating took place at about this time. Using known dates at which permanent teeth sequentially replace milk teeth in the red fox, I estimated that Cascade fox pups captured during the summer in Washington had been born in the second week of March and, thus, conceived in the first or second week of February (Aubry 1983). As elsewhere, mountain foxes can breed before they are 1 year old. Of two female pups I radio-collared during their first summer, one stayed with her parents and did not breed, whereas the other dispersed a distance of about 8 km and gave birth to a litter of at least 3 pups during her first winter. Grinnell, et al. (1937) reported that litter size for Sierra Nevada red fox varied from 3 to 9 with an average of 6.

Dens

One of the trappers consulted by Grinnell, et a1. (1937) had found several dens of Sierra Nevada red foxes, but never one that was dug into the ground. He was of the opinion that "the [Sierra Nevada red fox] does not normally use earthen dens, but chooses to live in natural cavities in the huge rock slides and talus slopes prevalent in its domain...". Another individual "knew of a den that was used by foxes year after year. It was most inaccessible, being situated in a huge pile of riven granite in a very wild spot...". However, these reports represent only a few anecdotal observations. Although the Sierra Nevada red fox clearly uses rock dens, it seems unlikely that they would not also use earthen dens. Rather, these reports probably reflect either soils that were too rocky to provide suitable earthen den sites, or the greater likelihood of discovering Sierra Nevada red fox dens in rocky outcrops, since earthen dens would probably be located in timbered areas, making them more difficult to discover. During the course of my field work, I located several dens of Cascade red foxes; all were typical earthen dens situated in relatively dense timber. I did not observe them denning in rocks, even though rocky outcrops and talus slopes were present in my study area (Aubry 1983). Although the use of rock dens is unusual among red foxes in North America (Ables 1975), Sierra Nevada red foxes probably den in the most suitable site available, whether in rocks or underground.

Mortality

Information on sources of natural mortality for mountain foxes is very scant. Grinnell, et al. (1937) described several instances of golden eagles (*Aquila chrysaetos*) preying on Sierra Nevada red foxes when they were caught in traps, suggesting that they may also prey upon them in other circumstances. They also speculated that bobcats (*Lynx rufus*) and mountain coyotes (*Canis latrans lestes*) may be predators of Sierra Nevada red foxes. Bailey (1936b) stated that Cascade foxes generally "occupy the areas where coyotes are not common, either because they are rival hunters of mice and small game, or because they are old time enemies with the size advantage all in favor of the coyote". There is no published information on diseases infecting mountain foxes.

It is likely that Sierra Nevada red foxes once suffered additional human-caused mortality during predator control operations in the early part of this century. According to a trapper quoted by Grinnell, et al. (1937), sheep were once herded throughout the high mountains, and "the practice of placing poison in all dead sheep was universal, the result being that thousands of fur animals were destroyed". Although trapping was once a source of mortality for Sierra Nevada red foxes, they have been protected from trapping since 1974 (Kucera 1993).

Home Range

The only available information on home range size for the Sierra Nevada red fox are estimates provided by a trapper to Grinnell, et al. (1937). After trapping for many seasons in what he considered to be the best Sierra Nevada red fox country, he stated that "on the average there is about one red fox to each square mile [259 ha]. Under favorable circumstances, three or even four foxes may be trapped in a single square mile". These estimates are remarkably similar to home range sizes I estimated for 4 adult Cascade red foxes using radio-telemetry (Aubry 1983). For these 4 foxes (2 males and 2 females), home range sizes varied from 65 to 308 ha, with a mean of 193 ha. During the summer that one of the females whelped pups, her home range was much more restricted in extent than her mate's (65 vs. 132 ha), suggesting that her activities were more restricted to the vicinity of the den than the male. During the next summer, when she did not breed, her home range size was over three times larger than it had been the previous summer (223 ha).

Food Habits

As with red foxes elsewhere, mountain foxes feed on a variety of animal and plant foods, but probably rely most heavily on small mammals. Grinnell, et al. (1937) reported finding the following prey remains in scats: mice, bushy-tailed woodrat (*Neotoma cinerea*), Douglas' squirrel (*Tamiasciurus douglasii*), Belding's ground squirrel (*Spermophilus beldingi*), alpine chipmunk (*Tamias alpinus),* and white-tailed jack rabbit (*Lepus townsendii*). These authors also report observations of Sierra Nevada red foxes pursuing golden-mantled ground squirrels (*Spermophilus lateralis*) and meadow mice (*Microtus* sp.). Carrion of large mammals was often used as bait to trap Sierra Nevada red foxes.

Bailey (1936b) described Cascade red foxes as stealthy hunters of small game, including mice, chipmunks, ground squirrels, birds, and rabbits, whereas Taylor and Shaw (1927) reported that scats they examined contained only insects and fruit. As explained below, the latter report is probably indicative of scats collected only in late summer or early fall. I described the seasonal food habits of Cascade red foxes by examining 413 scats containing 760 food items. Mammals were the most important item in the yearly diet, comprising 57% of all items found; fruits [strawberries (*Fragaria* sp.) and blueberries (*Vaccinium* sp.)] represented 20% of the diet; insects (mainly grasshoppers and beetles), 17%; birds, 4%; and other items, 2%. The importance of each dietary category varied seasonally, suggesting a diet driven largely by the seasonal availability of potential food items. In winter, the diet consisted of 89% mammals, 6% birds, and 5% other items. In order of importance, the most prevalent mammals in the winter diet were snowshoe hares (*Lepus americanus*), southern red-backed voles (*Clethrionomys gapperi*), northern pocket gophers (*Thomomys talpoides*), and heather voles (*Phenacomys intermedius*). During the summer months, however, mammals represented only 53% of food items found; fruits, 22%; insects 19%; birds, 4%; and other items, 2%. Interestingly, the northern pocket gopher was preyed upon more often than any other mammal species, and was the most commonly occurring item in the diet. Southern red-backed voles, heather voles and, especially, snowshoe hares, occurred at much lower prevalence in the summer than in winter. The general patterns I found are in accordance with virtually all food habits studies of the red fox conducted in North America. The most striking finding was the importance of pocket gophers in the diet, which occur only at trace levels in other studies. Although these findings may simply reflect a greater availability of pocket gophers to the foxes I studied, it is tempting to speculate that mountain foxes, which primarily occupy subalpine meadows and parklands that also support populations of pocket gophers, may have become specialists on this particular prey species.

Habitat

Detailed knowledge of the habitat relationships of the Sierra Nevada red fox is lacking. According to Grinnell, et al. (1937), the Sierra Nevada red fox is "restricted to the highest timbered peaks of the Sierra Nevada", but because of its association with boreal habitats is "found at much higher altitudes in the southern part of its range than in the northern parts". These authors further assert that "although the Sierra Nevada red fox forages well above timber line during the fall and even in midwinter, it breeds lower down amid the white-barked pines and alpine hemlocks". Ingles (1965) considered habitats occupied by Sierra Nevada red foxes to include red fir, lodgepole, and subalpine forests, as well as alpine fell-fields. Schempf and White (1977) reported that their records from the northern Sierra Nevada were more or less evenly distributed among fir, mixed-conifer, lodgepole pine, and pine vegetation types. In the southern Sierra, however, almost half of their records were in the mixed-conifer zone, but lodgepole and fir forest types were also important, and several records were found in oak woodland and barren (treeless) zones. Interestingly, they also noted that Sierra Nevada red fox sightings occurred in similar vegetation types as those of the American marten and wolverine (*Gulo gulo*).

The habitat affinities of the Sierra Nevada red fox are probably very similar to those of the Cascade red fox to the north. In Washington and Oregon, the Cascade fox occupies subalpine forests, parklands, and meadows near tree line in the Cascade Range; it does not occur in densely forested habitat (Dalquest 1948; Aubry 1983, 1984). According to Bailey (1936b) they "are absent from the densely timbered or brushy areas west of the Cascades, as well as from the arid sagebrush valleys east of the range. Open grassy parks and meadows afford their favorite hunting grounds, and the greatest abundance of mice and small rodents on which they largely subsist".

Conservation Status

The Sierra Nevada red fox is completely protected in California; trapping was prohibited in 1974, and they were listed as threatened by the California Fish and Game Commission in 1980 (Kucera 1993). After evaluating the distribution and abundance of sightings made since the work of Grinnell, et al. (1937), Schempf and White (1977) concluded that the Sierra Nevada red fox was either maintaining itself at a low level or, more likely, was declining. They concluded that the Sierra Nevada red fox was of greater conservation concern than any of the other five species they surveyed, including the wolverine, fisher, American marten, river otter (*Lutra canadensis*), and ringtail (*Bassariscus astutus*). They recommended that field surveys be conducted throughout its range, and that subsequent conservation measures be undertaken to ensure the continued existence of the red fox in the Sierra Nevada.

Lewis, et al. (1995) raised the possibility that introduced non-native red foxes may have expanded their range into the high Sierra, interbred with the Sierra Nevada red fox, and altered the genetic integrity of its populations. Because these two forms occupy dramatically different habitats, such hybridization could result in lowered survival rates for the Sierra Nevada red fox and ultimately affect its ability to maintain viable populations. Although work I conducted in western Washington showed that introduced red foxes in the Puget Sound region are restricted to low-elevation habitats (Aubry 1984), such may not be the case in California where the geographic and genetic origins of introduced red foxes could be substantially different. Sierra Nevada and non-native red foxes cannot be reliably distinguished on the basis of coat color (Grinnell, et al. 1937; Kucera 1995); consequently, genetic studies may be the only way to conclusively ascertain the taxonomic status of extant red foxes in the Sierra Nevada (Lewis, et al. 1995; Kucera 1995).

Management Considerations

The management of Sierra Nevada red fox populations was addressed by the California Dept. of Fish and Game when it granted this species complete protection from trapping in 1974. Because our knowledge of the current distribution, habitat relationships, and population status of the Sierra Nevada red fox is so limited, recommendations for habitat management seem unwarranted at this time. What is needed is to gather new data from additional population surveys and intensive field research to fill in these information gaps. Because Sierra Nevada red foxes occupy an elevational zone that receives ample snowfall each year, and their tracks are easily distinguished from other species occurring within their range, snow-tracking would seem to be a particularly effective way to survey large areas for their presence. Remote cameras would also be useful for survey work, and have been shown to record their presence (Kucera 1995). Finally, although it will be extremely challenging, intensive field research on the Sierra Nevada red fox using radio-telemetry techniques will be an essential precursor to any reliable conservation strategy.

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Weasels, Skunks, Ringtail, Raccoon, and Badger

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Introduction

This group of mesocarnivores includes the long-tailed weasel (*Mustela frenata*) and ermine (*Mustela erminea*), the striped (*Mephitis mephitis*) and spotted skunk (*Spilogale gracilis*), the ringtail (*Bassariscus astutus*), raccoon (*Procyon lotor*), and the badger (*Taxidea taxus*). All members of this group are well distributed throughout California and relatively common in the northern part of the state. Some notable exceptions to the statewide distribution of these species are the absence of badgers from Del Norte County and portions of Siskiyou and Humboldt counties; the raccoon, ermine, long-tailed weasel, western spotted and striped skunk, are uncommon in California's south-eastern desert region; and ringtails are not common in the central valley south of Sacramento. The ermine has perhaps the most restricted range of the group in California, limited to north coastal counties, the Cascades and Sierra Nevada mountains.

Some members of this group, such as the striped skunk and raccoon, have proliferated within urban settings and members such as the long-tailed weasel and badger are traditionally considered agricultural pests. Little research has been focused on this group, primarily due to the near ubiquitous occurrence of these species and presumed non-critical status of their populations in the State. Indeed, for most of these species, greater effort has been directed towards controlling the undesirable effects of conflicts with human interests. The mostly uncharismatic reputation of weasels, skunks, and badgers has unfortunately and unfairly led to caricatures metaphorically associating this group with politicians and other lower life forms.

Ringtails and raccoons belong to the family Procyonidae. These omnivores comprise the only members of the raccoon family in North America. Both the ringtail and the raccoon have more or less ringed tails, with that of the ringtail's being incomplete on the under side. Long-tailed weasels, ermines, badgers, and skunks belong to the family Mustelidae. A well represented family in North America, mustelids also include minks (*Mustela vison*), martens (*Martes americana*), fisher (*Martes pennanti*), wolverines (*Gulo gulo*), river (*Lutra canadensis*) and sea otters (*Enhydra lutris*). Mustelids are known for their well developed scent glands, which are most notably pronounced with the skunks. For the most part, mustelids possess beautiful and valuable pelts and many are still commonly trapped for their fur. Trapping commercially, and for damage control still occurs in California, with all but the ringtail considered a harvestable species.

This effort constitutes a compilation of generalized information for initial consideration of each species. Readers familiar with Ingles 1979, and Zeiner et a. 1990, will recognize significant that this paper borrowed heavily from their works which perhaps justly acknowledges the comprehensive treatment given these species by those authors. Technical biological information should be sought through further consultation with current scientific literature.

DESCRIPTION, DISTRIBUTION, HOME RANGE, FOOD HABITS AND PREDATOR/PREY RELATIONSHIPS

Ringtail (*Bassariscus astutus*)
The ringtail is a widely distributed, common to uncommon permanent resident in California. It occurs in various riparian habitats, and in brush stands of most forest and shrub habitats, at low to middle elevations (Zeiner et al. 1990). Suitable habitat for ringtails consists of a mixture of forest and shrubland in close association with rocky areas or riparian habitats.

The ringtail is known by several other common names including cacomistle, miner's cat, and civit cat. Based on slight morphological variations, Grinnell et al. (1937), described three subspecies of ringtail for California. The California ringtail (*B. a. raptor)* is found on the lower western slope of the Sierra Nevada as well as the Pacific Coast range from southern Oregon west of Mt. Shasta south to Ventura County. Here the California subspecies integrates with the San Diego subspecies, *B. a. octavus,* which extends south along the Pacific slope of southwestern California to Baja California. The Nevada ringtail, *B. a. nevadensis,* was thought to occur primarily on the mountain ranges east of the southern Sierra Nevada with only one specimen taken. on the west slope of the Inyo Mountains in Inyo County (Belluomini 1980a).

Ringtails usually find cover in hollow trees, logs, snags, cavities in talus and rocky areas. In northern California, Callas (1987) found ringtails using trees twice as much as rock outcroppings for diurnal rest sites. Natal dens are found in rock recesses, hollow trees, logs, snags, abandoned burrows, or woodrat nests. Young are reportedly often born in May and June (Walker et al.. 1968). Ringtails produce one litter per year with an average of 3 young per litter and a range of 1-5. Gestation lasts from 40-50 days. Females may drive males away 3-4 days prior to giving birth (Zeiner et al.. 1990). Trapp (1972) described the ringtail's adaptation to rough, broken terrain, including naked soles of feet providing traction on smooth surfaces, an ability to rotate their hindfeet in half circles, and dexterous forefeet with limited opposability of the first 2 digits, and numerous behavioral adaptations.

In California, home ranges were estimated to vary from 44-515 ha (109-1280 ac) (Grinnell et al. 1937). Density estimates as high as 10.5 to 20.5/km ^{2} (27.2 to 53.1/mi ^{2}) have been reported in the Central Valley (Belluomini 1980a, Poglayen-Neuwall and Toweill 1988). Home ranges of males overlap those of females (Zeiner et al. 1990). In northern California, Callas (1987) measured the home range size of eight radio-collared ringtails which averaged 175 ha (437 ac).

Ringtails are primarily carnivorous, eating mainly rodents (woodrats (*Neotoma* spp.) and mice) and rabbits but their diet also includes substantial amounts of birds and eggs, reptiles, invertebrates, fruits, nuts, and some carrion. They forage primarily on the ground, among rocks, in trees usually near water (Taylor 1954, Trapp 1978). Probable predators include bobcats (*Felis rufus*), raccoons, foxes, and especially large owls. Potential competition for food exists between ringtails and many sympatric species (such as raccoons, gray foxes (*Urocyon cinereoargenteus*), coyote (*Canis latrans*), barn owls (*Tyto alba*), great horned *owls* (*Bubo virginianus*), rattlesnakes (*Crotalus* spp.), and gopher snakes (*Pituophis melanoleucus*).

Raccoon (*Procyon lotor*)
Raccoons are widespread, common to uncommon permanent resident throughout most of the state. They occur in all habitats except alpine and desert types without water, and are considered marginal in Great Basin shrub habitats. Raccoons are most abundant in riparian and wetland areas at low to middle elevations (Zeiner et al. 1990). The juxtaposition of riparian habitats and other wetlands with forest and shrubland types is important to raccoon populations (Zeiner et a1. 1990). They are also known to use cover provided by abandoned buildings and dense vegetation. Raccoons are very adaptable and tolerant of most human activity and opportunistically benefit from this

relationship. Raccoons carry diseases such as trichinosis, rabies, leptospirosis, tularemia, and Chagas' disease.. Canine distemper is an important mortality factor, especially among the young (Johnson 1970).

Raccoons use cavities in trees, snags, logs, and rocky areas for dens and other cover. Natal dens are usually found to be secure in the sense that there is complete enclosure. Tree dens generally are 6.1 to 12.2 m (20-40 ft.) above the ground. In California, raccoons breed from January through March. Females ovulate spontaneously (Sanderson and Nalbondov 1973). Most young are born March through May. Litters average 3-4 and range from 1-8. Gestation lasts about 63 days (range = 54-65 days). Young are weaned at 60-90 days and become semi-independent at about 130 days. Males and females begin breeding in the first or second year (Lotze and Anderson 1979).

Ellis (1964) found home ranges averaging 225 ha (555 ac) and varying from 85-380 ha (210-940 ac.). Home ranges of females averaged 108 ha (268 ac) and varied from 5.3-376 ha (13-9,330 ac) (Stuewer 1943). Pregnant females have larger home ranges which may vary considerably. Lotze and Anderson (1979) suggest from their studies that male raccoons may be territorial towards other males but that females are not territorial.

