ASSESSING THE EFFECTIVENESS OF UMBRELLA SPECIES: A brief instruction manual for objective evaluation of the adequacy of umbrella effect.

Prepared by Troy Merrill, LTB Consulting, Moscow, ID. USA. troy1@moscow.com

Using this document:

This document describes a method for using available information on the ecology of wildlife species to assess their potential to provide adequate umbrella effects to other species. The approach may seem complicated but the contribution it makes to conservation planning is worth it. This document is basically an instruction manual. The tables and figures below in combination with the text descriptions will guide you through the method as it was applied to carnivore species in Idaho and Montana. Once the method is understood it can be applied to other species and new regions.

Introduction:

Conservation of biodiversity is a stated goal of most conservation organizations in North America. Unfortunately stating that conservation of biodiversity is a goal does not mean it is possible to develop conservation plans for each of the individual elements of which biodversity is composed. The majority of species diversity consists of species too small to see; many have never been named or described. Of the species that can be seen we have detailed life history information - knowledge of what it takes for them to survive - for only a small number. In the face of increasing human populations and the associated increase in threats to biodiversity there is not time or sufficient resources to fill the gaps in our knowledge. It is, therefore, unavoidable that we focus conservation actions on those species for which we have the most information. The species we know the most about tend to have fur or feathers and behaviors that humans find inspirational or endearing. Focal species can have very different ecological roles within a landscape and, therefore, will have different functions within a conservation plan. Some species are good indicators of specific environmental conditions (indicator species), others require a large area that coincidentally contains other species (umbrella species), or the species are considered essential for maintaining a specific ecosystem (keystone species), or they are so dang cute that people will mobilize to protect them (flagship species). An in depth analysis and discussion of the roles of focal species in environmental monitoring and conservation is provided by Caro et al. (1999) and Lambeck (1997).

Selection of focal species should be based on the goals of the conservation plan. Even if conservation of biodiversity is a goal of an organization it may not be an appropriate objective for a conservation plan. If the objective of the conservation is plan is narrowly focused on maintaining or restoring specific environmental conditions, frequently the case in stream conservation, the appropriate focal species may be an indicator species. Indicator species are selected based on a known response to a specific ecological insult, i.e. Harlequin ducks are known to be very sensitive to deterioration in water clarity and will not nest on streams that carry high sediment loads. The presence of Harlequin nests is an indication that water clarity is at acceptable levels. It is much easier to survey for nests than monitor water clarity directly. The presence of Harlequin ducks does not, however, tell us much about other conditions in the watershed. If the focus of the conservation plan is wider, looking at multiple conditions across a broader landscape the appropriate species should provide substantial umbrella effects. The presence of an umbrella species, i.e. grizzly bears, in the watershed is an indication of the state of a wider range of conditions such as the availability of food resources, road density and the number of humans using them, factors that are known to impact other species. The presence of grizzly bears would not, necessarily, indicate much about water clarity. Rarely the appropriate focal species would be a keystone species. Identification of keystone species is difficult and controversial, there are few ecosystems dependent upon a single species, e.g. there is generally some redundancy in the species performing ecosystem processes so the loss of a species from the ecosystem does not equal the loss of an ecosystem process (the ecosystem will be less resilient to future perterpations). Flagship species are a result of human attitudes and marketing not their role in the ecosystem. Regardless of the objective of the conservation plan there must be 'something' compelling enough that society will choose conservation over other alternatives. This 'something' maybe a perceived threat to human well-being, a widely held moral/ethical commitment, or a charismatic species that is associated with desirable social values. If it is decided that a flagship species would be useful in mobilizing humans to dedicate effort and resources to conservation it need be remembered a flagship species is much more valuable if it provides substantial umbrella effects.

Focal species for large-scale conservation planning are generally selected because they are believed to provide a substantial umbrella benefit to other species or they can serve as a flagship for conservation efforts or, most frequently both. Despite the potential importance of umbrella effects in achieving conservation goals, little progress has been made in conceptualizing or measuring these effects. By convention, umbrella effects have been measured as co-occurrence or overlap of a recipient species' range with the range of a putative umbrella (e.g., Andelman and Fagan 2000; Carroll et al. 2001; Suter et al. 2002). Rarely have cogent standards (e.g., viable recipient populations) been invoked to judge the sufficiency of area overlap or co-occurrence (Lambeck 1997; Lindenmayer et al. 2002). In any case, overlap or co-occurrence alone are likely to be poor measures of umbrella effects because, even where they co-occur, recipient species may not benefit from management actions taken to benefit the putative umbrella. Area overlap or co-occurrence are necessary but not sufficient parts of measuring umbrella effects. Shared sensitivity to limiting factors is another major dimension (Lambeck 1997). That said, an ideal measure would not just incorporate shared ecological sensitivities, but would also account for common responses to specific management actions. Despite disparate niches, many species may derive benefits from a single management action, such as closing roads, because of ecological ramifications (Trombulak and Frissell 2000).

Measuring or otherwise estimating the spatial, ecological, and managerial dimensions of umbrella effects is inherently problematic. Umbrella effects are relevant to conservation practice precisely because little is known about most species and because resources are lacking to remedy the deficit. Moreover, there will rarely if ever be the opportunity to test methods used to estimate or predict umbrella effects for the same reasons. Yet, there is an imperative to move beyond conjecture and assertion and make use of information that is available. Given these constraints, any method for estimating umbrella effects would ideally be transparent and robust to differences in levels and quality of information. Such a method would reveal assumptions and, on that basis, allow participants in conservation cases to make their own judgements about the limitations of predictions and change assumptions if desired.

In this paper we provide instructions on using our method for estimating and predicting umbrella effects and point out other immediate applications for the information compiled in order to assess umbrella effects (for a in depth discussion see Mattson and Merrill in prep). The method for assessing umbrella effects requires:

1. Range maps of the species for calculating range overlap (see Figure 2 as an example of how species ranges were treated)
2. Information on the species sensitivities to ecological factors,
3. Calculation of the similarity of species sensitivities to management activities,
4. Standards for judging the sufficiency of the area of protection imparted by the umbrella.

To illustrate the method, we apply it to carnivores in Montana and Idaho, USA (Figure 1), focusing on potential umbrella effects imparted by carnivores species protected by state or federal policies. While this approach is somewhat complicated it relies on information that is readily available from regional databases or ecological compilations, or based on general ecological relations. Therefore the method can be applied to more species and/or different regions without extensive and expensive research. We also use judgements about regional ecological relations that are expressed in explicit conceptual models. We believe this method derives the maximum possible insight about potential umbrella effects from available quantitative and qualitative information.

Our method consists of five main parts:

1. calculation of overlaps between ranges of putative umbrellas and other species, expressed as potential numbers of individual annual ranges,
2. calculation of similarities of sensitivities among species to ecological factors (what we call *proximal factors*),
3. development of a conceptual model relating proximal factors to management factors (what we call *distal factors*), decomposition of proximal effects onto distal factors, and calculation of similarities of sensitivities among species to distal factors,
4. calculation of range overlaps weighted by similarities of sensitivities to both proximal and distal factors (what we call *coverage*), and
5. the development and application of standards for judging coverage adequacy.

The tables below illustrate the type of information that is required to employ this method and how it should be organized. While we demonstrate the approach using carnivores this approach can be used to calculate umbrella effect or benefit for any type of species.

In addition to demonstrating how available information is used to assess the number of species that benefit from the of umbrella effect provided by a species and the sufficiency of the benefit the tables contain information that is interesting and useful in its own right.