Raccoons are omnivorous and highly opportunistic. Seasonal foraging patterns are known with springtime food items consisting of primarily animal matter such as crayfish, fish, arthropods, amphibians, and some small mammals, birds, and eggs. In summer and fall, they eat large amounts of grains, acorns, and other nuts and fruits. Foraging patterns along saline and freshwater riparian habitats, shallow water, in vegetation and on the ground are common (Zeiner et al. 1990). Raccoons are known for invading trashcans and pet foods left outside in urban/rural areas. Raccoons are preyed upon by owls, bobcats (*Felis rufus*), and domestic dogs (*Canis familiaris*).

Ermine (*Mustela erminea*)

Ermines are uncommon to common, yearlong resident of the Sierra Nevada, Klamath, and North Coast Ranges (Ingles, 1979), and are normally found from sea level to 3800 m (1-12,500 ft). They occur in various pine and fir forest habitats, including mixed conifer, red fir, lodgepole pine, and subalpine conifer (Seymour 1968, Burt and Grossenheider 1976). Ermines use mature, dense stages of forest habitats for breeding, and adjacent lower seral stages (grass/forb) and forest/meadow ecotones for feeding (Zeiner et al. 1990).

Most cover requirements for the ermine is provided by natural cavities in stumps, logs, uprooted trees, rock areas, under human structures, or in burrows (Zeiner 1990). Ermines den under stumps, logs, uprooted trees, rocks, human structures, or in burrows. They often use nests of prey, lined with hair from prey carcasses. They apparently breed in late spring and summer. Gestation may last up to 255 days, including delayed implantation. Embryos implant and begin development about 8 weeks prior to birth (Jackson 1961). Litter size averages 4-6, and ranges from 4-13 (Hall 1951, Maser et al. 1981). Females bear one litter per year; both parents care for young, which are weaned at about 5 weeks. Females become mature sexually during the first summer and usually mate, bearing their first litter the following spring. Males are probably not mature sexually until they reach 1 year of age (Maser et al. 1981).

Burt and Grossenheider (1976) reported that home ranges varied from 10-15 ha (25-37 ac). Population numbers vary with small mammal population fluctuations. Ermines usually change pelage color from brown to white in snow conditions. Agility, small size, and slender shape provide specialization as a predator of small mammals (King 1983).

Ermines are carnivorous. They eat small mammals, especially voles (*Microtus* spp.), as well as shrews (*Sorex* spp.), shrew-moles (*Neurotrichus gibbsii*), immature rabbits, chipmunks (*Tamias* spp.), deer mice

(*Peromyscus maniculatus*), jumping mice (*Zapus* spp.), and house mice (*Mus musculus*). Other prey items include small birds, frogs, small fish, and earthworms. Ermines forage widely during day and night hours, above and below ground and snow, in rock areas, in snags, stumps, and logs. They are know to pursue small mammals into their tunnels, runways, and burrows (Zeiner et al. 1990). Ermines are prey for mink, marten, fisher, bobcats, coyotes, and large owls and hawks, as well as domestic dogs and cats (*Felis catus*).

Long-tailed Weasel (*Mustela frenata*)
Long-tailed weasels are common to uncommon, permanent resident of most habitats, except xeric brush, shrub, and scrub in the Mojave and Colorado deserts (Grinnell et al. 1937). Weasels primarily use intermediate cover stages of conifer and deciduous habitats, interspersed with lower seral stages and open forest, woodland areas and shrubs, from sea level to alpine meadows (Zeiner et al., 1990). Long-tailed weasels use a mixture of intermediate cover stages of conifer and deciduous habitats for breeding, and lower successional stages and open forest, woodland, and shrub habitats for feeding (Zeiner et al. 1990).

Long-tailed weasels find cover in small cavities in the ground, rock areas, logs, snags, stumps, and burrows of prey and other mammals. Nests of long-tailed weasels are often located in burrows of chipmunks, ground squirrels (*Spermophilus* spp.), gophers (*Thomomys* spp.), moles, or mountain beavers (*Aplodontia* spp.). They also nest in cavities in trees, snags, logs, and under rocks or human structures. Mating occurs in July or August. Gestation averages 279 days and ranges from 205-377 days, including delayed implantation. Embryos implant 27 days before birth. Most young are born in April or May. Females bear one litter of 4-9 offspring per year; both parents care for young. Young begin to eat meat at 21-25 days, and are weaned at about 35 days. Females become mature sexually at 3 months, and breed during their first summer estrus. Males mature sexually at 10-11 months, during the onset of the spring molt (Wright 1947, 1948; Hall 1951).

Burt and Grossenheider (1976) and Quick (1951) report home rang sizes of 10-20 ha (25-50 ac). In good habitat, average density may be 1 weasel/km ^{2} (2.6/mi ^{2}) with a maximum of about 7/km ^{2} (18/mi ^{2}). In eastern Oregon, the suggested minimum area required by a pair of long-tailed weasels is approximately 259 ha (640 ac). Their populations respond to small mammal population numbers.

They molt to a white pelage in areas where snow is common (Zeiner et al. 1990). Long-tailed weasels are tolerant of most human activities and are often responsible for causing damage to irrigation channels and predating farm animals such as chickens and ducks.

Long-tailed weasels are carnivorous. They eat small mammals such as mice, gophers, chipmunks, ground squirrels, and rabbits. They also take birds, some insects, salamanders, and small amounts of fruit. Foraging occurs on the ground, among rocks, in snags, stumps, logs, wood piles, in brush, and occasionally in trees. Long-tailed weasels hunt day and night (Zeiner et al. 1990). This species is preyed upon by mink, marten, fisher, bobcats, coyotes, red foxes (*Vulpes vulpes*), and gray foxes.

Badger (*Taxidea taxus*)
Badgers are uncommon, permanent residents found throughout most of the state except in the northern North Coast area (Grinnell et al. 1937). Suitable habitat for badgers is characterized by herbaceous, shrub, and open stages of most habitats with dry, friable soils (Zeiner et al. 1990).

Badgers dig burrows in friable soils for cover. They frequently use old burrows, although some may dig a new den each night, especially in summer (Messick and Hornocker 1981). Badgers are common throughout much of central and western North America, but surprisingly little is know about their ecology and behavior (Sargeant and Warner 1972). Although not widely studied, badgers are know to be sometimes pests to agriculture, damaging crops, property and irrigation systems and prey on domestic fowl (Johnson 1983). Non-specific trapping and pest-control has had an impact on the species possibly contributing to eradication in some areas of the state. Although active year-long and non-migratory, badgers show a marked reduction in area used during the winter period is known for the species. Daily movement patterns indicated a strong nocturnal behavior, with daytime denning, although diurnal activity is also common. In winter, badgers become torpid but do not hibernate. Badgers, are primarily terrestrial; however, they do swim and even dive and may cool themselves in water on hot days.

Young are born in burrows dug in relatively dry, often sandy soil, usually in areas with sparse overstory cover. Badgers mate in summer and early fall. Gestation lasts 183-265 days, including delayed implantation. Embryos implant about 45 days prior to birth. An average litter of 2-3 (range = 2-5) born mostly in March and April (Long 1973). Young are altricial at birth, furred, and blind. Weaned in June, they disperse in late summer. The breeding season begins in the summer and continues into the fall. A few females may breed in the first year with males not maturing sexually until their second year. (Fowler 1931, Jackson 1961, Long 1973, Messick and Homocker 1981).

Density estimates have been reported by Hein and Andelt, (1995) to be 0.28/km^2, by Lindzey, (1971) to be 0.38/km^2, by Messick and Hornocker, (1981) to be 5/km^2, and by Clark et al. (1982) to be 1.83/km^2. Sargeant and Warner (1972) measured the home range of a single female badger in Minnesota and found three distinct patterns of home range use. In the summer period (29 July to 27 September) the badger occupied 764.5 ha (1,889 ac). During the autumn period (30 September to 30 November) the area used was 52.6 ha (130 ac). In the winter period (2 December to 9 January), home range size was restricted to a 2 ha (5 ac) area.

Badgers are carnivorous, feeding on rodents: rats, mice, chipmunks, ground squirrels, and pocket gophers. Badgers are also somewhat opportunistic sometimes eating reptiles, insects and carrion. Badgers change foraging habits in response to fluctuating prey (Messick and Hornocker 1981). Badgers may not be harmed by the venom of rattlesnakes and have few natural enemies. Whitaker (1989) describes a situation where coyotes sometimes benefit from prey that may be trying to evade a pursuing badger.

Western Spotted Skunk (*Spilogale gracilis*)
Western spotted skunks are common to uncommon, permanent residents in most habitats, except high mountains and those that are very dry, such as the Mojave and Colorado deserts (Grinnell et al. 1937). The California spotted skunk, *S. g. phenax,* ranges throughout most of the state west of Sierra Nevada crest, north from Kern County to southern Humboldt, Trinity, and Siskiyou counties (Belluomini 1980b). They occur in shrub and brush habitats with moderate canopy-closure and inhabit open forest and woodland with scattered openings, and riparian habitats (Zeiner et al. 1990). Western spotted skunks require a large diverse interspersion of cover in moderately open shrub and open forest habitats with herbaceous inclusions. Tree/shrub and shrub/herbaceous edges are frequented. Logs, stumps, slash, other woody debris, and cavities and crevices of all sorts enhance habitat for foraging and denning.

Spotted skunks use brushy areas, brush piles, slash, rock areas, burrows, and hollow logs, snags, and stumps for cover (Zeiner et al. 1990). Natal dens may be found in cavities, burrows, and natural crevices; in trees snags, logs, stumps, in rock areas, brush piles, and under buildings. Mating occurs in September and October. Gestations lasts 210-230 days, including delayed implantation. Embryos implant 28-31 days prior to birth. A female gives birth to one litter per year (average 4, range 2-6); most born in April and May (Mead 1968, Maser et al. 1981). Young are weaned at about 8 weeks, and young accompany females on foraging trips into autumn. Males and females mature sexually at 1 year.
Home ranges of males averaged 518-1036 ha (1280-2560 ac) during spring and summer, and 65 ha (160 ac) for both males and females

during the winter (Crabb 1948). Individuals seldom traveled further than 0.4 km (0.2 mi) from the central den during winter. Crabb (1948) estimated a population density of 5/km^2 (13/mi^2) for the non-territorial species.

Spotted skunks are omnivorous. Their diet consists primarily of insects and small mammals, along with reptiles, birds, eggs, carrion, fruits, and grains. They forage primarily on the ground, often digging, and occasionally climbing into low trees and shrubs (Zeiner et al. 1990). Domestic dogs, great horned owls, and humans appear to be the primary predators.

Striped Skunk (*Mephitis mephitis*)
Striped skunks are common, yearlong resident from sea level to timberline (Grinnell et al. 1937). The most extensive in occurrence is the northern California striped skunk, *M. m. occidentalis,* which occupies nearly all the areas of western and northwestern California, south to Monterey Bay and east to the Sierra Divide (Belluomini 1980c). Striped skunks are found in nearly all habitats but frequent earlier seral stages of conifer and deciduous forests, and intermediate-canopy stages of brush and scrub areas; commonly found in grass/forb stages of most habitats, riparian areas, and many natural, and human induced, herbaceous shrub and forest ecotones. They are absent from many xeric areas of the Mojave and Colorado deserts (Zeiner et al., 1990). Good habitat for striped skunk includes a complex mosaic of brush stages of forest habitats, riparian areas, meadows, or other open areas in brush and forest habitats. Striped skunks use edges between types exclusively. Logging, agriculture, and urban developments that create open areas, fragmented habitats, and mosaics of vegetation may improve habitat for striped skunks allowing them to expand their range (Zeiner et al. 1990).

Striped skunks use cavities and crevices in rock areas, snags, logs, stumps, under buildings, and abandoned burrows for cover. They excavate burrows in friable well drained soils, and may also den above ground in heavy cover (Zeiner 1990). Striped skunks den in burrows excavated in friable, well drained soils, or crevices in rock areas, snags, logs, stumps, and under buildings. Breeding occurs from late January through March (Verts 1967). Gestation lasts about 63 days on average (range 59-77 days). Females bear one litter per year of about 4 young (range 2-10) which are born April through June (Verts 1967, Maser et al. 1981). Young are weaned at 60-75 days. Both males and females mature sexually at 10 months (Wade-Smith and Verts 1982).

Storm (1972) reported home ranges of striped skunks in Illinois as varying between 34-753 ha (83-1,869 ac). Winter movement were restricted to a small area near the central den in areas of winter snow. Strom also reported females moved about freely within the home ranges of several males. In captivity, adult males and pregnant, or lactating females must be housed separately. Territory size was reported by Thomas (1979) to be 17-38 ha (43-95 ac). Thomas also estimated the minimum area required for a population in eastern Oregon to be about 259 ha (640 ac).

Striped skunks are omnivorous. They eat primarily insects, small mammals, other small vertebrates, eggs, crustaceans, fruits, seeds, and some carrion. Foraging includes searching for food on the ground, often digging, in stumps and under logs, (Wade-Smith and Verts 1982). Great horned owls, eagles, coyotes, badgers, foxes, and bobcats are known to prey on striped skunks.

STATUS AND MANAGEMENT CONSIDERATIONS

With the exception of the ringtail, which is fully protected in California; the raccoon, ermine, long-tailed weasel, badger, striped and spotted skunk are harvestable species and may be taken in California during the hunting/trapping season. Although all are technically furbearers, California hunting regulations considers only the badger and raccoon as such, while the weasels and skunks are considered non-game mammals.

The genus *Bassariscus,* which includes the ringtail, is fully protected in California under Fish and Game Code § 4700. As a fully protected mammal, members of this genus may not be taken or possessed for any purpose unless specifically authorized for scientific purposes. The badger is included on the California Department of Fish and Game's list of Mammalian Species of Special Concern (Williams 1986). This list includes species or subspecies of mammals that are declining in California, some of which may be on the verge of extinction but are not. Designated by the Fish and Game Commission as threatened or endangered. This list was compiled by the Department for administrative purposes to identify potentially endangered species or subspecies in need of research and management attention. Status as a "Species of Special Concern" is not a classification under any California Administrative Code, and a species so listed is not afforded any additional protection under State law.

The Environmental Impact Report for the trapping and hunting program administered by the Department of Fish and Game estimated the population size of those species classified as harvestable and subject to recreational or commercial taking (Table 1). Population estimates and densities for California were calculated by multiplying the total number of suitable acres of habitat for each species by the high and low density estimates from studies reported in the literature.

MITIGATION

Snags, cavities, logs, stumps, brush piles, and rock outcrops are all valuable habitat attributes for these species. . Recent past land management practices have specifically targeted many of these features for removal to satisfy safety and fire protection purposes. Current use of cull trees for chip and pulp production has further diminished the availability of snags and logs across the landscape for these and many other forest species as well.

Protection of snags, trees with cavities, logs, stumps, and rocks, especially within 60 m (200 ft) of streams will enable these species to find adequate denning and resting sites in areas frequently used for movement across and between adjacent habitat types. Consideration should also be given to retaining adequate numbers of green replacement trees for future recruitment as snags and logs.

DAMAGE CONTROL

Badgers eat primarily rodents but will also eat young rabbits or destroy nests of ground nesting birds and occasionally kill small lambs and poultry. Dens in crop fields may slow harvesting or cause damage to machinery, and the digging can damage earthen dams or dikes (Lindzey 1994). Badgers usually eat all of their prey except the head; however, signs of digging near prey remains are the best evidence of badgers. Badger tracks often appear similar to coyote tracks but on close examination they are distinctly "pigeon-toed" with impressions from the long toenails apparent (Dolbeer et al. 1994). Badgers can be excluded from an area with fencing. The fence should be buried to a depth of 12-18 inches. Control of rodents will discourage badgers by eliminating their prey base. Badgers can be live trapped using a dead chicken as bait.

Raccoons will eat almost anything, with garbage cans and pet foods being major sources of food in urban areas. They will occasionally kill small lambs, usually by chewing the nose. Occasionally, raccoons will enter poultry houses and take several birds in one night. There may be bits of flesh near water left behind following a raid by raccoons. Raccoons leave a distinctive five-toed track that resembles a small human hand print. Tracks are usually paired, the left hind foot beside the right forefoot (Murie 1954). Raccoon tracks may be difficult to identify in soft sand where toes do not show. Removal of food, which may be attracting raccoons is usually effective in discouraging their presence. Wire-mesh fences with overhangs can be effective in excluding raccoons from larger areas.

Table 1. Population and density estimates for California furbearer and nongame mammals (California Dept. Fish and Game 1997).

Species	Suitable Acres (mi^2)	Population Estimate	Calculated Density ($/mi^2$) Low	High
Raccoon	123,403	29,619 - 86,382	0.24	0.70
Ermine	29,119	291,195 - 815,319	10.0	28.0
Long-tailed weasel	91,849	238,809 - 1,653,290	2.60	18.0
Badger	96,362	96,362 - 1,252,705	1.00	13.0
Western spotted skunk	87,718	87,718 - 499,992	1.00	5.70
Striped skunk	79,968	103,958 - 495,801	1.30	6.20

Raccoons are easily captured using a large box type trap.

Skunks eat primarily insects and dig cone shaped holes in lawns, and meadows in search of beetle larvae. A common complaint is the objectionable odor accompanying skunks should they take up residence under buildings. Skunks may predate bee-hives. Skunks are serious nest robbers, opening eggs at one end a licking out the contents. Eggs are rarely removed from the nest any distance greater than 1 m (3 feet). Rabbits and bird carcasses are mauled when taken as carrion by skunks, small rodents may have bites and chewing around the head and foreparts but the carcasses are rarely eaten. Inhabited dens can be recognized by fresh droppings containing undigested insect parts near the mound or hole. Hair and rub marks also may be present. Dens usually have a characteristic skunk odor, although the odor may not be strong (Dolbeer et al. 1994). Areas under buildings should be blocked off with wire mesh, sheet metal or concrete. Bury fencing 1-2 feet where skunks can gain access by digging. Naphthalene in high concentrations can be an effective repellent for enclosed areas and ammonium soaked rags can also repel skunks. Skunks are easily captured using a box type trap.

Weasels kill prey by biting through the skull, upper neck, or jugular vein (Cahalane 1961). When they raid poultry houses at night, they often kill many birds, eating only the heads. When feeding on small rodents, weasels may make a small opening at the back or side of the neck. As the flesh and pieces of the adjacent hide are eaten, the ribs, head, and hindquarters are pulled through the same hole and the animal is skinned, turning the pelt inside out. Weasels may be more valuable in controlling small rodent population than a nuisance to humans. They are easily trapped using a box type trap and fresh meat as bait.

SURVEY TECHNIQUES

The following methods and techniques are listed to provide a range of options to consider for use in detecting small mesocarnivores.

> Scent stations, spotlighting, headlight surveys, road mortality, and numbers of captures per 10000 trap nights have been used to monitor badger populations (Johnson 1983). Using Softcatch traps with attached tranquilizers, and snares, Hein and Andelt 1994, captured 15 of 18 badgers in July and August, with an overall trap-success rate of 4.5 badgers / 1000 trap nights.
>
> Scent stations: Hein and Andelt, 1994 describe construction of scent stations. Conner et al., 1983, describes the efficacy of using scent station indices for population estimates. These same researchers in 1995 studied various scent attractants for badgers and coyote.

Carmens Canine Call was used to capture 12 of 20 badgers in their study area, the Rocky Mountain Arsenal, in Colorado. Visitation to scent stations was considered too low to provide and adequate population index.

Spotlighting: See Clark et al., 1982, and Messick and Hornocker, 1981.

Headlight surveys: Involves scanning roads and right-of-ways (Heir and Andelt, 1994).

Road mortality: Case 1978, analyzed data from seven species of road killed animals including skunk, raccoon, and badger. Most animals exhibited two periods during the year when they suffered greater mortality. Biologically, it appeared the two peaks were related to reproductive activities (courtship or young rearing) and dispersal. October had the highest mortality and January the lowest. No correlation was found with mortality and traffic on a monthly of annual basis while significant correlation was found between morality and traffic speed. Estimates conducted over a short period of time are highly susceptible to variation in weather, and other environmental factors.

Scat: Sargeant and Warner, 1972 cite Snead and Hendrickson, 1942, as finding similar evidence that badgers are secretive in their defecation habits and frequently deposit scats at the bottom of shallow excavations or bury them the mounds of earth at the entrances to burrows.

Tranquilizers: Balser, 1965 describes a method for adding a tranquilizer (diazepam) to the bait or trap help reduce injuries and minimize escape.

Sooted track plates: Sooted track plates have been successfully used in a variety of habitat types proving adept at identifying amongst other species, skunks, racoons, and ringtails (See Fowler and Golightly 1993).

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Bobcat (*Felis rufus*) Ecology and Management

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Description

The bobcat (*Felis rufus*) is a medium sized predator in the family Felidae found exclusively in North America. Extensive natural history information is available and is summarized in several bibliographies and reviews (Sweeny and Poelker 1977, McCord and Cardoza 1982, Boddicker 1983, Anderson 1987, Rolley 1987). The bobcat is a spotted cat with a short white-tipped tail, small dark ear tufts and is about twice the size of the house cat (*Felis domesticus*) because of the bobcat's longer bone structure (McCord and Cardoza 1982, Jameson and Peeters 1988). The bobcat weights between 5-15 kg with males larger than females. TL 700-1000, T 95-150, E (from crown) 60-75 (Jameson and Peeters 1988).

Taxonomy

The bobcat and lynx (*Felis lynx*) were placed into the same genus because of their ability to hybridize (McCord and Cardoza 1982). They also pointed out that the 11-14 proposed subspecies of bobcat exhibited little taxonomic differentiation and had little biological or management meaning. The taxonomy remains controversial and many authors think that lynx should be elevated to genus (Rolley 1987).

Distribution

The bobcat was historically distributed throughout the lower 48 United States and southern Canada, but has been extirpated in population centers of the central Atlantic coast and the mid-western states (Rolley 1987). In California the bobcat is common to uncommon permanent resident in almost all of the habitats throughout the state (Figure 1) (Ahlborn 1982).

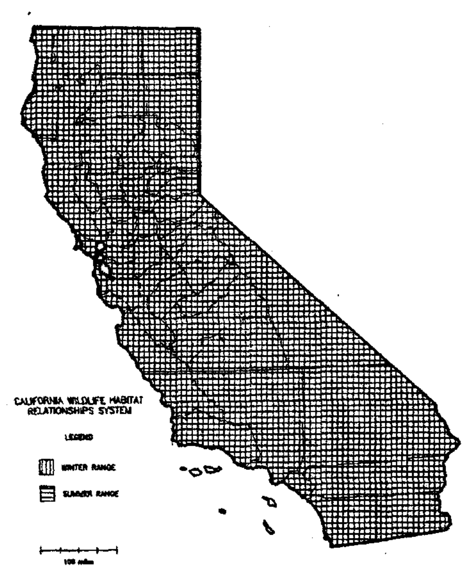

Figure 1. Distribution of bobcat in California (from Zeiner et al. 1990).

Reproductive Biology

Breeding Season

Mating occurs in late winter with births in the spring and early summer after a gestation period of approximately 50 days (Jameson and Peeters 1988). Average litter size is 2.4 (SE = 0.09) from 21 studies nationwide (Anderson 1987). Females are capable of breeding between 9-15 months but the percentage of females that actually conceive increases until about 3 years (Rolley 1987).

DEMOGRAPHY

Home Range

The home range of bobcats varies form 0.6 to 201 km^2 (McCord and Cardoza 1982). Male home ranges are generally twice the size of female home ranges. Female home ranges averaged from 19.3-28.5 km^2 across the country (Ahlborn 1982, Rucker et al. 1989, Lovallo and Anderson 1996). Male home ranges averaged from 42.1-64.2 km^2 across the country (Ahlborn 1982, Rucker et al. 1989, Lovallo and Anderson 1996). Home range shifts can occur rapidly with changes in prey base or the removal of conspecifics (Rolley 1987, Lovallo and Anderson 1995).

Dispersal

Despite all the literature on home ranges and habitat use, little is known about dispersal of young after they have left the den and protection of their mother.

Survivorship

Survivorship of adults in unexploited populations is quite high, 3% mortality, and juvenile survivorship is low, approximately 30 (Anderson 1987, Rolley 1987). In exploited populations survivorship of adults is about 53-66% and juvenile survivorship increases probably because of increased food availability (Anderson 1987, Rolley 1987). Natural causes of mortality are disease, starvation, predation, and injuries from prey (Rolley 1987). Fuller et al. (1995) reported that other causes of mortality in addition to hunting and trapping could be quite high, 53%.

FOOD HABITS - PREDATOR/PREY RELATIONSHIPS

The bobcat is a carnivore that can take a broad range of prey, mice, rabbits, birds, and deer (McCord and Cardoza 1982, Jameson and Peeters 1986, Rolley 1987). As with many predators, individual bobcats can become specialists on a particular prey species. Seth Riley (University of California, Davis, pers. comm.) had one male bobcat take adult and juvenile black-tailed deer (*Odocoileus hemionus*). Donagen (1994) found in a study of bobcat foraging behavior that they apparently tracked their capture success daily and responded to a decline in capture efficiency by changing hunting areas.

CONSERVATION STATUS

The bobcat is protected as a furbearer under California Department of Fish and Game (CDFG) Code, and harvest by trapping and hunting is regulated. Although the CITES quota for bobcat harvest is 14,400 per year, in 1996, 660 bobcat were trapped for the fur trade, an additional 410 were hunted, and 61 for depredation in California (Bill Grenfell, CDFG, pers. comm.) This contrasts markedly with the thousands of pelts sold in the mid-1970's and reflects the reduced demand for animal furs in the United States.

Population Trends

The population of bobcat in California is probably quite stable for the habitat available.

HABITAT REQUIREMENTS

The bobcat is adapted to a wide variety of habitats (McCord and Cardoza 1982). Suitable habitats for bobcat consist of rough, rocky terrain with brush lands, deciduous and conifer forest, chaparral, riparian habitat, and dense forest. (Ahlborn 1982). Availability of water may limit bobcat density in desert regions (Ahlborn 1982). Bobcats use brush piles, hollow logs, cavities in rocky areas, snags, stumps, or dense brush for cover and reproduction (Ahlborn 1982, McCord and Cardoza 1982).

Effects of Forest Structure, Use Openings or Non-forested Habitat

In a habitat suitability index (HSI) model develop for bobcat in the southeastern United States, Boyle and Fendley (1987) stated that bobcat were most abundant during early to mid-successional habitats and that food abundance was an important factor affecting distribution and abundance.

SURVEY TECHNIQUES

Presence of bobcat can be determined by tracks, scat, or visual observation (Spowart and Samson 1986). Smoked track plates are a useful tool for determining presence and relative abundance of bobcat (Barrett 1983, Howell and Barrett 1997 (in press)). We have also found during our research that remote cameras such as those made by Trailmaster[TM] are very effective for detecting bobcat in an area. Radio telemetry and capture-recapture techniques are necessary for home range and population size estimates. Use of padded leg-hold traps are effective and efficient for capturing bobcat. Box traps have been successfully used when care is take to place them in high use areas as demonstrated by accumulations of scat (Seth Riley, University of California, Davis, pers. comm.)

MANAGEMENT CONSIDERATIONS

Fuller et al. (1995) found that half the mortality of exploited populations came from other sources and that in managing bobcat populations it was necessary to have good estimates to prevent declining populations. They recommend the need to identify more reliable indices of bobcat abundance, food, and disease, and to better monitor illegal harvest.

Response to Human-caused Disturbance

Bobcat have utilized human features on ranches in their home range as travel routes or as hunting platforms (Bradley and Fagre 1988). In areas of high human use and no exploitation bobcat can be regularly seen in various stages of hunting and resting. In coastal scrub habitat bobcat readily responded to areas of prescribed burn and took advantage of the open habitat that exposed meadow voles (*Microtus californicus*) for food. In heavily gazed annual grassland that supported no meadow voles bobcat ate pocket gophers (*Thomomys bottae*). Seth Riley (University of California, Davis, pers. comm.) found that a male bobcat used the area over a highway tunnel as a corridor to additional hunting habitat.

Mitigations

As Fuller et al. (1995) pointed out accurate monitoring methods need to be developed to assess population trends in modified habitats. Maintenance of suitable foraging habitat with abundant prey species is probably the most important mitigation measure. Second, maintaining suitable habitat for cover and reproduction should support bobcat populations in modified habitats.

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Biology and Ecology of the Non-Native Red Fox (*Vulpes vulpes*) in California

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Description

The non-native red fox is typical of red foxes in appearance and description. It is a smaller member of the family Canidae, and is the largest member of the genus Vulpes. Their name is derived from their color, which may vary from deep rufus to a strawberry-blond. The non-native fox exhibits the three color phases (red, cross, and silver) typical of native red foxes, however foxes exhibiting the cross and silver phases are seldom seen in California. They are recognized by their appearance as a small slim canid as well as their color, pointed ears, narrow nose, and white-tipped tail. They can be confused with gray foxes (*Urocyon cinereoargenteus*), which are common in California, similar in size, and have an orange red coloration on their throat and belly. Red foxes exhibit sexual dimorphism, with females averaging 104 cm in total length and weighing about 4.25 kg, while males average 110 cm and weigh about 5 kg. The tail makes up about 35% of the total length. Juvenile foxes reach adult size by late fall (Lewis and Golightly, in prep.). Although the non-native red fox is a larger fox than the native Sierra Nevada red fox (*V. v. necator*) (Lewis and Golightly, in prep.), there is no known characteristic with which to distinguish the two foxes visually (Lewis et a1. 1995). Interested readers should see Grinnell et al. (1937), Storm et al. (1976), Lloyd (1980), Macdonald (1987), and Voigt (1987) for more comprehensive descriptions of the red fox.

Taxonomy

The red fox is one of three species within the genus *Vulpes* that occur in North America. The other two include the kit fox (*V. macrotis*) and swift fox (*V. velox*), which are smaller, arid-land foxes. No subspecific status has been given to non-native red foxes. A skull morphometrics investigation by Roest (1977) indicated that non-native red foxes from the Sacramento Valley were more closely related to Midwestern red foxes (*V. v. regalis)* than to native Sierra Nevada red foxes. Further, significant differences between gross morphological features of non-native red foxes and specimens of the native Sierra Nevada red fox indicate they have differing evolutionary histories (Lewis and Golightly, in prep.). Non-native foxes have been brought to California since the late 1800s from a number of regions for fox hunting, fur farming, and pets (Lewis et al. 1995). Consequently, non-native red foxes that occur in California today have descended from a diverse genetic base of ancestors, and have not been given subspecific status due to the confusion this genetic background causes.

Range

The red fox has the largest geographic range of any carnivore (Lloyd 1980, Voigt 1987). The introduction of non-native foxes to previously unoccupied regions (e:g., Australia) has greatly expanded this range (Macdonald 1987). Non-native red foxes occur throughout many of the lowland areas of California (Figure 1). They were first discovered in the Upper Sacramento Valley around 1885 (Grinnell et al. 1937). However, their range has expanded exponentially in the last 100 years to include the entire Sacramento Valley and northern Bay Delta Area by the early 1970s (Gray 1975), and the San Joaquin Valley, valleys in the southern Coast Range, and much of the lowland coastal areas from Monterey south to San Diego by the early 1990s (Lewis et al. 1993). Since we cannot visually distinguish native foxes from non-native foxes, it is possible that non-native foxes now occur within the range of the native Sierra Nevada red fox (Lewis et al. 1995). A number of fox farms were known to occur within the historical range of the Sierra Nevada red fox (as described in Grinnell et al. 1937) and releases of non-native red foxes have occurred within the historical range (Lewis et al. 1995).

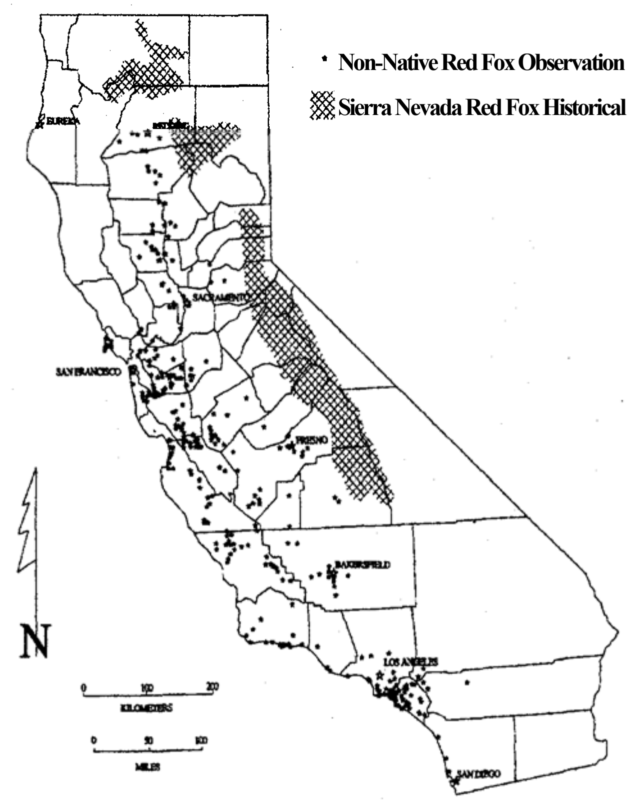

Figure 1. Distribution of non-native red foxes in California (modified from Lewis et al. 1993).

Reproductive Biology

Red foxes typically breed between late December and early March. Non-native red foxes in southern California bred from early January to mid February, with the peak breeding period occurring in mid to late January (Lewis and Golightly, in prep.). Females and males are capable of breeding at one year of age, and males may breed with more than one female during the breeding season. Pups are born in March and early April in southern California (Lewis and Golightly, in prep.), after a 52 day gestation period (Pearson and Bassett 1946). Average litter sizes from 4 to 8 pups have been reported (Voigt 1987), but litters of as many as 17 pups have been documented (Holcomb 1965). However, 2 reproductive females may combine their litters into a single den, confounding litter size estimates (Sheldon 1950, Tullar et al. 1976). In southern California, Lewis et al. (1993) found a mean litter size of 4 pups (range = 1-9) based on 7 litters. One litter of 9 pups was suspected to be a combined litter because of size differences among the pups, suggesting different birthdates and mothers. The sex ratio among pups in a litter is typically skewed toward one sex (Storm et al. 1976). Both males and females provide food for the pups. "Helpers," which are females from the parent's previous litter(s) (Macdonald 1979), may also provide food for the pups and act as a babysitter when the parents are away from the den. Red foxes may use a number of dens while raising their pups (Sheldon 1950).

Demography

Densities of red foxes have been described in numbers of fox families per km^2; where a conservative estimate of mean family size would be 6 foxes (2 adults and 4 pups). Densities in rural habitats are usually much lower ($\geq$ 0.50 families/km) than densities in urban areas (1 3.5 families/km^2). At one urban park in their southern California study area, Lewis et al. (1993) and Yaeger and Golightly (1994) used spotlight counts of marked and unmarked foxes and estimated densities of 14-18 foxes/km^2. Supplemental food provided for the foxes (Golightly et al. 1994) was thought to be largely responsible for the high densities and small home range sizes (0.63 ± 0.09 km^2, n = 6 foxes; Lewis 1994) of foxes at this park (Lewis et al. 1993). Larger home ranges were observed for foxes that resided outside this park (4.83 ± 1.22 km^2, n = 11 foxes; Lewis 1994) although some feeding occurred wherever foxes resided (Golightly et al. 1994).

Dispersal in red foxes has been characterized as male-dominated because males disperse more often than females and males typically disperse greater distances than females (Storm et al. 1976, Greenwood 1980, Trewhella et al. 1988). In urban southern California, males dispersed more often than females (36% vs. 11%) and juveniles disperse more often than adults (27% vs. 13%) (Lewis 1994). Red foxes in rural environments typically disperse greater distances than urban red foxes (Trewhella et al. 1988). Mean dispersal distances for rural foxes in Iowa and Illinois were 19 and 16 km for males and females, respectively (Phillips et al. 1972), while these distances were 8.8 km (n = 5 males) and 2.4 km (n = 1 female), respectively, for urban foxes in southern California (Lewis 1994). Dispersal distances of >200 km, however, have been reported for rural red foxes (Longley 1962, Ables 1965, Storm et al. 1976). Dispersal commonly occurs from late summer to March (Storm et al. 1976).