- Table 1 contains basic information on the carnivore species of the Northern Rocky Mountains including average home range size, body weight, and an estimate of the number of homeranges (individuals) needed for sufficient conservation. This information may be useful for such things as evaluating and commenting on management plans or rough estimates of the size of the conservation area needed.
- Table 2 provides a brief description of environmental and ecological factors known to limit carnivore species in the Northern Rockies.
- Table 3 shows which species are limited, and how substantial the limitation is, by each factor. Zero indicates that factor is not limiting to the species; a 4 indicates the factor is significantly limiting to the species.

- Table 4 lists management actions (distal factors) that have substantial effect on the proximal factors that directly limit carnivore species in the Rocky Mountains. It is through the distal factors that conservation activities influence the fate of these species. Understanding the relationship between distal and proximal factors requires examining the conceptual model illustrated by Figure 3 (and some head scratching, but it does work out in the end). On Figure 3a proximal factors are shown in white boxes with an '*' next to them. The arrows indicate the links between proximal and distal factors (shown in grey boxes). As shown proximal factors may be linked to more than 1 distal factor. When calculating the effect of a distal factor on a species if a proximal factor is related to more than one distal factor the effect of the proximal factor on the species (1 to 4) is divided between all linked distal factors. A more in depth, and complicated, explanation is provided in Mattson and Merrill (in prep). Linking proximal to distal factors is necessary for quantifying the relative limiting effects of the distal factors to each species; remember that the distal factors are the means by which humans influence the proximal factors and the proximal factors are what directly impact the species. How the effects of proximal factors are assigned to distal factors is illustrated in Figure 3b using grizzly bears as an example.
- Table 5 shows the relative importance of the limiting effects of distal factors to carnivore species in the Rocky Mountains (values have been standardized so that each row sums to 100, i.e. the 4.46 loaded on to the distal factor 'access' [Figure 3b] represents 35.3 % of the total effect of distal factors [table 5 col1 row1]). If for no other reason Table 5 is of interest because it summarizes the impact of management actions on a number of species.
- Figure 4 shows the results of a cluster analysis that grouped species based on the similarities of their sensitivity to (a) proximal factors and (b) distal factors.
- Table 6 contains the values used in calculating the 'coverage' provided by a putative umbrella to beneficiary species. Coverage is calculated as follows.

  We posited that the number of annual ranges contained within an area of overlap, weighted by the proportion of animals occupying those ranges likely to benefit from management of the umbrella species, was an index of umbrella coverage, or *coverage* for short. Thus, coverage, as a numeric value, was:

  $$pCoverage_{ij} = hrOverlap_{ij} \times piED_{ij}, \text{ or}$$

  $$dCoverage_{ij} = hrOverlap_{ij} \times diED_{ij},$$

  where $pCoverage_{ij}$ is coverage considering proximal effects only, $dCoverage_{ij}$ is coverage considering distal effects, $hrOverlap_{ij}$ is the number of annual ranges in the area of overlap with the putative umbrella, $piED_{ij}$ is the proportional inverse Euclidean distance between the recipient and umbrella species based on proximal effects only, $diED_{ij}$ is the distance including distal effects, 'i' denotes the recipient species, and 'j' the putative umbrella.

Developing and Applying a Standard

Population standards for judging the sufficiency of conservation are an on-going topic of debate. Yet standards are necessary, if for nothing else than setting benchmarks. We chose to apply a long-standing rule of thumb for short-term population robustness; "...on the order of 50 and 500" (Shaffer 1987). There is evidence that populations of large-bodied animals are more robust at about the 50 benchmark compared to populations of small-bodied animals, which need to be much more numerous to attain similar short-term prospects (Silva and Downing 1994). Because of this body mass-related variability, we scaled our standard for judging adequacy of coverage (*Standard*) to vary inversely with body mass (*Mass*) according to a log-log relation, with the smallest-bodied carnivore accorded a standard of 500 and the largest-bodied carnivore a standard of 50 (Table 1):

$$\ln(Standard_i + 1) = 6.2 - 0.50\ln(Mass_i + 1).$$

We obtained body masses from the CRC Handbook of Mammalian Body Masses (Silva and Downing 1995).

We divided *pCoverage* and *dCoverage* by *Standard* for each species 'i' to judge the adequacy of putative umbrella effects. If this ratio was ≥1, we judged coverage to be sufficient, considering proximal effects alone and with distal effects included. Table 6 provides an example of calculating coverage and applying standards for all carnivore species in Montana, considering grizzly bears as the candidate umbrella. For wolves, we multiplied the number of pack ranges by 6.5 (an average pack size; www.state.ak.us/local/akpages/FISH.GAME/notebook) to estimate number of animals to compare with *Standard*. Applied this way, we considered *Standard* to be conservative in that no annual range overlap among animals was assumed (i.e., number of annual ranges = number of animals). Annual ranges of most carnivore species probably overlap, as in the case of grizzly bears (Mace and Waller 1997).

Table 6 shows the umbrella effect provided by grizzly bears to other carnivore species in Montana. Grizzly bears are used simply as an example of the method, the umbrella effect provided by other species can be calculated in the same manner.

Coverage provided to black bears by managing for grizzly bears is 8.6 based on proximal factors. It is calculated using values from Table 6 as 850 [the number of home ranges in area of overlap] multiplied by .54 [the standardized euclidian distance for proximal factors] divided by 53 [the minimum number of ranges required for sufficency, Table 1]. Coverage considering distal factors is calculated in the same manner except the inverse euclidian distance for distal factors (.82) is used.

- Table 7 shows the relative impact of distal factors across all species this can be interpreted as a ranking of the inverse impact of management actions for carnivore species. Aggregated over all species, loadings varied substantially among distal factors (Table 7). Median and mean loadings were > 2× higher for road and trail access than for any other factor. Moreover, this heavy loading on road and trail access was consistent among species, as indicated by the small interquartile range (Table 7). Timber harvest policies and practices were next most heavily loaded, although among-species loadings varied substantially. Otherwise, numbers of humans, fire control policies, trapping regulations, and agricultural practices had intermediate loadings, whereas fishing regulations, protective laws, and hunting regulations had very small median loadings.
- Tables 8 and 9 show the umbrella benefits provided to other carnivore species by special status carnivore species.

Conclusion:

If you have worked through the method described above and understand it, congratulations. If not try again, it took me several times of walking through the method step before I truly understood it and I helped develop it. Once understood the value of being able to quantify the sufficiency of umbrella effects becomes much more apparent. This approach allows us to much better assess whether or not our conservation actions will yield the desired result.

Table 1. Name, status, female annual range size, female body mass, and minimum number of ranges used to judge sufficiency of umbrella effects in this analysis, for carnivores in Montana and Idaho, USA.