Survival varies significantly among the sex and age classes, with juvenile males having the lowest survival rates, followed by adult males, and then by females (Lewis 1994). In Orange County, California, low survival rates for juvenile males reflected the risks of being an inexperienced disperser; 3 of 5 radio-collared juvenile males were killed while dispersing. Storm et al. (1976) reported that survival rates (presumably annual) for foxes tagged and commercially trapped in the Midwest. They estimated survival rates of 0.18 for foxes tagged as juveniles and 0.23 for foxes tagged as adults. Urban foxes, that received no trapping pressure, had survival rates ≥ 0.43 (Lewis 1994). Survival rates for red foxes in rural areas of California, which presently receive no commercial trapping pressure, are unknown. Causes of mortality include predation by larger canids (e.g., dogs and coyotes), vehicle collisions, disease, accidents, and predator control efforts.

Food Habits

The diet of the red fox is composed of a wide variety of foods. It includes small and medium-sized birds and mammals (including livestock), insects, fruits and other plant material, carrion, herpetiles, refuse, and eggs (Korschgen 1959, Harris 1981, Macdonald 1977, Doncaster et al. 1990, Golightly et al. 1994). A major component of the urban red fox diet is human-provided foods; i.e., handouts given to foxes, specifically (Golightly et al. 1994). In urban southern California, Golightly et al. (1994) found that invertebrates, mammals, and seeds were found in > 64% of 449 scat samples, while birds and refuse material were found in > 40%.

Population Trends

Since the late 1800s, the distribution of the non-native red fox of California has expanded from the northern Sacramento Valley to include most of the lowland areas west of the Sierra Nevada (Lewis et al., in review). Their range expansion exhibits the exponential growth typical of many invading species (Hengeveld 1989). It is reasonable to assume that this dramatic range expansion was the result of population growth as well as further introductions by humans. Population growth in California may still be occurring as foxes colonize unoccupied habitats.

Habitat Requirements

Red foxes are habitat generalists. They occupy habitats as varied as arctic tundra, arid deserts, forested farmland, and urban centers (Macdonald 1987). However, some features of fox habitat appear consistent across ecosystems. Red foxes are typically found in the vicinity of open areas, however a variety of habitat types may be interspersed among these open areas within an individual fox's home range. Lewis et al. (1993) reported that 57% of non-native red fox observations (n = 124) in northern California were associated with grassland, agricultural, or wetland habitats. These open areas allow foxes to use their keen eyesight to detect danger (e.g., dogs, coyotes, humans) from a distance; their speed allows them to escape this danger quickly. These open areas commonly provide access to small mammals and ground nesting/roosting birds that often make up the bulk of the red fox diet (Golightly et al. 1994).

Survey Techniques

Like many mesocarnivores, trends in red fox populations are commonly detected by changes in harvest levels. However, since non-native red foxes are not commercially harvested in California, other techniques to assess their presence, distribution, and abundance are necessary. Fortunately, red foxes are easily identified even by untrained observers, and they typically occur in open areas and suburban/urban areas, where they are readily detectable (Lewis et al. 1993). Consequently, determining the presence and distribution of non-native red foxes could be accomplished efficiently by conducting telephone interviews with wildlife professionals across the state (Lewis et al. 1993). Surveys by rural mail carriers (Allen and Sargeant 1975), and surveys of urban school children (Harris 1981) have also been used to assess red fox populations. Red foxes have been detected at camera stations in the Sierra Nevada (Kucera 1995), however our ability to consistently detect their presence using camera and track-plates stations (see Zielinski and Kucera 1995 for techniques) has not been formally tested. Labor intensive surveys (e.g., spotlight surveys, track surveys) are successful but are not necessary to detect red foxes, as many if not most red foxes are detected incidentally (e.g., observations of road-killed foxes, fox families, and den sites).

MANAGEMENT CONSIDERATIONS

Management of non-native red foxes has been focused on reducing their impacts on native fauna, especially predation on endangered species. Since their introduction red foxes have colonized a number of coastal areas that provide habitat for several of California's rarest birds (Burkett and Lewis 1992, Zembal 1992, Lewis et al., in review). Protection for the light-footed clapper rail (*Rallus longirostris levipes*), California clapper rail (*R. 1. obsoletus*), and the California least tern (*Sterna antillarum browni*) involved trapping and euthanization of red foxes (Witmer et al. 1996). However, animal rights groups were opposed to trapping and euthanization, and brought their concerns to the courts (U. S. Fish and Wildlife Service and U. S. Navy 1990). Animal rights groups suggested distributing red foxes to other states, but no other state would accept them. They also suggested placing red foxes in zoos, however, with 2 exceptions, those zoos questioned did not need or want additional red foxes. Although trapping and euthanization were approved by the courts as a means of red fox management, opposition to trapping and euthanization from animal rights groups remained strong. Animal rights groups have opposed a commercial trapping season proposed for non-native red foxes in California. Consequently, the proposal was not accepted by the California Fish and Game Commission. Additionally, animal rights groups suggested that a fox reserve be created to protect a fox population in the southern Bay-Area at Shoreline Park in Mountain View, California. The groups suggested that coyote urine could be placed at the perimeter of the designated reserve which would prevent foxes from leaving the reserve and becoming threats to nearby endangered species. A consulting firm hired by the City of Mountain View to evaluate the proposal concluded it would be ineffective, and consequently, the proposal was rejected.

Most management concerns surrounding the non-native red fox have involved the protection of endangered species and the controversy that resulted from trapping and euthanizing red foxes. Little or no attention has been given to the potential for this population of non-native red foxes to transmit diseases to humans, pets, and native fauna. The extensive distribution, urban/suburban affinities of some red foxes, and the extensive interactions between foxes and humans, pets, and other wildlife makes this an important issue. Management concerns involving additional endangered species that could be affected by non-native red foxes also deserve attention.

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Biology and Ecology of Feral, Free-Roaming, and Stray Cats

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TAXONOMY

Feral cats are the free-roaming offspring of the domestic cat, *Felis catus.* They generally fall into two categories: 1) domestic animals adapted to living on their own in rural and urban areas; or 2) homeless, lost, or abandoned pets that live on their own (Roberto 1995). The cat is a medium-sized carnivore of the family *Felidae* which usually weighs between 3.3 and 4.5 kg and measures between 73 to 79 cm in length (Nowak 1991). The ancestral wild species, the European and African wild cat, *Felis silvestris,* was domesticated around 7,000 years ago, most likely around the Middle East and eastern North Africa. As humans shifted from nomadic life to permanent settlements, agriculture increased and granaries were built, attracting rats and other rodents. Cats were most likely "tamed" to prey on the rats (Newman 1977). In Egypt cats were known to have been domesticated by 2000 B.C. Egyptians revered cats and built statues to commemorate them. Through breeding and isolation the domestic cat has evolved to the point that it is now accepted as a separate species, *Felis catus* (Serpell 1988). In Europe domestic cats still freely interbreed with the European wild cat.

DISTRIBUTION

Feral cats are widely distributed throughout the world, including populations in cold temperate or sub-polar oceanic islands (Jones 1977). They tend to be concentrated around populated areas where they are turned loose or left to run wild by their "owners", but are also widely distributed in remote locations. Cats probably arrived in North America with the first colonists several hundred years ago. Since that time cats have thrived as pets, unwanted strays, and semi-wild predators (Coleman et al. 1997).

REPRODUCTIVE BIOLOGY

Domestic cats reach reproductive maturity between 7 to 12 months of age. A breeding female, called a queen, can be in estrus as many as five times per year, but usually produces two litters per year. The gestation period lasts 63 to 65 days. The average litter is four kittens (Nowak 1991). In a farm cat study in Illinois, the survival rate was 1.5 kittens per female per year (Warner 1985). Longevity of free-ranging cats is estimated at 4 - 5 years; domestic cats can live from 15 to 17 years as house pets.

HOME RANGE

Cats in rural areas tend to have larger home ranges than cats in urban areas (Dards 1978, Tabor 1981). At Bodega Bay, a study of radio-collared cats has shown that an individual feral cat may range more than one mile (1.4 km) in a single day (Stallcup 1991). Liberg (1980) found a population in rural southern Sweden of 2.5 to

3.3 cats per square kilometer with a home range of 30 to 40 ha. Feral male cats in the Swedish population had home ranges 2 to 4 km across. Home ranges of free-ranging cats in Brooklyn, New York, averaged between 1.7 and 2.6 hectares; where there is a feeding station, free-ranging cats do not keep out other cats (Haspel and Calhoon 1989).

Food Habits

Cats are carnivorous. An adult cat may eat 5 - 8% of its body weight per day, and a female feeding kittens may consume 20% of its own weight (Scott 1976). Subadult cats may consume 9.5% of its weight (Howard 1957). Diet includes insects such as bumblebees and grasshoppers, rodents, amphibians, reptiles, and ground nesting and ground roosting birds which are particularly vulnerable. Cats have been reported to have killed and eaten animals up to 3500 grams, a weight equal to their own (Hill 1997).

Joe Mitchel, University of Virginia, kept a tally of the wildlife kills of his four family cats over 11 months. The total was 104 individuals of 21 species: 6 species of birds, 8 species of mammals, and 7 species of reptiles. Species taken included flying squirrels (*Glaucomys volans*), chipmunks, wrens, and cardinals. Peter Stangel with the Fish and Wildlife Foundation in Washington, D.C. recorded 15 species of birds, mammals, and reptiles killed by his two cats in a four month period where he lived in South Carolina.

Conservation Status

Feral cats are not protected or listed by state or federal agencies in California. Estimates based on 1970 U.S. Census data of households claiming cats as pets placed the population of cats "owned" as pets at 30 million (Pet Food Institute 1982). This did not include semi-wild or free ranging cats. Nationwide, approximately 30% of households have cats. In rural areas where free-ranging cats are not usually regarded as pets, approximately 60% of households have cats. In 1972 an estimated 31 million cats lived across the country (American Humane Assoc. University of Georgia's Savannah River Ecology Laboratory (1996) and Nassar and Mosier (1991) estimated that there are 60 million cats in the United States. According to another estimate, 50 million feral cats live in alleys, lots, abandoned buildings, and parks in the United States (PAWS 1997). George (1974) estimates that one-third of the cats in the United States occur in our rural areas.

Locally, the Arcata Marsh and Wildlife Sanctuary is home to 12 to 15 free-roaming feral cats (Roberto 1995).

Habitat Requirements

Many of the cats are free-roaming domestic pets, returning to human habitation after foraging bouts. Others are wild-living, using abandoned buildings and farm outbuildings as resting areas. Feral cats are found on islands denning rock outcrops and burrows (Jones 1977). In urban parks cats use trees and shrubs as resting and hiding sites. In grassland areas, culverts and hedgerows provide cover for feral cats.

Survey Techniques

Sooted trackplates easily detect cats. Cat tracks can easily be confused with small canids such as kit foxes (*Vulpes macrotis*), grey foxes (*Urocyon cinereoargenteus*), and red foxes (*Vulpes vulpes*). The cat track is more rounded than canid tracks (Taylor and Raphael 1988). The small canids may not show the claws. According to Orloff et al. (1993) cat tracks on sooted trackplates can be distinguished by the three lobes on the posterior border of the palm pad and one or two lobes on the anterior border. Since the foot is not as well furred, the palm and toe pads are usually distinct. The anterior portion of the palm pad usually extends to a point halfway through the posterior toe pads, and the posterior toe pads often extend almost halfway through the anterior toe pads. Cats apparently have no hesitation about stepping on trackplates; placing their full weight on the soot, creating clear prints. In contract, many canids may be hesitant, producing indistinct or blurred prints (Orloffet al. 1993).

MANAGEMENT CONSIDERATIONS

The issues regarding free-ranging cats are really social ones. Cats can be a major factor in the killing of native wildlife including threatened or endangered species, reducing the prey needed for native predators to survive, and spreading diseases. For further discussion of these issues the authors recommend reading Coleman et al. (1997) and Luoma (1977).

Coleman et al. (1997) states that cats, worldwide, may be the second-most leading reason behind habitat destruction for bird species extinction. Nationwide cats are contributing to the endangerment of such species as least terns (*Sterna antillarum*), piping plover (*Choradrius melodus*), and loggerhead shrike (*Lanius ludovicianus*). Marsh rabbits (*Sylvilagus palustris*) in Key West, Florida, have been threatened by predation from domestic cats.

On Anacapa Island, cats have caught and eaten young brown pelicans (*Pelecanus occidentalis*) (Anderson et al. 1989). Along with non-native red foxes, free-roaming feral cats are a major threat to the endangered California clapper rail (*Rallus longirostris obsoletus*) (Frederick 1996, Roberto 1995). In Hawaii feral cats were responsible for the reduction of the Hawaiian dark-rumped petrel (*Pteroderma phaeopygia sandwichensis*) (van Riper 1978).

According to U.S. Fish and Wildlife Service biologist Don Edwards of the San Francisco Bay National Wildlife Refuge, feral cats forage along the tidal sloughs and levees ravaging burrowing owls (*Athene cunicularia*), snowy plovers (*Charadrius alexandrinus*), and salt-marsh harvest mouse (*Reithrodontomys raviventris*) populations - all species at risk.

Recent research (Coleman and Temple 1994) indicates that rural free-ranging cats in Wisconsin may kill between 8 and 217 million birds each year. Reasonable estimates indicate that over 39 million birds are killed annually in that state each year. Nationwide, rural cats probably kill over a billion small mammals and millions of birds each year.

Studies in England and Wisconsin have documented that well-fed domestic cats kill as many prey as feral cats (Churcher and Lawton 1987, Coleman and Temple 1994). Free-roaming cats fed at feeding stations continue to hunt natural prey, according to Scott Craven in Luoma's 1997 Audubon article.

Cat feeding habits may be detrimental to the survival of natural predators. George (1974) studied three cats responsible for eating 18 species of mammalian prey in raptor home-range territories. In a study in rural Illinois between January 1968 and December 1971, rodents accounted for between 82 and 95% of free-ranging cats prey. This area was also hunted by red-tailed hawks (*Buteo jamaicensis*), American kestrels (*Falco sparverius*), and northern harriers (*Circus cyaneus*). Pearson (1964) recorded the removal of 4200 mice from a 35 acre study plot by six cats. According to Scott Craven, "Anything a cat consumes is one less bit of prey for a native predator."

Cats may transmit diseases to wild animals and humans. Dr. Stan Deresinski (*in* Roberto 1995) listed 21 cat associated infections which can be transmitted to humans. Some free-ranging domestic cats carry rabies and toxoplasmosis which can be easily transmitted to humans (Warfield and Gay 1986). According to Ron Lapham of the Humboldt County Humane Society, cats may be responsible in Humboldt County for an increase in raccoon distemper. Feline distemper (panleukopenia) and an immune deficiency disease may have been spread to the endangered Florida panther (*Felis concolor coryi*) (Roelke, et al. 1993). Feline leukemia virus was documented in a mountain lion (*Felis concolor*) which staggered onto the Sacramento State College campus in 1993 (Jessup et al. 1993). Native wild cats may have an antibody against the feline immuno deficiency virus (FIV).

MITIGATIONS

Controlling cats in urban areas will require the education of cat lovers from the general public as well as from such groups as Stray Cats and TTVAR (Trapped, Tested, Vaccinated, Altered, and Released) who advocate feeding stations. Controlling the number of free-ranging rural cats primarily will depend on enlisting the help of rural residents who maintain them.

At Stanford University a habitat conservation plan was rewritten to consider the impacts of free-ranging cats on listed species around the campus. Nationally, cat-loving groups are attempting to set up free-roaming cat sanctuaries on public and corporate lands. Conversely, National Park Service's George Washington Memorial Parkway in Virginia implemented a trapping policy to remove feral cats and feeding stations. The National Park Service now has a lawsuit pending by cat-lovers over its trapping policy.

What can we do? The following suggestions are from Coleman et al. (1997).

- Keep only as many pets as you can adequately care for.
- If you have a cat, keep it indoors.
- Declaw your cat.
- Neuter your cat and encourage other to do the same.
- Locate bird feeders in sites that do not provide cover for cats to wait in ambush.
- Eliminate sources of food that attract stray cats.
- Don't feed stray cats. Feeding maintains high densities of cats that competes with native wildlife populations.

In addition;

- Trap stray cats and take them to your animal shelter. (Humboldt County Humane Society euthanizes over 200 cats a month.)
- Enforce current laws prohibiting the feeding of wildlife.

The city of Novato in Marin County, California now requires cats to be licensed and implanted with an identifying microchip. Communities can set heavy fines for failure to spay or neuter cats, abandonment of domestic animals, and feeding in public places.

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Snow Tracking

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INTRODUCTION

This manuscript is an updated but greatly condensed version of the Snow Trapping chapter by Halfpenny, Thompson, Morse, Holden and Rezendes in American Marten, Fisher, Lynx, and Wolverine: Survey Methods for Their Detection by Zielinski and Kucera (1995). For extended and detailed information, figures and photographs, and field and laboratory forms, the reader should consult that manual.

Snow tracking is used to conduct reliable field surveys to detect American marten, fisher, lynx, and wolverine (MFLW). Surveys to detect mammals do not require the statistical considerations of those designed to monitor changes in population size or to determine habitat preference. However, the field biologist must be able to provide records that will withstand the scrutiny of the professional community, because efforts to determine the presence of rare species often are linked to activities such as proposed timber harvests or recreational or residential developments. Results of surveys may be challenged, even in court, so methods must be rigorous and data should be collected in a standardized fashion.

OBJECTIVES

After reading this paper, the tracker should be familiar with the fundamentals of designing and conducting a snow-tracking survey for MFLW. However, becoming a good tracker takes time. Spend that time by gaining experience in the field and by learning from others. Where MFLW are legally harvested, seek the advice of local trappers. Special seminars and workshops on tracking are also available (Halfpenny et al.

1995). Attend these, and compare notes with other trackers.

ASSUMPTIONS

Methods for snow tracking were designed so that field effort would provide a reasonably similar probability of detecting MFLW when compared to camera stations and bait stations. Reasonable distribution of search trails in favorable habitat across the sample area is a prerequisite for equal probability of detecting MFLW. Sample areas should not be reduced in size and in mountainous regions it may be necessary to search several short valleys to meet trail and area requirements. Length of trails and sample areas are defined below.

Two methods for detecting the presence of the target species are discussed: "Searching for Tracks" and "Tracking at Bait Stations." The former, and historically more common, method involves traversing trails and roads in search for tracks. The latter method, suggested by recent observations by Copeland and Harris (1994), involves the detection of tracks in the snow at bait stations. This chapter does not cover snow tracking from the air. Snow tracking from airplanes is used in Alaska and Canada not only to detect individuals, but also to inventory and monitor populations in relatively open habitats, (e.g., Golden 1993). However, if the target species prefers closed habitats or is of low density, it is possible to miss the tracks from the air. The probability of missing tracks must be weighed against the advantage of covering large numbers of miles per day from the air.

Although airplanes and helicopters have seldom been used for the detection of rare species in the contiguous United States, this technique should be considered, especially if large areas with good surface visibility are to be surveyed. When possible, use flight time to supplement ground time. Aerial trackers require special training to search clearings and edges, spot tracks within the forest, and identify tracks seen from the air. Some features, such as wolverine dens, are more visible from the air (Magoun *in* Golden 1993) but require training to recognize. Additional references on the use of aerial snow tracking are provided in the section on Inventory and Monitoring, below.

SURVEY SEASON AND DURATION

Snow-tracking surveys depend on conditions that may vary across regions and over time, and in some areas snow tracking may seldom be possible. The minimum requirement is snow deep and soft enough for identifiable footprints to register. If possible, wait until the second morning after a snowfall to allow tracks to accumulate. This allows the animals time to lay down trails, but is not so long that tracks of other animals make it difficult to find those of the target species. On some days it is not possible to track. For example, tracking during snowfall or during strong winds is not advised because tracks are quickly obscured.

In early spring, the sun melts snow on south-facing slopes, and this can rapidly destroy tracks each morning. Although a wet afternoon snow makes excellent tracks, the target species tend not to travel then. Later, when the snow freezes, animals may move on top of it without leaving detectable tracks. During periods of melting and freezing, tracking must be done early in the morning. When recurring melting and freezing prevent tracking on south-facing slopes, good tracking may be possible on the north-facing slopes.

DEFINING THE SURVEY AREA

Conduct surveys in 4-mi^2 sample units (Zielinski and Kucera, 1995). Distribute trails across the sample area as dictated by favorable habitat and restricted by topography. Layout of sample areas may differ depending on whether the survey is a "Regional Survey" or a "Project Survey." In each case, however, we recommend that 4-mi^2 sample units be the basis of the survey. For regional surveys, see Zielinski and Kucera (1995) for methods of stratification. In project-level surveys, focus first on the sample units within the project area. Conduct surveys on as many sample units each winter as time, personnel, and funds will permit, and survey as many sample units in a day as possible.

SEARCHING FOR TRACKS

Route Selection, Mode of Travel, and Duration

Drive by truck or snowmobile to the area(s) of the sample unit with the most likely habitat for the target species (or the area where unconfirmed sightings have been reported), and start your search there. Conduct the search on foot, using either skis or snowshoes. Conclude the search after either a minimum of 10 km have been traversed or the target species is (are) detected.

Routes should be chosen to favor preferred habitats. Use motorized vehicles for speedy transport between habitats not preferred by MFLW. The most thorough job of tracking is done on foot, either on skis or snowshoes. The best approach is to use skis or snowshoes to travel routes in preferred habitats and a snowmobile or other vehicle to reduce travel time between focal areas.

If snowmobiles must be used, avoid routes used by other snowmobiles, and travel between 5 and 15 mph. Two snowmobiles or two observers per snowmobile will decrease the likelihood that tracks are missed. When the track of a potential target species is sighted, stop the snowmobile and examine the trail on foot. Fatigue while driving a snowmobile contributes to poor performance, so be certain that, as the day wears on, all potential tracks and trails are checked carefully: The tracks of target species traveling on packed trails made by ungulates or snowshoe hares can easily be missed!

Topographic features may provide important travel routes for target species. Within appropriate habitat, select survey routes on ridges, saddles, and valley bottoms or drainage's. Avoid locations with avalanche potential, including avalanche chutes and steep, open slopes (see Safety Concerns, below).

Survey Frequency

Wolverine, Fisher, and Marten: Survey each 4-mi[1] sample unit at least three times during one winter or until the target species is (are) detected. Distribute survey outings throughout the snow season.

Lynx: Survey each sample unit three times per winter and for three consecutive winters (or at least three out of five winters) or until lynx are verified on the sample unit.

As snow conditions permit, traverse the survey routes in a sample unit at least three times during the winter. If suitable snow is available for only a short time, sample all the routes in a sample unit at least twice; one survey per winter is inadequate. Lynx populations exhibit cycles in abundance, especially in northern latitudes. Although the magnitude of these cycles is unknown in the southern part of their range, we recommend that surveys acknowledge the possibility of extremely variable population sizes. Where lynx are of interest, each sample unit should be surveyed three times per winter for at least 3 years, consecutively if possible. This will minimize the probability that sampling will occur during the low point in the lynx population cycle and misrepresent the status of lynx in the area.

TRACKING AT BAIT STATIONS

Baits and Lures

Use road-killed deer, fish, or a combination of the two. Use as large an amount as possible, up to a whole deer carcass, but at least 5 kg. A commercial lure such as skunk scent may help attract mustelids. For lynx, a freely hanging bird feather or wing, or piece of aluminum foil and a commercial lynx lure and catnip should be used in addition to the bait.

Station Number and Distribution

Establish a minimum of two bait stations in each sample unit, no closer than 1 mile apart, at the sites of the most appropriate habitat or where unconfirmed sightings have occurred.

Attach the bait to a tree or stump with wire or heavy rope so that it cannot be dragged away. Fish and smaller meat baits may need to be enclosed in wire mesh (welded wire or chicken wire) and nailed to the trunk of a tree. Be prepared to move the bait up the trunk as snow accumulates during the winter. Seek a location that lacks complete canopy closure so that snow can fall directly on the ground in the vicinity of the bait. However, avoid open, south-facing slopes where the sun may quickly ruin the tracking surface.

Survey Duration and Check Frequency

Check each station for tracks every few days if possible, especially after new snow, for a minimum of 30 days or until the target species is detected.

Because the objective of the survey is to determine whether a sample unit is occupied, effort need not be expended beyond the detection of the target species. The minimum duration is set primarily on the basis of data for wolverine provided by J. Copeland (pers. comm.) who found that wolverine tracks in snow were first detected at bait stations after a mean of 26.7 days. Five of six first detections occurred within the first 31 days. Because the densities of fishers, martens, and possibly lynx are probably higher than that of wolverines, it is assumed that 30 days are sufficient to establish presence within the sample unit.

METHODS

Preparations for the Field

Data collected must be compatible with those of other trackers. Preparation for the field should include an understanding of tracking terminology and methods, as well as the ecology of MFLW. Here we provide a background on tracking techniques, including the interpretation of the effects of changing snow conditions on tracks.

Background

Modern tracking goes beyond sketching a track and recording a few measurements. Today's biologist must know how to measure prints, identify gait patterns, recognize pattern changes with speed, interpret behavior, and document field evidence. Decisions about the presence of rare species will often rest solely on track evidence. Details about tracking MFLW will be found in Zielinski and Kucera (1995). Tracking books such as those by Forrest (1988), Halfpenny (1987), Murie (1954), and Rezendes (1992) have good overviews of the target species.

Footprints form the basis for mammal identification from tracks. However, it is often not possible, especially in snow, to find a clear print. When identifiable prints are not available, an understanding of the trail left by an animal, its preference for habitats, and its behaviors provide valuable clues and may sometimes be used to identify the species. Always examine the entire scene, following suspect trails forward and backward as far as time will allow. During the trailing procedure, study the gait patterns and look for clear prints in sheltered areas. The strongest evidence from snow tracking comes from footprints cast in plaster or photographed. However, because obtaining clear footprints in snow may be difficult, trail patterns and gaits provide supporting evidence. Be careful of identifications made only from patterns and measurements of trails. The combination of footprint and trail information is best, but one may be lacking, so the tracker must be familiar with both. Refer to Halfpenny et al. (1995) for detailed information on the following topics.

Footprints in Snow

Tracking in snow presents two types of interpretive problems: tracks often lack definitive shapes because of the fragile nature of the snowpack, and snow metamorphism may alter tracks. Understanding how tracks change in the snow is critical to proper identification. Failure to interpret metamorphic processes may result in incorrect print and gait measurements. For example, the metamorphosed tracks of a bobcat or coyote can easily be misidentified as those of a lynx by the inexperienced or unprepared tracker.

Understanding Gaits

It is necessary to identify track patterns left by different gaits and to understand how the patterns change with speed; otherwise, measurements taken from track patterns may result in erroneous identification. For example, gait measurements are used to distinguish among bobcat, lynx, and mountain lion; mistaking a gallop for a walk could result in misclassifying a lynx as a mountain lion.

Measuring Tracks and Trails

Footprints

Track size is influenced by the depth that the foot sinks into the surface; feet leave larger footprints in soft substrates than in hard ones. Measurements of tracks from the same animal in different substrates may be considerably different. A track that sinks into the surface may be several millimeters bigger than one on a hard surface. Because area increases with the square of the linear measurement, the track appears to increase dramatically in size when it is only slightly longer and wider. Therefore, visual impressions of track size can be misleading, especially to the untrained observer.

Fjelline and Mansfield (1989) controlled for depth-induced variation by measuring just the portion of the foot that would touch a hard surface, measured from the break of the track on one side to the break on the other side (Halfpenny, et al, 1995). The sides are not included in the measurement. This is the Minimum Outline (MO). The measurement that includes the sides is referred to as the Variable Outline (VO) because the same foot may yield different track sizes. MO measurements are more consistent across all surfaces, and their use reduces variation when measuring multiple tracks of one animal and when different observers measure the same track. Although measurements are often difficult to obtain in the field, they should be the standard for measurements from track impressions that are brought into the laboratory However, when working with photographs or data from others not using the MO methods, you must usually use VO methods. For complete sets of measurements see Halfpenny et al. (1995)

Trails

Trail measurements add to our ability to discriminate among species when individual print measurements are difficult to obtain, and are essential when using discriminant analysis to distinguish the tracks of felids. Four measurements should be made of the walking trail: stride, straddle, center straddle, and trough (Halfpenny et al. 1995).

Trail measurements are made parallel or perpendicular to the line of travel (Halfpenny et al. 1995). Data should be collected using the following three reference locations: 1) the center of prints, 2) the outer margin of prints, and 3) the trough created by foot drag. Straddle measurements are affected by curves in the trail and should be recorded only where the trail is straight. Center measurements are important because they are easily recorded and change little with metamorphosed snow. To obtain center measurements, mark the center of each footprint with a small dot; a pencil may be pressed into the surface. Lay a ruler between print centers on one side of the trail to measure the stride. Center stride is the same as the regular stride. Center straddle is the distance perpendicular from the center stride line to the center of the footprint on the other side and is always smaller than the regular (outer margin) straddle. The trough is a common feature of lynx trails where the hair on the feet drags along the snow surface. The trough is measured from the left-most outside drag mark to the right-most outside drag mark. It differs from the straddle measurement, which spans only the edges of the foot pad. If no hair drag is discernible, the straddle and the trough are the same.

Detailed tables of measurements and description of MFLW tracks and trails will be found in Halfpenny et al. (1995).

Measuring Tracks and Trails in the Field

Select the best footprints available along a trail, and mark them with a nearby scratch in the snow. Locate both front and hind prints, if possible. Try to locate at least three front and three hind prints so measurements may be averaged. Take some photographs before disturbing tracks, and then take additional photographs with a scale. Make a drawing on the back of the Track Observation form (Halfpenny et al. 1995) to supplement measurements. If a measurement, e.g., toe length, cannot be made because of track quality, indicate in field notes.

Carry two rulers to facilitate measuring. Rulers marked in both English and metric units are best; measure in metric whenever possible. A folding ruler provides a rigid straight line for marking between two tracks to measure the straddle. The folding ruler may also be used along a trail to provide continuous perspective in spite of parallax problems. A plumber's rule is best because it is made out of fiberglass and will not warp when it gets wet. Rigid Plumbing manufactures such a ruler. A retractable, power return ruler (e.g. Stanley Powerlock 33-328) can be used to complete measurements. The 3m /10 ft combination is light for travel, but rigid enough to span tracks in the snow without collapsing and destroying the track. Calipers or drafting dividers improve the ability to measure prints in the snow.

The best measurements of gait patterns are made on level ground where the animal is moving in a relatively straight path. Select the most uniform section of strides to provide the position of gait measurements. Avoid sections where gaits change. The walking gait is the most important for identification. Avoid sections where the animal is trotting. To do this you will need to know the approximate length of a walking stride for the target species (see individual species accounts above). Follow the trail in both directions to find the walking gait with the smallest strides. The section of trail with direct registry, neither understep or overstep, will represent the true walking gait of the animal.

To obtain center measurements from the trail of a walking animal, mark the center of each footprint with a small dot; a pencil may be pressed into the surface. Lay a ruler between print centers on one side of the trail to measure the stride. To obtain center straddle, draw a line along your ruler, and measure perpendicularly from the line to the center of the footprint on the other side. Take the trough measurement from the left-most outside drag mark to the right-most outside drag mark.

Straddle and trough vary with curves in the trail; try to measure straight sections of trail. Three to five sets of measurements should be taken and later averaged. The more measurements the better, within time and safety limitations.

Track Preservation

When track identification is critical to a search, preserve a record for later analysis. Three methods of preservation are commonly used: drawing, casting, and photographing. For details of these methods see Halfpenny et al. (1995).

Scat and Hair

Identification of scat and hair is not within the scope of this manual. Bile acids have been used to distinguish carnivore scat (e.g., Quinn and Jackman 1994), and new molecular genetics techniques permit the identification of species from DNA in hair, scat, and small fragments of tissue (Foran, Crook, Minta in press, Foran, Minta, Heinemeyer in review). Therefore, all hair and scat suspected to be from a rare species should be collected. Try to learn of individuals, laboratories, or universities in your region that specialize in these techniques and can help with identification.

Identification of scats in the field can reduce the amount brought home. Halfpenny (1987) and Rezendes (1992) provide color photographs and simple scat keys. Methods for collecting scat are covered in (Halfpenny et al. 1995).
Microscopic hair identification is best done in the laboratory by someone with considerable experience. The best guides to identifying hair by morphology are by Adorjan and Kolensosky (1980), Brown (1942), Mayer (1952), Moore, and others (1974), and Stains (1958).

DATA MANAGEMENT

Four forms are recommended to aid in snow tracking and for data preservation: Snow Tracking, Track Observation, Survey Record, and Species Detection forms. These forms are available in Halfpenny et al. (1995).

INVENTORY AND MONITORING

Growing concern over rare species and their management emphasizes the importance of developing methods to monitor changes in abundance over time (Weaver 1993), yet developing monitoring programs requires considerable statistical and logistic planning. Snow tracking, more than the other detection methods, has been used to attempt to inventory and monitor changes in populations of MFLW (see review in Halfpenny et al. 1995). A review of more than 40 published and unpublished papers that deal with inventory and monitoring methods (noted with an asterisk in the References section) revealed a lack of consistency in snow tracking techniques. Most snow tracking methods have never been tested for their power to detect differences in densities, habitat use, or changes in abundance over time. Key considerations for designing snow surveys for inventory and monitoring will be found in Halfpenny et al. (1995).

Monitoring techniques should provide early detection of significant population changes or differences in habitat use so that management actions can forestall extirpation or extinction. Verner and Kie (1988) recommend that biologists be able to detect these changes at "5 percent significance levels and statistical power of at least 80 percent". Using these values, a pre-survey model can be developed to determine the sample size (number of trails and their length) needed. Once a statistically appropriate sample size has been estimated, costs for the survey should be calculated. For low-density species, costs of monitoring may be higher than can be afforded. Indeed, it may not be possible to monitor rare species for change over time using survey methods. The only financially feasible and practical solution may be to detect presence, and then protect the species from harvest while maintaining habitat and prey.

SAFETY CONCERNS

Winter Hazards

Techniques described in this manual will be used during winter when potentially hazardous conditions exist. Obtain training about winter hazards and camping. Carry adequate equipment to spend the night comfortably in case of an emergency. Avoid working alone in the field during winter. It is the responsibility of the supervisor to evaluate potential hazards in the survey area and to obtain proper training for all personnel before they go to the field. Being a field biologist does not necessarily mean that one is competent to conduct winter work.

Job descriptions for field technicians should stress winter field skills including skiing, snowshoeing, snowmobiling, snow camping, and avalanche training. Employees can be trained using in-house experts, or by any of the schools and individuals.

Scat Collection Hazards

It is possible to pick up some diseases from scats. Therefore, do not smell scats too closely. Use latex gloves or an inverted plastic sack for handling. Wash your hands after handling scats, even with snow.

Costs

Assumptions:

- Five adjoining units, each 4 mi^2, are surveyed simultaneously for a total survey of 20 mi^2.
- Each sample unit is surveyed three times during one winter. Effort to survey each sample unit is limited to one day per survey.
- All access is relatively simple, but survey routes are covered on skis.
- No target species are detected during the survey. Because surveys in a sample unit are terminated when the target species is (are) detected, costs could be significantly less if the target species is detected early in the session.
- The work is conducted by a crew of federal employees at FY 1994 rates. No contractors are used.
- The minimum crew size is two persons traveling together, each carrying a personal radio. While crew members may be separated over short distance (within earshot), two crew members should work together in all dangerous situations including snowmobiling and traveling on backcountry routes, especially if avalanche danger exists.
- Costs of winter training are not included.
- Extra costs may be incurred for snowmobile use and safety equipment. Please see the safety section in Halfpenny et al. (1995) for approximate cost estimates.