Species	*Status**	*Size of female annual range (km²)*	*Female body mass (kg)*	*Minimum number of ranges*
Grizzly bear (*Ursus arctos*)	T, EXPN (USFWS, MT, ID)	210.0	100.0	50
Black bear (*U. americanus*)		21.5	88.6	53
Gray wolf (*Canis lupus*)	E, EXPN (USFWS, MT, ID)	900 (per pack); 6.5 animals per pack	33.0	13 ranges; 84 animals
Coyote (*Canis latrans*)		20.5	12.2	140
Red fox (*Vulpes vulpes*)		2.5	3.6	238
Swift fox (*V. velox*)	SS (USFS, MT)	8.1	2.0	295
Mountain lion (*Puma concolor*)		190.0	48.0	72
Lynx (*Lynx canadensis*)	T (USFWS, MT, ID)	35.0	8.0	170
Bobcat (*L. rufus*)		18.5	7.2	178
Raccoon (*Procyon lotor*)		12.5	6.5	186
Wolverine (*Gulo gulo*)	SS (USFS, MT, ID)	380.0	10.1	153
Badger (*Taxidea taxus*)		1.5	5.6	199
River otter (*Lutra canadensis*)		42 (linear)	7.9	171
Fisher (*Martes pennanti*)	SS (USFS, MT, ID)	24.5	1.9	300
Marten (*M. americana*)	SS (USFS)	4.5	0.6	405
Mink (*Mustela vison*)		2.5	0.8	382
Ermine (*M. erminea*)		10.0	0.2	468
Long-tailed weasel (*M. frenata*)		0.2	0.1	488
Least weasel (*M. nivalis*)		0.3	>0.1	500
Black-footed ferret (*M. nigripes*)	E, EXPN (USFWS, MT, ID)	0.5	0.7	393
Spotted skunk (*Spilogale putorius*)		0.6	0.6	405
Striped skunk (*Mephitis mephitis*)		3.6	2.1	291

*T = Threatened, E = Endangered, EXPN = Experimental non-essential, SS = Sensitive or special status species; USFWS = US Fish and Wildlife Service, USFS = US Forest Service, MT = State of Montana, ID = State of Idaho

Table 2. Definition of proximal factors identified as substantially limiting at least one carnivore species in Montana and Idaho, USA. Compared to distal factors, proximal factors have effects spatially and temporally nearer to births and deaths of carnivores.

Factor	*Acronym*	*Definition*
Other human-caused mortality	OHCM	Deaths caused by poaching, defense of life & property, removal by managers to resolve conflicts, etc.
Hunter kill	HK	Deaths caused by legal hunting targeting the species
Targeted trapping	TT	Deaths caused by legal trapping targeting the species
Non-targeted trapping	NTT	Deaths caused by trapping not targeting the species
Road kill	RK	Deaths caused by collision with motor vehicles
Forest cover & coarse woody debris	CVR	Extent of favorable ambient conditions produced by forest cover & shade or microsites associated with woody debris
Elk	ELK	Numbers of elk (*Cervus elaphus*)
Deer	DEER	Numbers of deer (*Odocoileus* spp.)
Moose	MOOSE	Numbers of moose (*Alces alces*)
Red squirrels	REDSQ	Numbers of red squirrels (*Tamiasciurus hudsonicus*)
Prairie dogs	PRDOG	Numbers of prairie dogs (*Cynomys* spp.)
Ground squirrels	GRDSQ	Numbers of ground squirrels (*Spermophilus* spp.)
Hares	HARE	Numbers of hares (*Lepus* spp.)
Rabbits	RABB	Numbers of rabbits (*Sylvilagus* spp.)
Porcupines	PORC	Numbers of porcupines (*Erethizon dorsatum*)
Redback voles	RBVOLE	Numbers of redback voles (*Clethrionomys gapperi*)
Mice & other voles	MICE	Numbers of mice & voles (*Peromyscus* & *Microtus* spp.)
Fish	FISH	Numbers of fish that are potentially prey
Fruits & seeds	FRT/SD	Amounts of large fleshy and fatty fruits or fatty seeds
Invertebrates	INVRT	Amounts of edible invertebrates
Owl-caused mortality	OWL	Deaths caused by owls (*Bubo virginianus*, etc.)
Golden eagle-caused mortality	EAGLE	Deaths caused by golden eagles (*Aquila chrysiotos*)
Coyote-caused mortality	CYTM	Deaths caused by coyotes
Wolf-caused mortality	WLFM	Deaths caused by wolves
Mountain lion-caused mortality	MLNM	Deaths caused by mountain lions
Fox-caused mortality	FXM	Deaths caused by foxes

Table 3. Weighted effects of proximal factors (columns) on vital rates of carnivores (rows) in Montana and Idaho, USA. Weights are ordinal, with '0' signifying no substantial effects and '4' substantial limiting effects. Proximal factors are defined in Table 2.

	Proximal factors																								
Species	OHCM	HK	TT	RK	CVR	ELK	DEER	MOOSE	REDSQ	GRDSQ	PRDOG	HARE	RABB	PORC	RBVOL	MICE	FISH	FRT/SD	INVRT	OWLM	EAGLEM	CYTM	WLFM	MLNM	FXM
Grizzly bear	4	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0
Black bear	3	4	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0
Mtn. lion	1	4	0	0	0	2	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wolf	4	0	0	1	0	3	2	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Wolverine	3	0	0	0	0	3	3	3	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Coyote	3	3	3	1	0	1	2	0	0	1	0	2	2	0	0	2	0	0	0	0	0	0	2	0	0
Red fox	0	3	4	2	0	0	0	0	0	0	0	3	3	0	0	3	0	2	0	0	0	1	0	0	0
Swift fox	3	0	3	2	0	0	0	0	0	2	1	0	3	0	0	3	0	0	1	0	1	2	0	0	0
Badger	4	3	2	3	0	0	0	0	0	3	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
Lynx	1	0	0	1	3	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0
Bobcat	0	3	4	0	0	0	1	0	0	2	0	0	3	0	0	2	0	0	0	0	0	0	0	2	0
Marten	0	0	4	0	2	0	0	0	2	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0
Mink	0	0	4	1	0	0	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0
River otter	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0
Fisher	0	0	1	0	3	0	0	0	0	0	0	3	0	2	0	0	0	0	0	0	0	0	0	0	0
Ermine	0	0	3	0	0	0	0	0	0	0	0	2	3	0	0	4	0	0	0	0	0	0	0	0	2
L.t. weasel	0	0	3	0	0	0	0	0	0	3	0	0	0	0	0	4	0	0	0	0	0	0	0	0	2
Least weasel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	2	0	0	0	0	1
Black-footed ferret	2	0	0	0	0	0	0	0	0	0	4	0	0	0	0	1	0	0	0	2	2	2	0	0	1
Spotted skunk	4	0	3	1	0	0	0	0	0	0	0	0	0	0	0	2	0	0	2	0	0	0	0	0	0
Striped skunk	4	0	3	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2	0	0	0	0	0	0
Raccoon	0	3	4	1	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	0	2	0	0	1

Table 4. Definition of distal factors identified as having a substantial effect on proximal factors affecting carnivores in Montana and Idaho, USA. Distal factors are human practices or the direct outcome of decision processes in the human domain.

Factor	*Acronym*	*Definition*
Road & trail access	Access	Amount of accessible roads and trails in or near carnivore range
Number of humans (resident & visitors)	# of humans	Number of resident or visiting humans in or near carnivore range
Fire management policies	Fire control	Policies for the management and control of wildfires or prescribed burns
Timber harvest practices/policies	Timber harvest	Timber harvest methods and policies governing overall timber harvest programs
Hunting regulations for prey species	Hunting (prey)	Regulations governing the hunting or species that are important prey of the carnivore
Hunting regulations for the carnivore species	Hunting (predator)	Regulations governing the hunting of the carnivore species
Protective laws for the carnivore species	Protective laws	Special laws or regulations designed to protect the carnivore species
Fishing regulations	Fishing regs.	Regulations governing the harvest of fish species that are important prey of the carnivore
Agricultural practices	Agric.	Normal practices of husbandry and cultivation and policies affecting these practices
Animal damage & control practices/policies	Damage control	Normal practices for the control of depredating animals and the policies affecting these practices
Trapping regulations	Trapping regs.	Regulations governing the trapping of fur-bearers, either the carnivore or other species whose harvest puts the carnivore at risk
Number of trappers	# of trappers	Number of humans engaged in trapping carnivores or other species for economic gain
Value of pelts	pelt value	The market value of pelts from carnivores or other species whose harvest puts the carnivore at risk

Table 5. Loadings of proximal effects on distal factors (columns) for carnivore species (rows) in Montana and Idaho, USA. Distal factors are defined in table 3. Loadings are standardized to sum to 100 across rows.