Refer to Table 1 for cost analysis.

Training in Tracking

You can enhance the probability of success of a survey by receiving training from a biologist experienced in tracking lynx, wolverines, fishers, and martens. Try to identify local expertise, such as trappers, to train field personnel before the survey starts. General tracking seminars are taught through the Glacier, Grand Teton, Rocky Mountain, Yellowstone, and Yosemite National Park Associations, and by private individuals around the United States. Professional seminars titled "Field Verification of Rare Species" and training slide shows and computer disk self study programs (Halfpenny 1986) are available from Dr. James C. Halfpenny, A Naturalist's World, P.O. Box 989, Gardiner, MT 59030, (406) 848-9458. For additional reading on tracking see Forrest (1988), Halfpenny (1987), Murie (1954), and Rezendes (1992).

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Table 1. Cost Analysis for Snow Tracking Surveys

1. Labor			
	Day planning	2 pd @ $75	$150
	Training	4 pd @ $75	$300
	Track surveys (3 surveys/winter)	2 people @ 5 field days 10 pd @ $75	$750
	Lost field days due to bad tracking conditions	2 pd @ 2d/survey 2 pd @ $75	$450
	Data Analysis	2 pd @ $75	$150
Subtotal Labor			$3,300
2. Vehicle & Gas			$700
3. Materials - misc. supplies			$250
TOTAL			**$4,250**

pd = person day

Aluminum Track Plates

Richard R. Mug
Simpson Timber Company,
PO Box 68
Korbel, CA 95550

INTRODUCTION

Carbon-sooted aluminum track plates have been used in various forms to detect and monitor many mammalian species. The method was first used to monitor rodent abundance (Mayer 1957) and was adapted by Barrett (1983) to survey for American martens (*Martes americana*). This application enclosed the aluminum plate in a plywood box that was attached to the side of a tree. Track impressions were "negatives" in that they were created when an animal's foot removed soot and revealed the underlying plate surface. A record of the track was created by transferring the track image to transparent tape by pressing the tape onto the track and lifting the tape. The method was also adapted for more general use by placing a larger (162.8 x 81.4 x 0.06-cm) unenclosed plate on the ground with bait attached to the center (Barrett 1983, Raphael and Barrett 1984, Raphael 1988).

In 1991 the technique was significantly improved with the addition of a surface capable of collecting a positive track impression (Fowler and Golightly 1991). A slightly tacky, white paper (Con-Tact® brand shelf liner) was placed across the distal end of a rectangular sheet of sooted aluminum. The plate was inserted into a plywood box scaled to a size that would permit the entrance of marten and fisher (30.0 x 26.7 x 81.3 cm) to protect it from moisture and debris. The soot that adhered to an animal's foot as it entered the box was transferred to the white paper when the animal walked to the rear of the box. The positive track impression, often transferred in great detail, was cut out from the paper and stored in a clear acetate envelope. The clarity of tracks is sufficient to distinguish the previously confusing male marten and female fisher (*Martes pennanti*) tracks using dicsriminant function analyses (Zielinski and Truex 1995).

Two types of sooted aluminum plates will be described here. The first is the enclosed plate system that records tracks on white paper. This device has been effective at detecting marten and fisher (Fowler and Golightly 1991, Zielinski et al. 1995) as well as gray fox (*Urocyon cinereoargenteus*), spotted skunk (*Spilogale gracilis*), striped skunk (*Mephitis mephitis*), ringtail (*Bassariscus astutus*), raccoon (*Procyon lotor*), and Virginia opossum (*Didelphis virginiana*) (Klug, pers. obs.). It has also detected black bears (*Ursus americanus),* bobcats (*Felis rufus*), coyotes (*Canis latrans*) and weasels (*Mustela* spp.) (Klug pers. obs.) This was the detection device recommended in the original USDA Forest Service protocol for detecting fisher and marten in Region 5, California (Zielinski 1992). The second device is the larger, unenclosed plate without the track-receptive paper (Barrett 1983, Raphael and Barrett 1984). This is the only adequately field-tested track-plate method that is capable of detecting lynx (*Lynx canadensis*) and wolverine (*Gulo gulo*) its well as marten and fisher and other small and medium carnivores.

A logical combination of the two approaches is to enclose the large plate, partially covered with Con-Tact' paper, in a large box. However, boxes larger than that recommended in the Forest Service, Region 5 protocol have not received much testing. Large plywood (35.6 x 38.1 x 78.7 cm) and cardboard (61.0 x 61.0 x 86.4 cm) were used in a modest pilot test in northern Idaho were marten, fisher, lynx and wolverine were thought to occur, but only marten were detected (A. Dohmen, pers. comm.) A 40.6 x 30.5 x 81.3 cm version was used in a study of the mammalian carnivores associated with the Sacramento river in California.

OBJECTIVES

There are two primary objectives of track plate surveys. The first is to determine if any number of potential target species occur within a particular area of interest. These areas of interest include project areas (do fisher occur within a proposed timber harvest plan) and regional areas (do marten occur within the Orleans Ranger District of the Six Rivers National Forest). The second objective is to determine what habitat attributes are associated with the occurrence of a certain species. These surveys usually cover a much larger area than those associated with a particular area of interest. A third objective, which has not yet been highly used, into monitor the populations of some species such as fisher.

ASSUMPTIONS

The primary assumption associated with sooted track plates is that these surveys verify presence only. Because the effectiveness of this detection method has not been adequately tested, the absence of a detection of the target species does not mean that the species does not occur in the surveyed area, simply that it was not detected during the duration of the survey.

DESCRIPTION OF DEVICES

Track Plate Box

This device is composed of a carbon-sooted aluminum plate (20 x 76.2 x 0.1 cm) partially covered with white Con-Tact® paper that is enclosed in a plywood box with the inside dimensions 25.4 x 25.4 x 81.3 cm. Bait is placed at the back of the box beyond the Con-Tact® paper. The box described here is designed to be placed on the ground. Somewhat smaller boxes have been attached to the boles of trees (Barrett 1983, Martin 1987), presumably to dissuade visits by non-target species. However, this assumption has not been tested, and because arboreal plates require more time to install and are more expensive than terrestrial boxes, they will not be described in detail here. Those interested in attaching boxes to trees should consult the references cited above.

The aluminum plate should be about 1 mm thick (0.063 gauge). Thicker material has no advantage and is heavier. Aluminum can usually be acquired as flat stock from a sheet metal shop. The preferred method for applying soot is with acetylene gas from a welding torch. Carbon production is maximized by closing the oxygen valve on the torch handle. The soot can also be applied from a burning kerosene-dipped wand. Suspend the plates horizontally above the ground between sawhorses (or some similar support), and soot them from below as the soot rises. Soot the plates outdoors in a well-ventilated area. A water source or fire extinguisher should be available at all times to prevent the spread of fire. A half-mask respirator and safety glasses are recommended to minimize inhalation of the soot (see Safety Concerns). If the respirator is not available wear a dust mask to block large particulates. Soot should cover the plate evenly and lightly; do not oversoot, as excessive soot may produce a poor quality track on the paper. The area of the plate that will be covered with the paper need not be sooted. When learning the process, test that the soot is sufficient by transferring some from the plate to a piece of Con-Tact® paper with your finger.

After the plate is sooted, wrap a 31 x 23 cm piece of Con-Tact® paper, with the sticky side up and backing intact, around the plate, and tape it to the back of the plate using pieces of duct or masking tape. Align the paper so it is slightly rear of the center of the plate but with about 9 cm of exposed plate beyond it where the bait is placed. To save time, prepare the pieces of Con-Tact® paper and tape in advance. Keep the protective backing on the paper until the plate is placed in the field for use, then peel it off.

The box is constructed of four pieces of 1/2 inch, medium-grade plywood. If the boxes will be exposed to long periods of wet weather and are expected to be used for several years, exterior grade plywood may be used. The back of the box is open to facilitate construction and transportation and to minimize cost. The top and bottom pieces should have two approximately 1/2 inch grooves running the length of their inside surfaces into which the two side pieces can be slid or gently hammered. Rope, strips of tire tubes (often available at no cost from local tire dealers), or plastic banding (applied with a commercial banding tool) can be used to hold the sides together. Do not use hardware to assemble the boxes unless they can be stored and transported fully assembled. Heavy . woody debris placed carefully around the box in the field will strengthen it further.

A lighter-weight alternative for protecting the track plate uses thin plastic sheets. The plastic is bent into a half cylinder and the edges are placed inside a raised lip on each of the outer edges of a galvanized steel base (28 x 76 x 0.1 cm with a 1.0 cm raised lip along the sides) and are kept in place by a combination of the force acting to straighten the plastic and liberal use of duct tape. Alternatively, holes can be drilled through the raised lip of the steel base and through the plastic at corresponding locations so that sheet-metal screws can be used to secure the canopy (Foresman and Pearson 1995). Although one large piece of plastic is sufficient, two smaller pieces (each 40.5 x 70.5 x 0.2 cm) can fit in a in a backpack more easily. At the station location, each piece is bent, positioned in the base, and then taped together where they overlap. The sooted aluminum plate with Con-Tact® paper is placed on the galvanized base. Track-plate stations with this type of protection have successfully detected marten and fisher. The materials for this design weigh somewhat less than the plywood box, but the structure is much less sturdy. The roof is very flexible and cannot support woody debris that might be used to strengthen and camouflage it. The entire enclosure appears to move more readily when an animal enter it than does the plywood box. In addition, the plate may be less protected from moisture than when the absorbent plywood box is used.

There are several means by which the sooted plates can be transported in the field. For storage in a vehicle, a travel case should be constructed that can accommodate field-ready track plates (sooted with Con-Tact® paper and backing attached). This can be a sturdy wood or plastic box with parallel grooves cut on the inside surface of two sides into which the plates can slide. Grooves separated by at least ½ inch will keep plates apart during travel, and a box lid will prevent dust from settling on the plates. To protect individual plates from being marred while you walk from the vehicle to the station location, cover the sooted plate(s) with an unsooted one and bind them together tightly with duct tape or welding clips. Alternatively, holes can be drilled in diagonal comers of each plate; a bolt and wing-nut can secure a number of plates firmly together. Nothing need be placed between the plates, provided each Con-Tact® paper has its protective cover in place and plates are stacked front to back. This procedure is particularly useful when multiple plates must be back-packed into a roadless area.

Unenclosed Track Plate

This device is an uncovered, carbon-blackened aluminum plate made of the same material described above and sooted in the same fashion. The plate is actually composed of two plates (40.0 x 80.0 x 0.1 cm each), placed side-by-side, to create an 80. x 80.0 cm surface. Because this method does not involve the use of a white track-receptive surface, it is important that the soot be applied lightly enough so that the feet of visiting animals remove it all and expose the underlying plate. Bait is placed in the center of the two plates.

To prevent the sooted surfaces from rubbing together carry the plates in wooden boxes bolted to pack boards. Flat, army surplus pack boards made of particle board are the best. The lightest boxes are made of ¼ inch plywood on the front, back, and the bottom; the sides and the hinged top are made ½ inch plywood. One box, 41.5 cm long and 135 cm deep, will hold six sets of plats. Cut six slots, 5 mm wide and 5 mm deep, spaced about 12 mm apart, into the interior surfaces of the box. Fit the sheets into the slots back to back. A larger sturdier box of the same general design that can be carried in a vehicle will be helpful in transporting many plates at once.

SURVEY SEASONS

Because both the enclosed and unenclosed plates are placed on the ground where they could be quickly covered with snow, and because of the increased costs of operation, avoid conducting surveys during winter. However, because the target species may be more easily detected during winter when food may be less available, conduct surveys as soon after snowmelt in the spring and (if necessary) as late as possible in the fall. It is recommended that two surveys per year be conducted unless the target species is detected during the first survey.

SURVEY DURATION

Because the objective of the survey is usually to determine whether a sample unit is occupied, effort need not be expended beyond the detection of the target species. However, the minimum effort without detection is set at 12 nights in response to a number of sources of information on the "latency to first detection" for marten and fishers. In reviewing the results of 207 track-plate and line trigger camera surveys, Zielinski et al. (1995) found that the mean (SD) latency to first detection for surveys that had from 6 to 12 stations (n=50) was 4.2 (2.4) and 3.7 (2.6) days for fisher and marten, respectively. This estimate is biased downward, however, because it included only those surveys that detected a target species before the surveys were concluded. Raphael and Barrett (1984) recommended that 8 days were sufficient to achieve high detection probabilities when measuring mammalian carnivore diversity at a site. Jones and Raphael (1991), however, discovered that 60 percent (3 of 5) of first detections during marten surveys in Washington occurred after day 8 but before day 11. They concluded that surveys should run more than 11 days. Foresman and Pearson (1995) detected marten after a mean of 3.3 and 2.3 days at enclosed and open plates, respectively; fishers were detected after a mean of 5.3 days at enclosed track plates. Fowler and Golightly (1993) found that a 22-day survey duration was needed to be 95% confident that they could detect radio collared marten if track plates were placed within an individuals home range. In a two year track plate survey in coastal northern California to detect fishers (Klug 1996) found that 33.3 percent (14 of 42) of the surveys that detected fishers, obtained the first detection between day 13 and 22. In the same surveys it took, on average, 14.6 days to obtain the first bobcat detection on surveys that detected bobcat. He also found that 61.5 percent (8 of 13) of the surveys that detected bobcat obtained the first bobcat detection after day 12. It would be reasonable to assume similar results when surveying for lynx.

METHODS

Survey Area

The survey area should be defined by the objectives of the survey. If the survey is a project survey for a proposed timber harvest plan the survey area should include the plan area and a reasonable buffer around the plan area. This buffer would vary in size depending on the home range size of the target species. In a regional survey the survey area should include everything within the region being surveyed. This is usually within a certain administrative boundary.

Number and Spacing of Stations

Detection success increases with an increase in the number of stations in the survey (Zielinski et al. 1995). In short the more stations that can be checked, the better. There are currently at least two different approaches being used to determine the number and spacing of adjacent stations. The first, as described in Zielinski and Kucera (1995), involves delineating the sample area into 4-mile^2 sample units. Then place a minimum of 6 stations within each sample unit. Distribute them as a grid, with a 0.5 mile intervals between stations. Place the station within the most appropriate looking habitat. A second approach utilizes a transect method in which roads serve as the transect lines. This approach, obviously, should only be used in areas that are well roaded. In smaller project surveys the entire area should be surveyed by placing stations along the transects at 1 km intervals. Adjacent transects can be further apart than 1 km and is usually dictated by the road density in the area. In larger regional surveys, the transects are divided into 5 km segments throughout the survey area. Six stations area placed at 1 km intervals along alternating 5km segments. Adjacent transects should be separated by 5 km.

Equipment Preparation
It is usually most efficient to assemble all boxes before heading afield and trucking them to the survey area. A standard bed pickup truck with an in-bed tool box will easily hold 24 enclosed boxes. It is also more efficient to soot and paper as many track plates as possible before starting the survey.

Baits and Lures
In tests with captive fishers, chicken and tuna were equally attractive, but in the field, chicken elicited significantly more detections of a variety of carnivores, including martens (Fowler and Golightly 1983). Chicken is used exclusively for bait in the original USDA Forest Service, Region 5 protocol (Zielinski 1992) because it is readily available, relatively inexpensive, of a convenient size for use in the boxes, and poses no greater risk of microbial disease than other meats if hands are washed after use (see Safety Concerns). However, other baits have successfully attracted fisher (e.g., fresh fish, deer carrion) and marten (e.g., fresh fish, deer, beef bones, jam). Laymon et al. (1993) found that jam did not increase visits to detection stations, and Jones and Raphael (1991) suggested that martens prefer chicken bait without the addition of jam. There is no consensus as to the relative effectiveness of different bait combinations. The unenclosed plates have typically been used with a perforated can of tuna cat food in the center and the excess juices distributed on surrounding vegetation. However, alternative baits were not tested. In the box or canopy-enclosed plate, place the bait behind the paper; with the unenclosed plate, place bait at the union of the two plates.

Commercially available trapper lures such as skunk scent may be useful attractants, and it is recommended that they be used in addition to chicken bait. Sources of these lures include M&M Fur Company, P.O. Box 15, Bridgewater, SD, 57319-0015, (605-729-2535); Minnesota Trapline Products, 6699 156th Ave. NW, Pennock, MN 56279, (612-599-4176); and Carman's Superior Animal Lures, New Milford, PA, 18834, (1-800-545-8737). Fish emulsion, sold as fertilizer in garden-supply stores, can also be an effective lure, especially when mixed with vegetable oil to retard evaporation.

Visual attractants (e.g., suspended bird wings, aluminum pie tins) are frequently used by commercial trappers, but their effectiveness at increasing detection has received only one modest test, in which they did not increase detections of "carnivores" (a group of species that included marten but excluded lynx, wolverines, and fishers; Laymon et al. 1993). This is insufficient evidence to discourage their use, especially in light of the reputed value by trappers (Young 1958, Geary 1984, R. Aiton, pers. com.). Whenever possible, use a visual attractant, and use it consistently. Suspend either a dried wing, feather, or aluminum foil about 2 m above the ground within 5 m of the station.

When there is the potential that surveys results will be used in comparisons with other study areas or to monitor populations through time it is very important to standardize the baits that are used for eliciting detections. Probably the simplest way to achieve standardization is to use only the chicken and avoid the use of scent lures and visual attractants.

Placement of Stations
First conduct reconnaissance to verify the existence and location of roads and trails that will be used to access the stations. To ensure proper spacing between stations, use maps or aerial photographs to locate the area that each track plate station will be placed before going into the field. Locate each station at least 50 m perpendicular to the road if the survey is on public property or off of a public road. Placement of stations closer to well traveled roads may reduce their attractiveness to target species and make them more visible to people. If the survey is on private property were access is limited, using lightly traveled roads (less than 1

or 2 vehicles per day), stations can be placed closer to the road thus increasing the efficiency of the crews that check the stations. All stations should be flagged or otherwise marked in the field. Their location should be recorded on maps or aerial photographs and entered into a GIS whenever possible. It is also advisable, where conditions permit, to record GPS locations of the stations. In roadless areas be sure that the stations and a description of how to find the stations are adequately described so that others can find the location with ease.