	Distal factors											
Species	*Access*	*# of humans*	*Fire control*	*Timber harvest*	*Hunting (prey)*	*Hunting (predator)*	*Protective laws*	*Fishing regs.*	*Agric. practices*	*Agric. damage control*	*Trapping regs.*	*Value of pelts*
Grizzly bear	35.3	12.5	5.9	29.7	5.9	0.0	10.5	0.0	0.0	0.0	0.0	0.0
Black bear	30.3	13.9	6.3	26.8	0.0	15.1	7.6	0.0	0.0	0.0	0.0	0.0
Mtn. Lion	31.9	7.2	4.0	17.0	24.0	12.8	3.2	0.0	0.0	0.0	0.0	0.0
Wolf	36.0	16.3	4.7	23.3	10.5	0.0	9.3	0.0	0.0	0.0	0.0	0.0
Wolverine	35.7	12.2	5.2	26.1	13.9	0.0	7.0	0.0	0.0	0.0	0.0	0.0
Coyote	38.2	9.3	5.9	13.5	6.2	6.2	0.0	0.0	6.9	5.5	6.2	2.1
Red fox	37.6	5.8	7.1	16.1	0.0	5.8	0.0	0.0	9.6	7.7	7.7	2.6
Swift fox	38.4	9.3	7.0	0.0	0.0	0.0	4.7	0.0	17.4	14.0	7.0	2.3
Badger	38.0	17.1	4.3	0.0	0.0	7.7	6.8	0.0	10.7	8.6	5.1	1.7
Lynx	37.6	6.3	8.9	44.6	0.0	0.0	2.5	0.0	0.0	0.0	0.0	0.0
Bobcat	35.0	2.6	4.4	6.9	2.6	7.7	0.0	0.0	15.0	12.0	10.3	3.5
Marten	35.9	0.0	7.8	38.7	0.0	0.0	0.0	0.0	0.0	0.0	13.3	4.4
Mink	37.5	6.4	4.5	15.8	0.0	0.0	0.0	2.0	6.8	5.4	16.2	5.4
River otter	48.1	25.1	2.1	10.6	0.0	0.0	0.0	6.3	7.8	0.0	0.0	0.0
Fisher	36.6	0.0	9.7	48.8	0.0	0.0	0.0	0.0	0.0	0.0	3.7	1.2
Ermine	35.8	0.0	9.1	20.2	0.0	0.0	0.0	0.0	12.7	10.1	9.1	3.0
L.t. weasel	36.5	0.0	8.6	12.4	0.0	0.0	0.0	0.0	15.5	12.4	11.1	3.7
Least weasel	33.8	0.0	12.4	26.0	0.0	0.0	0.0	0.0	15.5	12.4	0.0	0.0
Black-footed ferret	37.8	7.0	8.8	0.0	0.0	0.0	7.0	0.0	21.9	17.5	0.0	0.0
Spotted skunk	42.1	22.5	3.1	7.6	0.0	0.0	0.0	0.0	3.7	3.0	13.5	4.5
Striped skunk	42.7	26.2	1.8	4.4	0.0	0.0	0.0	0.0	2.2	1.8	15.7	5.2
Raccoon	35.8	9.0	3.0	11.3	0.0	13.5	0.0	0.0	1.9	1.5	18.0	6.0

Table 6. An example of calculations for estimating coverage for other carnivore species, in this case by managing for conservation of grizzly bears in Montana, USA. Coverage is calculated as total number of female ranges contained in areas of overlap (D) weighted by standardized inverse Euclidean distances based on vectors of loadings on proximal factors (A) or distal factors (B). Figures in (E) are bolded where coverage exceeds the minimum number of ranges judged to be sufficient for each species. Coverages based on proximal and distal factors, respectively, are separated by a '/'.

Species	*(A) Standardized inverse Euclidean distance (proximal factors)*	*(B) Standardized inverse Euclidean distance (distal factors)*	*(C) Total area of overlap (km^2)*	*(D) Number of ranges in area of overlap*	*(E) Coverage based on number of ranges & proximal or distal effects*
Black bear	0.54	0.82	18 750	850	**8.6**/**13.2**
Wolf	0.63	0.92	11 167	78	0.6/0.8
Coyote	0.47	0.76	18 698	890	**3.0**/**4.8**
Swift fox	0.45	0.60	205	26	0.0/0.1
Red fox	0.38	0.74	1 303	166	0.7/**1.3**
Mountain lion	0.34	0.73	17 811	94	0.4/**1.0**
Lynx	0.26	0.79	6 803	194	0.3/0.9
Bobcat	0.32	0.63	730	38	0.1/0.1
Raccoon	0.34	0.67	19 456	1 497	**2.8**/**5.4**
Wolverine	0.61	0.90	7 638	20	0.1/0.1
River otter	0.10	0.69	19 484	464	0.3/**1.9**
Badger	0.46	0.65	1 817	909	**2.1**/**3.0**
Fisher	0.24	0.72	10 267	411	0.3/**1.0**
Marten	0.24	0.74	12 960	2 592	**1.6**/**4.8**
Mink	0.22	0.72	16 188	5 396	**3.1**/**10.1**
Ermine	0.28	0.71	17 371	1 737	**1.0**/**2.6**
Long-tailed weasel	0.25	0.65	15 368	15 368	**7.8**/**20.5**
Least weasel	0.15	0.71	1 307	1 307	0.4/**1.9**
Black-footed ferret	0.40	0.57	0	0	0.0/0.0
Spotted skunk	0.48	0.68	517	517	0.6/0.9
Striped skunk	0.48	0.64	4 402	1 101	**1.8**/**2.4**

Table 7. Loading of proximal effects on distal factors, for all carnivores in Montana and Idaho, USA. Figure 2 shows relations between distal and proximal factors.

Distal factor	*Median loading*	*Interquartile range*	*Mean loading*
Road & trail access	36.6	2.3	35.5
Timber harvest practices/policies	16.0	18.5	18.2
Numbers of humans (resident & visitors)	8.1	11.3	9.5
Fire control policies	5.6	4.3	6.1
Trapping regulations	5.6	11.1	6.2
Agricultural practices	5.2	12.7	6.7
Animal damage & control practices/policies	2.4	10.1	5.1
Value of pelts	1.9	3.7	2.1
Hunting regulations (carnivore)	0.0	6.2	3.1
Hunting regulations (prey)	0.0	2.6	2.9
Protective laws	0.0	6.8	2.7
Fishing regulations	0.0	0.0	0.4

Table 8. Estimated coverage (umbrella effect) afforded other carnivores by managing protected or special status carnivores in Montana, USA. Coverages considering proximal and distal effects, respectively separated by a '/', are given for each species combination. Coverages exceeding the threshold of '1' are bolded. Species with bolded names are protected under the US Endangered Species Act.