Station Setup

Set out all the detection stations you plan to check during the survey before baiting them. Because the original location and establishment of the stations will require more time then checking them, it is best to bait them after all have been established. The largest determining factor in the time needed to set up and monitor the stations is the travel time needed to get to and from the stations. For reference, I was able to set up 24 covered track plate stations in a 10 to 12 hour day depending on the distance I needed to travel before getting to the first station. Depending on overtime constraints and the need to work in pairs, one crew (1 or 2 people) should be able to set up at least 18 stations per 8-10 hour day. Considerably fewer if the survey area is roadless. No more stations should be established than can be checked in two days. If all the stations cannot be checked in one day, divide the stations and check half each day.

Generally it is best to place track-plates in the most appropriate looking habitat near the predetermined station location. Stations should also be placed near areas of unconfirmed sightings. If the results will be used as part of a habitat analysis, however, they should be placed in whatever habitat is present at the predetermined location. The exception being that there is little need to survey non-habitat (e.g. if the survey is targeting forest carnivores there is little need to survey non-forest habitats). It is also important to remember, however, that what looks like the best habitat to people may not, in fact, be the best habitat for the animals.

Track-Plate Box

If possible assemble the boxes before going afield. Place the box on the ground so that it will not move when entered. A McLeod rake works well for leveling out a spot to place the box. Place the baited end of the box against the base of a tree, rock, or log to discourage entry form the rear. Cover the box with debris to hide it from passers-by. Remove the protective cover from the Con-Tact paper, and insert the sooted plate in the box. Place the bait on the plate behind the Con-Tact* paper. Placing the bait in a container such as a tuna or cat food can or a foil tart pan reduces mess and clean up time of the plates.

Unenclosed Track Plate

At each station clear and level an area of about one square meter. Again a McLeod rake works well. Place the sooted plates side-by-side onto the cleared spot in a manner that will provide a stable surface for animals to step on. Attach the bait with wire to the center of the sheets. If the plates stand a chance of being discovered by passers-by it may be advisable to leave a note in a conspicuous location explaining the purpose of the plate and the name and phone number of the crew leader.

Checking The Stations

Check the station every other day for a minimum of 12 days (see "Survey Duration" section), including weekends. Replace the plates as necessary, either when the soot becomes ineffective (test with a forger) or when the tracks of non-target species occupy more than 20% of the plate. Re-bait at every visit and remove old bait from the station area. If surveys are conducted during winter (cold temperatures) the plates may be re-baited less frequently, as long as the bait remains fresh. If lures are used, follow the manufactures suggestions on frequency of use.

The day the station is baited is Day 0. Subsequent checks should be made on Days 2,4, 6, etc. If rain or snow renders the stations ineffective (especially common for the unenclosed plate) additional days should be added to compensate for the days that visits could not be detected.

Survey crews should be familiar with the tracks of potential species. The track guide of Taylor and Raphael (1988) describes the tracks of species that commonly occur in the Pacific Northwest. Examples of fisher and marten tracks can be found in Zielinski and Kucera (1995). It is extremely helpful to build a library of full-size examples made from Xerographic copies of actual tracks obtained from other track plate surveys prior to starting surveys.

Record survey results carefully regardless of the results. If tracks of any target species are obtained immediately record the station number and date on a corner of the Con-Tact® paper with permanent marker and return the plate to the field station. Cut out an 8" x 10" section of the Con-Tact' paper with the tracks on it and place it in a clear acetate document protector. These can then be stored in a 3-ring binder. To collect and preserve tracks from the sooted portion of plates, place a wide strip of clear tape over each print. Press the tape on the print using a smooth hard object (a spoon or a capped pen). Carefully peel away the tape, and transfer it to a piece of heavy white paper.

Data Management

Zielinski et al. (1995) recommends using three forms for data: Survey Record, Track-Plate Results, and Species Detection Form. These data sheets should be made on waterproof paper and written on with indelible ink. All data forms should be stored in 3-ring binders as a permanent record of the survey.

The Survey Record form contains all the information on the location and configuration of the survey as well as its outcome. This should include both the legal description and UTM coordinates. The Track-Plate Results form is a record of the daily checks of the stations. Record the date, the survey area or transect name, the weather since last check, the visit number (visit 1 for day 2, visit 2 for day 4, etc.), and the observers initials. As each station is checked record the identity of all tracks on the plate. This should be written in pencil if there is any doubt as to the species identity. This should include negative results as well as positive for each station. Unidentified tracks on Con-Tact® paper can easily be photocopied and faxed to a qualified biologist for identification. Always maintain two copies of this form and store each copy in a separate location. When a survey is successful at detecting the target species, complete a Species Detection form to submit to the states Natural Heritage office, and archive a copy at the administrative office of the land manager on whose property the survey was conducted. This is most efficiently done at the end of the field season so that all the Species Detection forms can be submitted at one time. This is a standardized form and characterizes successful surveys for marten, fisher, lynx, and wolverine and is used for all methods of survey.

SAFETY CONCERNS

Sooting The Plates

Soot the plates outdoors where there is adequate ventilation and where the risk of fire is low. A "half-mask respirator" with organic vapor filter and goggles is recommended. At a minimum, a dust mask should be worn to exclude large particulates. Always 'receive training in the use of the welding equipment from an experienced technician. A "Job Hazard Analysis" for sooting plates is available upon request from Bill Zielinski (Redwood Sciences Laboratory, USDA Forest Service, 1700 Bayview Dr., Arcata, CA 95521).

Handling Bait

Uncooked chicken and many other meat baits are a potential source of *Salmonella* bacteria. Contact with both fresh and old bait should be minimized. Chicken pieces should be individually wrapped. or handled with kitchen tongs. Carry soap and water to wash hands thoroughly before meals. The risk of poisoning the target species with rotting meat baits is also negligible, as most target species regularly consume carrion.

LIMITATIONS

As mentioned in the assumptions section the main drawback is that track-plates can confirm presence only. Negative survey results do not mean that the target species does not occur in the survey area or in adjacent areas. Track-plates, also, do not provide any information on the status of the population (i.e. is successful reproduction occurring?)

Unenclosed track-plates have the added disadvantage that they become inoperable in inclement weather. However, the unenclosed plates are probably more likely to detect species such as bobcat, lynx, and wolverine than the enclosed track-plates.

COSTS

A detailed cost outline is provided in Zielinski (1995). He estimated a cost of $5,936 to survey on a 20-$m^2$ survey area (30 stations) with adequate road access. The area was surveyed twice for 12 days each survey with a crew of two federal employees paid about $75.00 per person per day. The cost will decrease significantly if the target species is detected early in the first survey as the second survey would not be needed. In my experience I found no advantage to having two people on the crew, and would recommend that only one person per crew be used. This would also decrease the cost significantly ($4,961 total cost with a one person crew). Surveys of additional areas would also be less expensive as there would be lower materials cost since the track plates and boxes have already been purchased (about $500). Labor costs would be higher in roadless areas where hiking is required to check the stations. Surveys would be somewhat less expensive if one 22 day survey were conducted because stations would only have to be put out and picked up once.

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Videography

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Introduction

A recent assessment of the conservation status of American marten (*Martes americana*), fisher (*M. pennanti*), lynx (*Felis lynx*), and wolverine (*Gulo gulo*) in the western United States (Ruggiero et al. 1994) identified assessment of current distribution as a primary information need for all 4 species. Because of concern over loss of habitat and perceived extirpations of peripheral populations in the western United States, 4 petitions have been submitted to the U.S. Fish and Wildlife Service during the last 6 years to list fishers, lynx, or wolverines under the Endangered Species Act. As a result, survey techniques for forest carnivores have received much attention in recent years as natural resource biologists and managers have recognized that obtaining baseline data on geographic distribution is the starting point of any conservation effort.

Largely in response to these concerns, Zielinski and Kucera (1995) developed a manual that presents detailed descriptions of recommended techniques for surveying large areas to detect the presence of various species of small to medium-sized forest carnivores. The methods described in this manual include: sooted track stations (see also Barrett 1983, Taylor and Raphael 1988), 35-mm and 110 remote camera stations (see also Jones and Raphael 1993, Kucera and Barrett 1993), and snow tracking (see also Forrest 1988, Halfpenny 1987, Thompson et al. 1981).

Recent advances in video technology have led to the development of remote video surveillance systems for use in wildlife research. Although remote video cameras are not discussed in Zielinski and Kucera (1995), they offer many advantages over single-frame 35-mm and 110 remote camera systems. For the last several years, we have been using remote video cameras in southwestern Oregon to conduct surveys of forest carnivores and to augment our radio-telemetry studies of fishers. We described our experiences with these devices and offered recommendations for modifying and using a commercial video surveillance system for such applications in a paper that will soon be published in the Proceedings of the 2nd International Martes Symposium (Aubry, et al. *In press).* Much of the discussion presented here is extracted from this paper.

Objectives

Although we used video technology for several applications other than survey work, including identifying potential trapsites and monitoring natal and maternal dens of fishers (see also Jones, et al. *In press*), we will limit this discussion to the use of video cameras for conducting surveys of forest carnivores. The objectives for surveys with video cameras are the same as those described by Zielinski et al. (1995) for other survey techniques: either for Regional Surveys to determine the presence of carnivores within a management or administrative unit, or for Project Surveys to determine presence of a target species within a proposed management area.

METHODS

The Video Camera System

The video system we use is a modified version of the Compu-Tech™ model RM-680 video camera system[1] (Compu-Tech Systems, P.O. Box 6615, Bend, Oregon 97708; 541-389 9132). The system sold by the manufacturer consists of a weatherproof housing, an 8-mm Sony™ video camera with 20X zoom capability, a PIR-12 dual-sensor transmitter/receiver for activating the camera system, a KR-70 nocturnal lighting system, and an EM-100 external microphone. To improve the performance of the system, we make the following modifications:

Battery--To increase the battery life of the system, we add an external, heavy-duty, deep-cycle 12-volt marine battery that we place in a polyurethane ice chest. In areas with sufficient snow, the ice chest can be buried in the snow to provide additional insulation. We run the battery wires through the drain plug in the ice chest. With this configuration, the battery will operate the camera for as long as needed to record the entire length of videotape under typical winter conditions.

Lighting system--The KR-70 nocturnal lighting system consists of a krypton flashlight mounted on top of the camera unit. However, this light provides relatively low illumination and a narrow field of view. At night, animals detected in the lighted portions of the video image can be difficult to identify to species and the peripheral portions of the image are dark. To increase illumination and widen the field of view on the video image during nighttime exposures, we replace the KR-70 lighting system with 55 or 100 W flood lamps designed for external use on off-road vehicles (ORVs). We place the lamp in a rectangular plywood housing to protect it from weather and falling debris, and run the wires through a hole in the bottom of the housing. Compu-Tech has begun to manufacture a box (model EB-100) for hooking up an external light that includes heavy duty relay contacts designed to handle the higher wattage of an ORV light. In several years of use, however, we have experienced no problems with our home-made external lights. To maximize the illuminated field of view, we mount the unit on a tree either next to the camera or directly above it, aiming the lamp directly at the bait.

Number of Stations, Survey Seasons, and Duration of Sampling

As Kucera et al. (1995) recommend for 35-mm systems, baited video stations are most effective during the winter when food is generally less available and carnivores are most likely to visit baits. For video camera surveys, we recommend applying the basic sampling protocol established by Zielinski and Kucera (1995) for 35-mm cameras, whereby 2 camera stations are established at least 1 mi apart within a 4-mi^2 sample unit and operated until either the target species is detected or a minimum of 28 sample-nights have elapsed (note that this differs slightly from the 28 sample-days recommended by Kucera et al. 1995). Technical problems or animals running out the videotape during one lengthy visit may result in one or both of the camera stations being inoperable during part of the survey. However, extending the sample period an additional sample-night for each night that one or both of the cameras are not operating continuously often gets prohibitively time-consuming. Because forest carnivores are most often detected at night, we recommend the following protocol: sample-nights are added onto the sample period only in the event that

[1]The use of trade names is for reader information only and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

both cameras are inoperable at any time between the hours of 6 pm and 6 am of a sample-night. If at least 1 of the cameras is operating during this time period, we consider that night to be a sample-night. With any remote sampling device involving electronic equipment, there are many potential technical problems. To minimize wasted sampling effort, we check the cameras as often as possible, but at least once per week, replacing baits as necessary.

Configuring the Video Station

Because the video cameras use dual-sensor triggers, the configuration of video stations are similar to that described by Kucera et al. (1995) for dual-sensor 35-mm Trailmaster cameras, with some important differences. We pile bait on the ground, rather than wiring it to a tree or hanging it between 2 trees and we use 2 sensors instead of l. We recommend setting video cameras 5-10 m from the bait, and aiming 2 sensor beams directly over the top of the bait pile (Fig. 1). This provides the best compromise between maximizing the field of view and discerning details in the video image. We place the camera system about 1.5 m from the ground, pointing slightly downward to reduce glare and obstruction of the lens by rain or blowing snow. To minimize glare from the sun in daytime exposures, especially during winter, we aim the camera toward the north.

After the sensor is activated, there is a minimum delay of 2 seconds before the system turns the lights and camera on, and an additional 3-second delay before the video camera begins recording an image. This results in a minimum delay of 5 seconds after an animal enters the range of the sensors before the camera begins recording. If the field of view is too small, an animal that is not going to the bait may move out of range before the camera starts recording. We found that adding a second sensor to the system and crossing the beams over the bait to increase the area covered by the sensors helped to reduce the frequency of blank footage. Because animals may leave the bait station immediately after the lights come on and not be recorded on tape, we are currently experimenting with modifications to the system that delay light activation until after the camera has begun operating. We set the timer on the sensors to record for 35 seconds per activation. This interval works well to minimize the amount of tape wasted on non-target species, but still provide sufficient footage to identify target species. To increase the likelihood that weasels and other small forest carnivores are detected, we set the sensitivity of the sensors at maximum.

Baits and Lures

For video cameras, the most satisfactory way to place bait is in a fairly large, rounded pile. The zoom on the camera should be set so that the entire bait pile is visible in the frame along with 2-3 ft. of area above, below, and to both sides of the pile. A variety of baits will work but for most mesocarnivores, we find that small packets of bait (e.g., chickens or fish) generally work better than large pieces, such as deer carcasses. We obtain whole, unplucked chickens from a local egg farm and salmon or steelhead from a local fish hatchery. To deter aerial scavengers, especially ravens (*Corvus corax*), we place baits under dense canopy cover. We scent the stations with one or more types of skunk-based attractants, which are generally available from trapping supply houses. We rescent the station after about 2 weeks or if there is a heavy rain.

DATA MANAGEMENT

To quantify our video detections for comparison with other survey techniques or to examine trends in detections over time, we tally the number of video sequences in which detections are made. We define a video sequence as any camera activation (35-second recording interval) in which a target species can be positively identified. If an animal remains at the bait for more than 35 seconds and reactivates the camera, or is detected removing pieces of bait from the bait pile in successive video segments, these segments are treated as 1 video sequence.

COSTS

The only drawback of using video cameras for conducting surveys of mesocarnivores is their cost. The cost of our modified video systems is about 8 times that of the Trailmaster 1500 35-mm system (about $5000 vs. $600), but there are

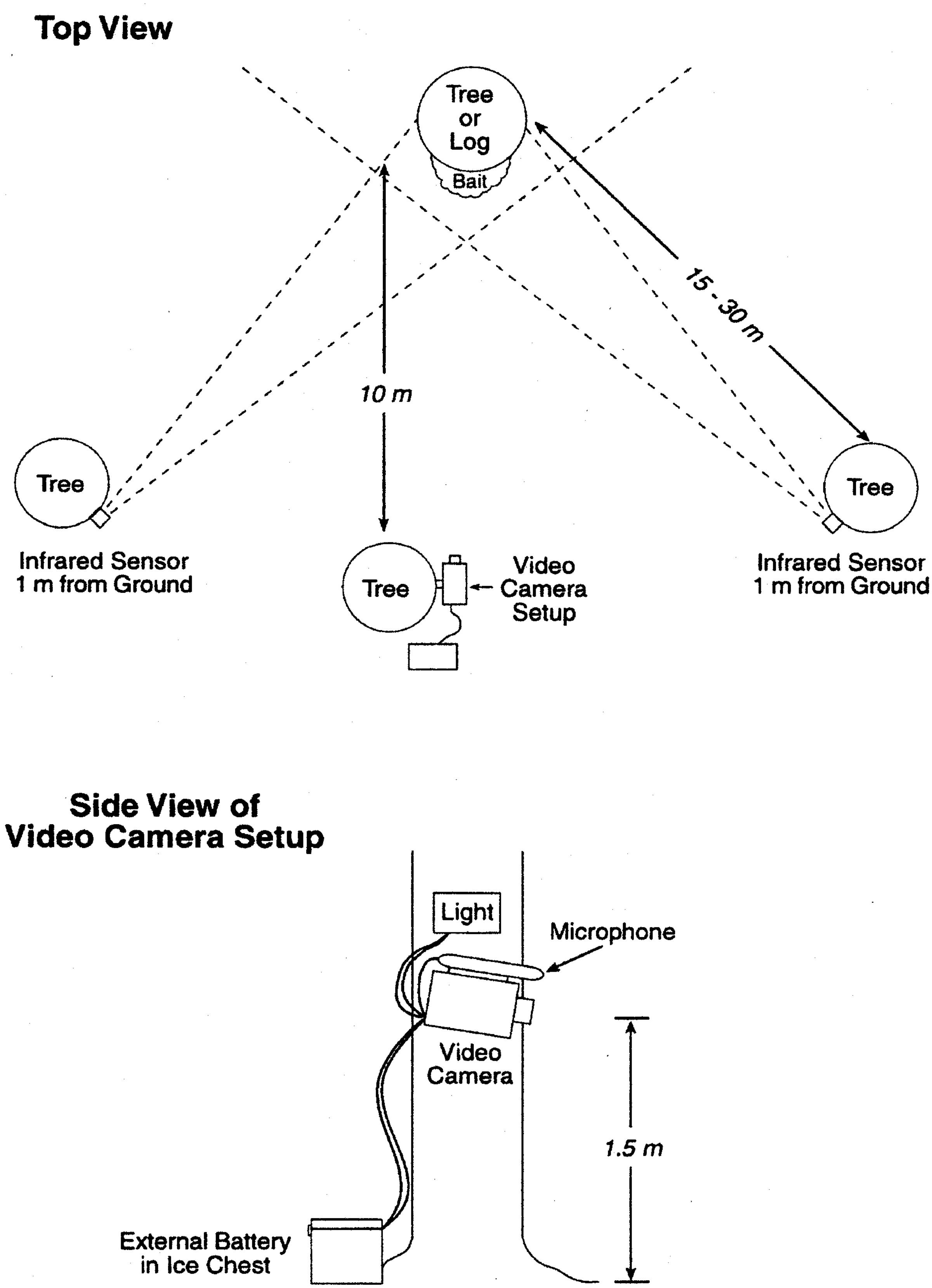

Figure 1. Schematic configuration of remote video camera system for monitoring forest carnivores.

several advantages to the video system that may justify the additional expense. We experienced far fewer technical problems with the video system compared to the Trailmaster 35-mm system. Because of frequent problems, the 35-mm systems need to be checked more often than the video systems, which adds significantly to the cost of using them. Another advantage is that videotape does not need to be developed; consequently, determining if a target species has been detected and relocating the station to another sampling unit can occur more rapidly than with 35-mm cameras. This could increase the efficiency of camera surveys by enabling more units to be surveyed during the sampling period. In addition, video cameras enable biologists to gather behavioral data that cannot be obtained with single-frame cameras. Video cameras can be used for research purposes, such as monitoring den sites, but they can also be used to study the behavior of target species at 35-mm camera stations, sooted track stations, or trapsites to gain insights into how such devices might be modified or deployed differently to improve their performance.