	Protected or special status species (potential umbrella)							
Species	***Grizzly bear***	***Wolf***	***Lynx***	***Black-footed ferret***	*Wolverine*	*Fisher*	*Marten*	*Swift fox*
Grizzly bear	–	0.8/**1.2**	0.1/0.4	0.0/0.0	0.5/0.7	0.2/0.6	0.0/0.1	0.0/0.0
Wolf	0.6/0.8	–	0.3/0.6	0.0/0.0	0.3/0.4	0.2/0.4	0.3/0.8	0.0/0.0
Lynx	0.3/0.9	0.7/**1.3**	–	0.0/0.0	0.2/0.6	**1.6/2.1**	**1.9/5.1**	0.0/0.0
Black-footed ferret	0.0/0.0	0.0/0.0	0.0/0.0	–	0.0/0.0	0.0/0.0	0.0/0.0	**13.6/20.4**
Wolverine	0.1/0.1	0.1/0.1	0.0/0.0	0.0/0.0	–	0.0/0.1	0.0/0.1	0.0/0.0
Fisher	0.3/**1.0**	0.4/0.8	**1.3/1.7**	0.0/0.0	0.4/0.9	–	**1.2/2.4**	0.0/0.0
Marten	**1.6/4.8**	**2.2/5.3**	**5.5/15.1**	0.0/0.0	**1.2/3.1**	**4.3/9.1**	–	0.0/0.0
Swift fox	0.0/0.1	**1.0/1.2**	0.0/0.0	**2.3/3.4**	0.0/0.0	0.0/0.0	0.0/0.0	–
Black bear	**8.6**/13.2	**8.9/16.4**	**12.4/26.5**	0.0/0.0	**4.8/8.9**	**7.9/15.7**	**15.9/36.4**	0.4/0.6
Mountain lion	0.4/**1.0**	0.9/**1.4**	0.6/**1.8**	0.0/0.0	0.5/0.8	0.4/**1.1**	**1.0/2.5**	0.1/0.1
Bobcat	0.1/0.1	0.2/0.3	0.2/0.4	0.2/0.3	0.0/0.0	0.0/0.0	0.2/0.3	**1.6/2.1**
Coyote	**3.0/4.8**	**6.1/8.0**	**6.0/9.0**	**1.6/2.2**	**2.3/3.3**	**4.0/5.4**	**9.3/13.6**	**52.4/56.1**
Red fox	0.7/**1.3**	**5.6/9.7**	0.2/0.3	**6.0/9.4**	0.2/0.3	0.4/0.5	0.0/0.0	**205.7/233.4**
Raccoon	**2.8/5.4**	**4.9/8.9**	**5.3/10.3**	**1.7/2.3**	**2.1/3.8**	**4.2/6.3**	**12.8/16.8**	**54.5/61.0**
River otter	0.3/**1.9**	0.8/**3.2**	0.8/**3.4**	0.0/0.0	0.3/**1.3**	0.8/**1.9**	**1.0/4.7**	**3.2/8.5**
Badger	**2.1/3.0**	**11.8/15.2**	0.4/0.5	**10.7/18.1**	0.4/0.6	0.7/0.9	0.1/0.1	**358.2/437.6**
Striped skunk	**1.8/2.4**	**5.4/7.0**	**1.2/2.1**	**3.3/4.6**	0.8/**1.2**	**1.1/1.6**	**2.2/2.9**	**107.3/119.2**
Spotted skunk	0.6/0.9	**2.2/3.1**	0.4/0.6	0.0/0.0	0.2/0.2	0.2/0.3	**1.0/1.4**	**3.7/4.1**
Mink	**3.1/10.1**	**5.9/15.0**	**6.7/20.3**	0.0/0.0	**2.5/6.6**	**6.0/12.7**	**22.2/33.4**	**12.0/17.0**
Ermine	**1.0/2.6**	**1.9/3.8**	**2.8/5.5**	0.0/0.0	0.8/**1.8**	**2.1/3.5**	**4.9/8.7**	**3.5/4.2**
Long-tailed weasel	**7.8/20.5**	**15.1/33.0**	**16.1/42.3**	**6.3/12.6**	**6.2/13.5**	**13.4/26.0**	**40.9/67.9**	**190.5/266.3**
Least weasel	0.4/**1.9**	**2.0/7.2**	0.1/0.7	**4.4/8.8**	0.1/0.4	0.2/**1.1**	0.4/**1.8**	**102.7/188.0**

Table 9. Estimated coverage (umbrella effect) afforded other carnivores by managing protected or special status carnivores in Idaho, USA. Coverages considering proximal and distal effects, respectively separated by a '/', are given for each species combination. Coverages exceeding the threshold of '1' are bolded. Species with bolded names are protected under the US Endangered Species Act.

	Protected or special status species (potential umbrella)					
Species	***Grizzly bear***	***Wolf***	***Lynx***	*Wolverine*	*Fisher*	*Marten*
Grizzly bear	–	**1.5/2.3**	0.4/**1.2**	**1.4/2.0**	0.5/**1.5**	0.1/0.3
Wolf	**1.2/1.7**	–	0.7/**1.3**	**1.4/2.8**	0.8/**1.6**	0.9/**2.1**
Lynx	0.7/**2.2**	**1.6/3.0**	–	0.9/**2.4**	**3.3/4.3**	**1.9/5.1**
Wolverine	0.2/0.4	0.3/0.4	0.1/0.2	–	0.1/0.3	0.2/0.5
Fisher	0.7/**2.2**	**1.3/2.6**	**2.6/3.4**	**1.2/2.7**	–	**2.3/4.8**
Marten	**3.5/10.7**	**5.4/12.7**	**5.6/15.2**	**5.9/14.5**	**8.4/17.9**	–
Black bear	**13.7/20.9**	**14.2/26.1**	**10.7/23.0**	**15.6/28.9**	**12.7/25.4**	**20.6/47.1**
Mountain lion	0.7/**1.6**	**1.4/2.3**	0.6/**1.5**	**1.6/2.5**	0.7/**1.8**	**1.3/3.3**
Bobcat	**3.0/6.0**	**5.3/8.9**	**3.3/6.2**	**5.3/8.6**	**5.1/7.2**	**11.6/14.7**
Coyote	**5.2/8.2**	**10.0/13.2**	**5.7/8.5**	**8.4/12.0**	**7.2/9.7**	**13.0/19.1**
Red fox	**8.1/15.6**	**17.0/29.5**	**9.4/14.6**	**12.5/22.6**	**11.9/16.3**	**28.9/43.9**
Raccoon	0.5/0.9	**1.9/3.5**	0.2/0.3	0.6/**1.0**	0.6/0.9	**1.2/1.6**
River otter	0.4/**3.1**	**1.3/5.0**	0.7/**3.1**	0.9/**4.4**	**1.3/3.3**	**1.3/6.4**
Badger	**2.8/3.9**	**14.4/18.4**	0.5/0.7	**4.0/5.7**	**3.3/4.3**	**1.2/1.6**
Striped skunk	**1.8/2.4**	**6.0/7.7**	0.5/0.8	**2.3/3.3**	**1.7/2.5**	**3.1/4.1**
Spotted skunk	**5.7/8.1**	**15.2/20.9**	**1.7/3.1**	**6.7/10.2**	**4.4/6.9**	**10.2/14.5**
Mink	**5.8/18.8**	**11.0/28.1**	**6.6/20.0**	**10.0/26.5**	**11.3/23.7**	**32.3/48.7**
Ermine	**1.9/4.7**	**3.0/6.0**	**2.9/5.6**	**3.2/6.7**	**3.9/6.5**	**7.2/12.8**
Long-tailed weasel	**16.2/42.2**	**28.6/62.6**	**17.9/47.1**	**27.7/60.5**	**28.8/55.6**	**66.9/110.9**