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Monitoring Mesocarnivore Population Status

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INTRODUCTION

Monitoring is all the rage. It is considered an essential step in adaptive management and almost every meeting of a scientific society includes a session on monitoring. Monitoring is a requisite of each National Forest Land Management Plan and can be a condition for acceptance of a Habitat Conservation Plan (HCP), as specified under the Endangered Species Act. Despite government mandates, increasing scientific discussion, and the ethical responsibility of doing so, very few terrestrial monitoring programs have been established and considerable debate and disagreement exists as to what qualifies as monitoring, how it is done, and how monitoring data are used to assist decision making (e.g. Verner and Kie 1988, Stout 1993, Montgomery 1995, Noon, in review).

Interest in monitoring mesocarnivore species arise for any number of the following reasons:

1) There are situations where some form of monitoring is either a legal requirement or strongly suggested by federal or state agencies. These apply to:
    a) any species under the state or federal Endangered Species Act.
    b) species - like lynx (*Lynx canadensis*) in Washington and Oregon - that are "Survey and Manage Species" under the Northwest Forest Plan (USDA and USDI 1994).
    c) some species included in HCP for which private companies are protected from future consultation if the federal status of a species changes (the proposed "no surprises" policy) (USFWS and NMFS 1996, Federal Register 1997).
    d) technically all species on land managed by the Forest Service, because the viability clause of the National Forest Management Act would appear to require monitoring to establish viability.
2) Carnivores are considered ecological indicators of the viability of other members of their communities ("umbrellas", Wilcox 1984).
3) Because carnivores occur at low densities, have relatively low mobility (compared to birds), and habitat fragmentation can lead to their genetic impoverishment (Wayne and Koepfli 1996).
4) Mesocarnivores provide important ecological services, including cycling nutrients and dispersing seeds, and they contribute culturally, esthetically and spiritually to human experiences (Clutton-Brock 1996, Buskirk in press).
5) Monitoring the occurrence of a species is the first step towards understanding its distribution, habitat needs, and demography. Monitoring is a beginning towards understanding the fundamental relationship of a species to its environment.

MONITORING DEFINED

Suter (1993) defines monitoring as the "measurement of an environmental characteristic over an extended period of time to determine its status or trend. Technically, monitoring a trend requires consideration of all the components of variance, and the recognition of a number of important assumptions". Dagum and Dagum (1988) divide time-series into four components: trend, cycles, seasonal variations, and irregular fluctuations. "Trend is the component that corresponds to sustained and systematic variations over a long period of time which is associated with the structural causes of the phenomenon in question, for example, population growth". The best monitoring plan will be designed to distinguish the trend in the variable of interest from the other components of time-series. Obviously, monitoring a trend is more than establishing what appear to be "enough" detection devices (or snow transects) and recording the number of detection's over time; it is an exercise that requires considerable forethought and consultation with a statistician (Zielinski and Kucera 1995).

Monitoring Carnivores: the Difficulty of Doing it Right

Carnivores pose special problems for monitoring trend, most notably their low densities. Mark-recapture population estimates (including recapture by trapping, hair snagging [Foran et al. in review] or photography [Hiby and Jeffrey 1987, Mace et al. 1994]) are inaccurate when the total population is small or the proportion of individuals "recaptured" is small (White et al. 1982); conditions that often apply to mesocarnivores.

Low densities are also a problem when an **index** of population size is the goal, because of the difficulty of achieving sufficient detection's over a reasonable area to detect changes over time. Consider a survey that includes a number of camera or track plate detection stations or snow-transect segments that are checked for evidence of target species on multiple occasions. Lets refer to each station or snow transect segment, or perhaps a small number of stations or segments, as a sample unit. The monitoring response variables usually considered are either:

1) the average number of detection's per sample unit, or
2) the proportion of sample units where the target species is detected.

These are roughly similar to the familiar indices used at bird point count transects; the former being analogous to the mean count per point count station and the latter equivalent to what is referred to as "frequency" (proportion of counting stations at which a species is recorded). However, it is important to realize that unless the individuals detected at a sample unit can be distinguished (as they can with birds, but usually cannot with mesocarnivores), the former approach has severe limitations. With this caveat in mind, lets first consider the number of sample points necessary to detect change in average number of detection's per sample unit over two sample periods.

To determine, with statistical confidence, that an index has changed requires consideration of statistical power; a concept that will not be reviewed here but for which there are many good references (e.g. Cohen 1988, Forbes 1990, JWM editors 1995, Thomas and Krebs 1997). Assuming an alpha (Type I error rate) of 0.05 and a power (1-Type II error rate) of 0.80, the sample size necessary to detect a drop from an average of 0.6 detection's per sample unit to 0.3 would be about 80 sample units. However, in most cases the number of detection's per sample unit are much less; detecting a 50% decrease from an average of 0.2 to 0.1 would require 336 sample units (Dawson 1981, Nur et al. in prep., Verner in press). The drawback of extensive sampling costs is further compounded by the difficulty in interpreting the meaning of a detection when multiple visits by an individual cannot be distinguished from visits by multiple individuals.

Now consider the situation that occurs when we attempt to distinguish a change in the **proportion** of sample units with a detection, an estimator that should be less influenced by the re-visitation behavior of individuals attracted to baited sample units. Before considering the sample size needs for this metric we should consider the issue of independence. The proportion of sample units with a detection is a useful index if, and only if, users adhere to the assumption that detection's at sample units are independent (Cochran 1977). The good news is that this criterion is much easier to achieve using proportion as the population index than using **average number of detection's.** However, independence can only be achieved by distributing the units a sufficient distance apart such that individuals do not visit more than one sample unit (Diefenbach et al. 1994). This constraint has an obvious logistical cost; as the number of sample units necessary to detect a change in the index increases, so must the spatial extent of the sample area. This is obviously a bigger problem sampling a wolverine (*Gulo gulo*) population than it is for a spotted skunk (*Spilogale gracilis*) population. Once the assumption of independence is met, the required sample size to detect large changes in relatively large proportions are rather reasonable (e.g. a 50% decline from 60% to 30% of the units with a detection requires 48 sample units [Fliess 1981]). However, detecting smaller changes for proportions that are lower (and more typical of those for carnivore surveys) necessitates an increase in sample size. For example, 945 sample units are required to detect a change from 20% to 15%.

Given the considerations described above, detecting changes in an index over time will usually require sampling large areas if the species of interest has a large home range. This was the conclusion we reached when we simulated monitoring to detect change over two time periods, in an index of fisher (*Martes pennanti*) abundance in California (Zielinski and Stauffer 1996). The assumption of independent sample units required that they be about 10 km apart and the expected spatial variation in the fisher population across the state favored a stratified approach. Using the best estimates of expected fisher detection's in each of the 10 strata resulted in the conclusion that a 20% decline in an index of fisher abundance could be detected over two time periods by sampling 115 units/stratum: a total of 1150 units throughout the fisher range on public land in California. This example demonstrates the geographic scale necessary to achieve a defensible monitoring program for one of the least common mesocarnivores. If smaller, more common species are of interest the task will be less daunting.

Up to this point I have been discussing the statistical considerations for testing the hypothesis that some index of abundance has changed between two time periods. While this information is useful, how does the plan to conduct monitoring over 3 or more time periods affect the sampling effort? Regression methods are usually preferred over using paired t-tests, which compare the difference in successive intervals. The significance of a regression over an extended period of time is influenced most by the variance in the estimate at each time point. Smith et al. (1994) found no relationship between the rate of raccoon visitation to scent stations and the minimum_known population size over 20 intervals during the course of a year. They attributed this failure to a number of density-independent sources of variation,. however the relatively low number of sample units also led to high variability within each sampling period. If the resample interval is a year, it may take many years to distinguish the background of chronic, continuous decline from annual variation in detection probabilities. Simply put, the stringent sample size and effort requirements to distinguish change over two time points are not substantially relieved when monitoring is extended to >2 time periods. As an example, the venerable US Fish and Wildlife Service Breeding Bird Survey, when releasing data to the public caution against trusting state or regional trend analyses based on fewer than 14 routes, each with 50 counting stations (Robbins et al. 1986, Verner in press). This is equivalent to a mesocarnivore survey with a minimum of 700 snow track segments, track plates or cameras, each spaced a sufficient distance to insure independence. Moreover, these data have been demonstrated to be biased if 1) they occur over less than 5 intervals, 2) there are low densities, or 3) there is observer variation (Geissler and Sauer 1990).

CHANGE IN SPATIAL DISTRIBUTION: A PRACTICAL ALTERNATIVE POPULATION INDEX

It is not easy to fulfill the monitoring requirements described above for most of the mesocarnivores. Detecting change in an index of population size may either be too expensive because of the large number of samples required or impractical because a management area is of insufficient size to establish the required number of spatially-independent sample units. Stringent assumptions are inescapable. However, I do not mean for this paper to discourage those interested in monitoring mesocarnivores; just the opposite. It important to realize that even activities that cannot possibly estimate or index the number of individuals with great precision still have value. We are at a stage in the evolution of monitoring mesocarnivore populations where we are still developing and testing new approaches and techniques. Valuable data can be collected without fulfilling some of the more rigorous statistical assumptions described above. Many biologists are responsible for the health of mesocarnivore populations that occur on relatively small pieces of land and coordinating surveys with -managers of other land units, although desirable, is difficult. So, what can be done on a particular district, private parcel, or even watershed? I suggest that monitoring a species' **distribution** rising an atlas approach is a practical, yet useful, way to assess change in a mesocarnivore population.

The atlas method has a long-standing tradition in Europe as a means of monitoring populations of birds and mammals (Arnold 1978, Smith 1990). Some standard amount of survey effort is expended in each block of a grid over a reasonably short period of time and the presence or absence of a species in each block is reported. Applications of bird atlas projects include: 1) mapping range expansion and contractions; 2) detecting and monitoring population change; 3) documenting effects of habitat fragmentation; 4) land use planning to document areas of special conservation value; and 5) correlation with forest cover types (Robbins et al. 1989). The distribution of detection's across the grid is a valid method to assess population status. Atlas projects have been considered a form of monitoring (e.g. Robbins et al. 1989, Harding 1991) because species that are rare on the basis of abundance are usually also rare on the basis of geographic distribution (Gaston and Lawton 1990; though see Arita et al. 1990 for an exception). Furthermore, some studies have confirmed that changes in measures of abundance are paralleled by changes in presence/absence (e.g. Bart and Kloeisewski 1989). Usually, the assessment of change in distribution over time is done qualitatively -- by eye --and only profound changes in distribution are detectable. This has been the basis of assessing change in the status of martens (*Martes americana*) in the Sagehen Creek watershed in the Tahoe National Forest, before and after timber harvest (S. Martin, unpublished). More sophisticated statistical methods are also available to distinguish two spatial distributions (e.g. Robbins et al. 1989, Syrjala 1996), but spatial autocorrelation must be considered (Legendre and Fortin 1989). Atlas methods can be used to monitor distribution in areas with minimal human impact and as tools for monitoring the effect of management activities.

We have previously suggested the atlas method to biologists conducting surveys for rare forest mesocarnivores (Zielinski et al. 1995) and I believe it is the easiest way to conduct detection surveys that are of qualitative value in assessing change in population status. Certainly, atlas maps do not provide the resolution to detect change in abundance that some of the methods described earlier do, but they provide a great deal more information than doing nothing at all. And, although not all suitable habitat patches are occupied by a species all the time (Pulliam 1988), species that are well distributed across appropriate habitat within their historic range probably have longer persistence times than species that are absent from large portions of their range. Finally, it is important to emphasize that atlas methods, like other methods that rely on the detection of sign, are unable to identify the sex or age of individuals that are detected. Thus, for most species it will be impossible to describe the demographic characteristics(sex or age distribution) of the sample or to distinguish populations 'sources' from population 'sinks' (Pulliam 1988).

COLLATERAL BENEFITS OF A MONITORING PROGRAM

As described above, monitoring changes in the status of a mesocarnivore population is possible, but only by either considering a large enough geographic area to establish sufficient independent samples or by settling for less meaningful data on the spatial distribution of detection's over a smaller area. Either exercise is time-consuming and expensive so it is prudent to use these data for as many additional purposes as possible. Foremost among these is the collection of environmental information associated with the locations where target species were, and were not, detected. Given sufficient detection's these data can also be used to develop regional habitat models that in some cases may be preferable to spatially explicit demographic models in understanding the effects of habitat loss and fragmentation (Karieva et al. 1997). Intensive field study, primarily using telemetry, has been the classic way to understand habitat. associations. However, these studies are uncommon, probably because they can be as expensive as monitoring. In fact, one could argue that survey and monitoring data are more useful to the decision-making process than are data from intensive studies which are usually focused on the home ranges of a few individual members of a high-density population (Smallwood and Schoenwald 1996). On the whole, intensive autecological studies and extensive survey and monitoring activities complement one another by addressing different scales of habitat association. And, on a practical note, an expensive monitoring program will more likely survive budget cutting if collateral benefits, such as understanding habitat associations, are emphasized.

Habitat data collected at any scale can be of use. Standard vegetation plot measures at all sample locations will, at a minimum, produce a list of environmental and vegetation attributes at locations where the target species is detected. This analysis will usually be exploratory, and the information may help refine additional monitoring plans. These types of analyses can also be extended to contrast sites that did and did not report detection's, or where the number of detection's varied (e.g. Spencer 1981, Martin 1987, Raphael 1988 using track plates; Thompson et al. 1989, Powell 1994 using snow transects). Environmental features associated with fisher detection's at track plate stations have also helped refine our understanding of fisher habitat in commercial forest landscapes (R. Klug in prep., M. Higley, unpublished). As with monitoring in general, caution should be exercised in interpreting habitat data when the sample units are not considered independent.

More sophisticated habitat analyses include data extracted from GIS layers. Occurrence data at point locations can be the foundation of empirically based landscape models of habitat use (e.g. Mills et al. 1993, Ramsey et al. 1994, Mladenoff et al. 1995, Raphael et al. 1995, Pedlar et al. 1997) or of more modest comparisons between locations and aerial photograph interpreted landscape information (Rosenberg and Raphael 1988). Even if the original data were not collected with a systematic sampling design in mind, they can be of use as a starting point for developing an adaptive habitat model (Raphael et al. 1995, Carroll 1997) which can then be tested and refined with systematic surveys (e.g. Carroll and Zielinski, in prep.). We developed a model that predicts, with 80% success, the probability of fisher occurrence using landscape features of vegetation structure and a regional trend surface described best by a precipitation gradient. This model was tested using surveys designed originally to parameterize a statewide monitoring program, but yielded results about habitat use that are of equal utility to those related to the monitoring goals. In fact, it may be through the development and testing of habitat models of this nature we are able to shift from the more expensive mode of monitoring animals to the less expensive mode of monitoring features of their environment that are associated with viable populations. This is the direction that monitoring the northern spotted owl (*Strix occidentalis caurina*) is headed

(Noon, in review). However, habitat monitoring alone must be continually linked to validation of the relationship between the population parameter of interest (e.g. occurrence, survival, fecundity, lambda, sex ratio) and the habitat index. And, the caution described earlier about the inability of most methods to distinguish sexes or ages of individuals is especially valid when interpreting habitat data. Neither the presence of a species nor the frequency of its detection are necessarily related to the ability of the habitat to sustain individuals, or a population, over time (Van Home 1983).

In sum, a survey or monitoring exercise is a valuable opportunity to collect geographically and environmentally referenced information on the occurrence of an uncommon carnivore. Although the conditions under which surveys will constitute the basis for an adequate monitoring scheme can be rigorous, they are not impossible. The atlas approach to monitoring distribution is a practical and valuable tool for managers of relatively small areas who wish to track population status. Every time a thoughtful survey is executed it is an opportunity to monitor the distribution of a target species, to develop a time series of this information, and an opportunity to understand more about the habitat of the target species. None of these opportunities should be wasted if and when the opportunity to conduct a survey arises.

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