Figure Captions

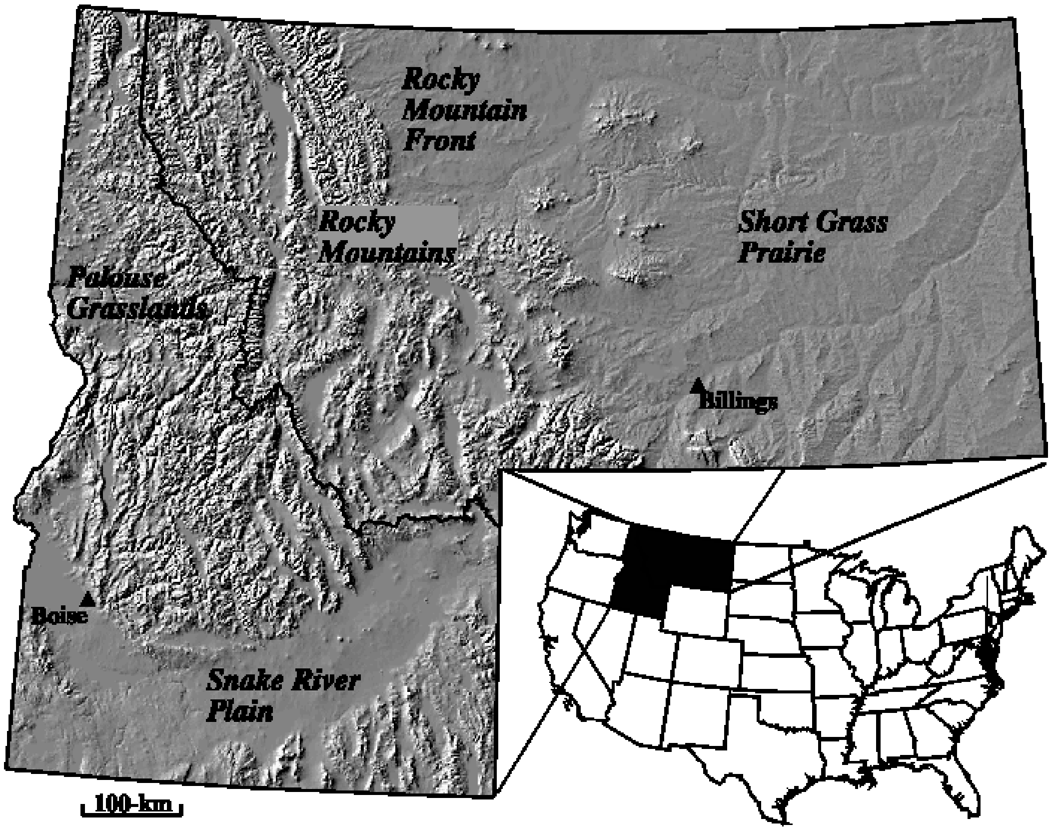
Figure 1. Montana and Idaho, USA, showing vegetation and geomorphic provinces and the cities of Billings and Boise.

Figure 2. Predicted range for grizzly bears in Montana and Idaho, USA, (a) based on the original map by Carroll et al. (2001) and (b) after filtering through an annual-range-size window and deleting patches <1 annual range in size.

Figure 3. (a) A conceptual model relating proximal factors (denoted by an '' and framed by shadowed boxes) to distal one (denoted by rounded boxes with a gray background), for carnivore species in Montana and Idaho, USA. (b) An example, using grizzly bears, of how proximal effects were decomposed onto distal factors using the conceptual model and rule set. Bolded values are the total load on distal factors. Italicized values are the load associated with a given linkage.*

Figure 4. Clustering of carnivore species in Montana and Idaho, USA, based on average linkages and (a) similarity of sensitivities to proximal factors or (b) similarity of sensitivities to distal factors. Species that form clusters according to the given cutpoint are framed in boxes shaded gray. Names of protected or special status species are bolded.

Figure 1.



Rocky Mountain Front
Rocky Mountains
Short Grass Prairie
Palouse Grasslands
Billings
Boise
Snake River Plain
100-km

Figure 2

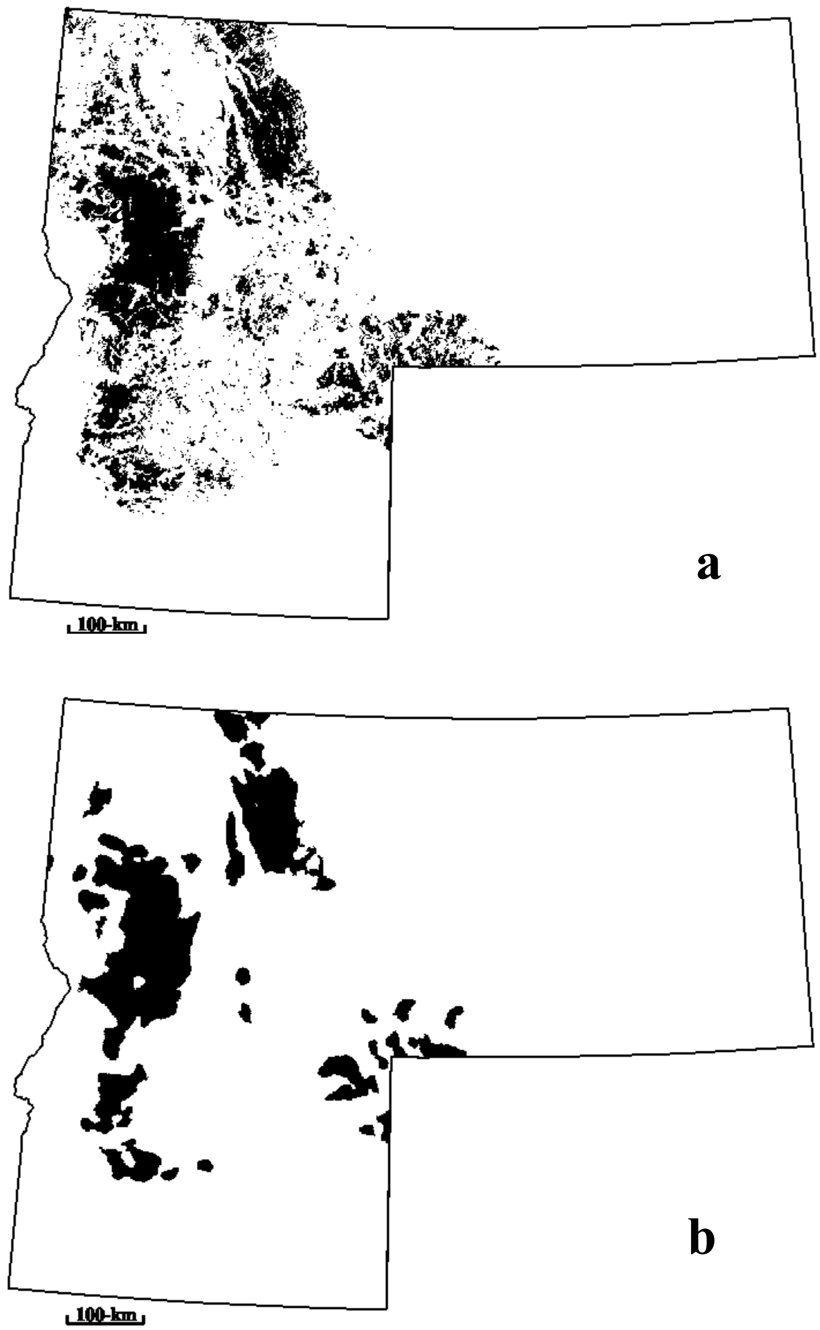
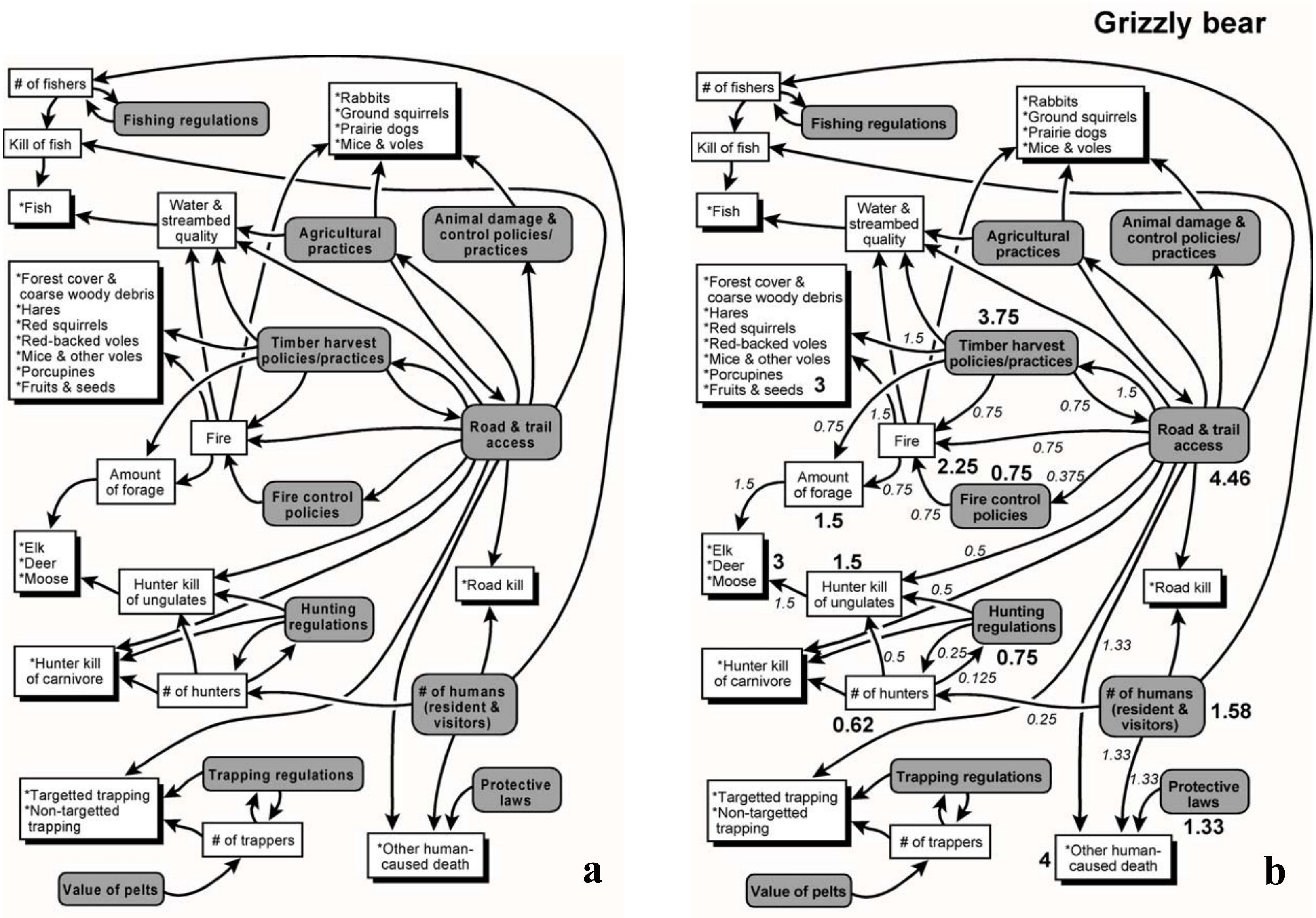
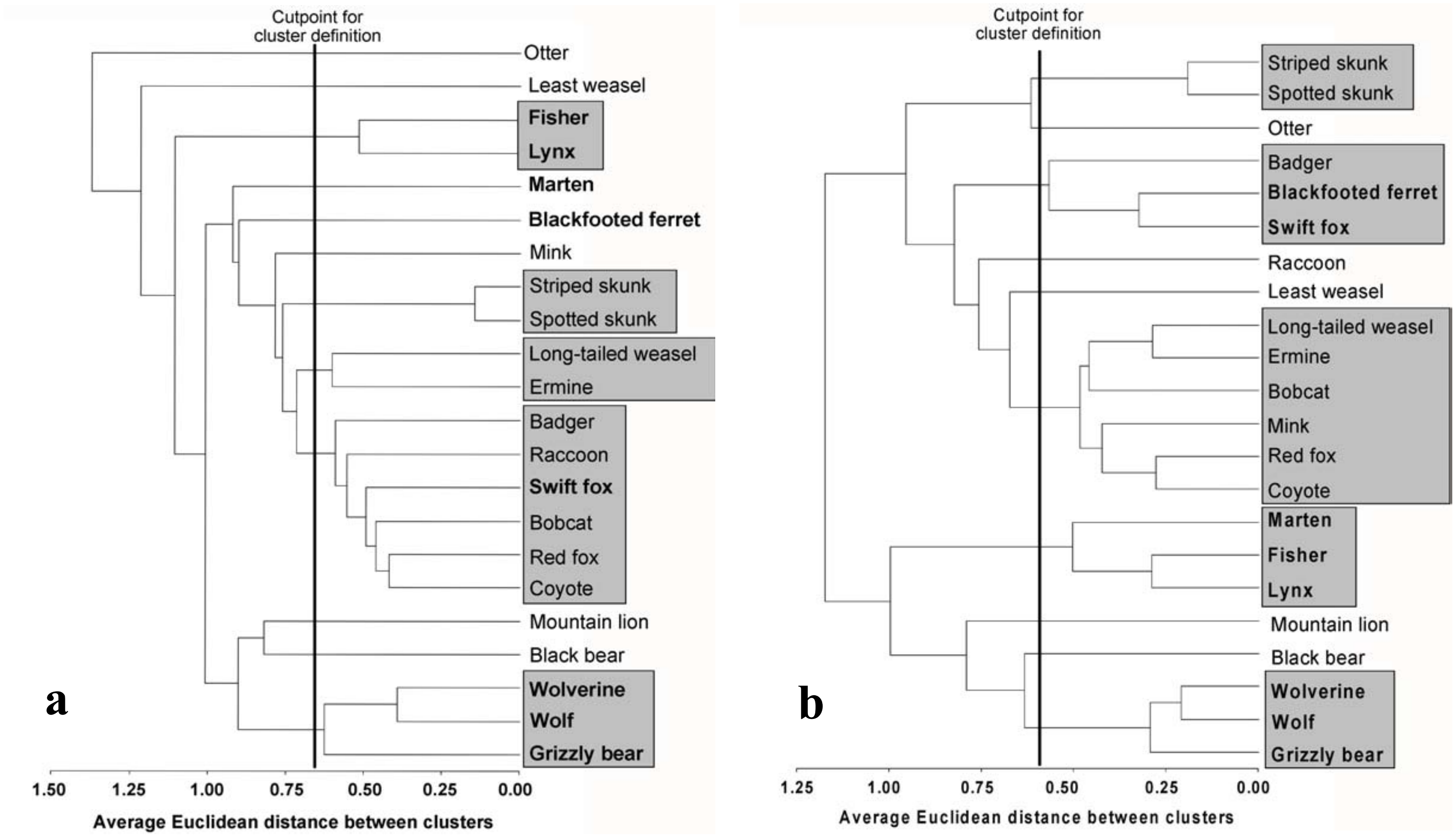


Figure 3



# of fishers
Fishing regulations
Kill of fish
*Fish
*Rabbits
*Ground squirrels
*Prairie dogs
*Mice & voles
Water & streambed quality
Agricultural practices
Animal damage & control policies/ practices
*Forest cover & coarse woody debris
*Hares
*Red squirrels
*Red-backed voles
*Mice & other voles
*Porcupines
*Fruits & seeds
Timber harvest policies/practices
Fire
Road & trail access
Amount of forage
Fire control policies
*Elk
*Deer
*Moose
Hunter kill of ungulates
Hunting regulations
*Road kill
*Hunter kill of carnivore
# of hunters
# of humans (resident & visitors)
Trapping regulations
*Targetted trapping
*Non-targetted trapping
# of trappers
Protective laws
*Other human-caused death
Value of pelts
a
Grizzly bear
3.75
1.5
3
0.75
1.5
0.75
1.5
0.75
0.75
2.25
0.75
0.375
4.46
1.5
0.75
0.75
1.5
0.5
3
1.5
0.5
1.5
0.5
0.25
0.75
0.125
1.33
0.62
0.25
1.58
1.33
1.33
1.33
4
b

Figure 4


Cutpoint for cluster definition
Otter
Least weasel
Fisher
Lynx
Marten
Blackfooted ferret
Mink
Striped skunk
Spotted skunk
Long-tailed weasel
Ermine
Badger
Raccoon
Swift fox
Bobcat
Red fox
Coyote
Mountain lion
Black bear
Wolverine
Wolf
Grizzly bear
a
1.50 1.25 1.00 0.75 0.50 0.25 0.00
Average Euclidean distance between clusters
Cutpoint for cluster definition
Striped skunk
Spotted skunk
Otter
Badger
Blackfooted ferret
Swift fox
Raccoon
Least weasel
Long-tailed weasel
Ermine
Bobcat
Mink
Red fox
Coyote
Marten
Fisher
Lynx
Mountain lion
Black bear
Wolverine
Wolf
Grizzly bear
b
1.25 1.00 0.75 0.50 0.25 0.00
Average Euclidean distance between clusters

Literature Cited

Andelman, S. J., and W. F. Fagan. 2000. Umbrellas and flagships: efficient conservation surrogates or expensive mistakes? Proceedings of the National Academy of Sciences **97**: 5954–5959.

Banci, V. 1994. Wolverine. Pages 99–137 in L. F. Ruggiero, K. B. Aubry, S. W. Buskirk, L. J. Lyon, and W. J. Zielinski, editors. American marten, fisher, lynx, and wolverine in the western United States. U.S. Forest Service General Technical Report RM-254.

Barbour, M. G., and W. D. Billings, editors. 1988. North American terrestrial vegetation. Cambridge University Press, New York.

Beecham, J. J., and J. Rohlman. 1994. A shadow in the forest. University of Idaho Press, Moscow.

Bekoff, M. 1982. Coyote (*Canis latrans*). Pages 447–459 in J. A. Chapman and G. A. Feldhamer, editors. Wild mammals of North America. The Johns Hopkins University Press, Baltimore, Maryland.

Busch, R. H. 1995. The wolf almanac. Lyons and Buford, New York.

Buskirk, S. W., and L. F. Ruggiero. 1994. American marten. Pages 7–37 in L. F. Ruggiero, K. B. Aubry, S. W. Buskirk, L. J. Lyon, and W. J. Zielinski, editors. American marten, fisher, lynx, and wolverine in the western United States. U.S. Forest Service General Technical Report RM-254.

Caro, T. M., and G. O'Doherty. 1999. On the use of surrogate species in conservation biology. Conservation Biology **13**: 805–814.

Carroll, C., R. F. Noss, and P. C. Paquet. 2001. Carnivores as focal species for conservation planning in the Rocky Mountain region. Ecological Applications **11**: 961–980.

Clark, T. W. 1989. Conservation biology of the black-footed ferret *Mustela nigripes*. Wildlife Preservation Trust, Special Scientific Report No. 3.

Clark, T. W. 2002. The policy process: a practical guide for natural resources professionals. Yale University Press, New Haven, Connecticut.

Copeland, J. P. 1996. Biology of the wolverine in central Idaho. M.S. Thesis, University of Idaho, Moscow.

Dixon, K. R. 1982. Mountain lion (*Felis concolor*). Pages 711–727 in J. A. Chapman and G. A. Feldhamer, editors. Wild mammals of North America. The Johns Hopkins University Press, Baltimore, Maryland.

Fagerstone, K. A. 1987. Black-footed ferret, long-tailed weasel, short-tailed weasel, and least weasel. Pages 548–573 in M. Nowak, J. A. Baker, M. E. Obbard, and B. Malloch. Wild furbearer management and conservation in North America. Ontario Ministry of Natural Resources, Ontario.

Fleishman, E., D. D. Murphy, and R. B. Blair. 2001. Selecting effective umbrella species. Conservation Biology in Practice **2**: 17–23.

Godin, A. J. 1982. Striped and hooded skunks (*Mephitis mephitis* and allies). Pages 674–687 in J. A. Chapman and G. A. Feldhamer, editors. Wild mammals of North America. The Johns Hopkins University Press, Baltimore, Maryland.

Howard, W. E., and R. E. Marsh. 1982. Spotted and hog-nosed skunks (*Spilogale putorius* and allies). Pages 664–673 in J. A. Chapman and G. A. Feldhamer, editors. Wild mammals of North America. The Johns Hopkins University Press, Baltimore, Maryland.

Kaufmann, J. H. 1982. Raccoons and allies (*Procyon lotor* and allies). Pages 567–585 in J. A. Chapman and G. A. Feldhamer, editors. Wild mammals of North America. The Johns

Hopkins University Press, Baltimore, Maryland.

King, C. 1989. The natural history of weasels and stoats. Comstock Publishing, Ithaca, New York.

Koehler, G. M. 1987. Demography of a low productivity bobcat population. Ph.D. Thesis, University of Idaho, Moscow.

Koehler, G. M., and K. B. Aubry. 1994. Lynx. Pages 74–98 in L. F. Ruggiero, K. B. Aubry, S. W. Buskirk, L. J. Lyon, and W. J. Zielinski, editors. American marten, fisher, lynx, and wolverine in the western United States. U.S. Forest Service General Technical Report RM-254.

Lambeck, R. J. 1997. Focal species: a multi-species umbrella for nature conservation. Conservation Biology **11**: 849–856.

Lindenmayer, D. B., A. D. Manning, P. L. Smith, H. P. Possingham, J. Fischer, I. Oliver, and M. A. McCarthy. 2002. The focal-species approach and landscape restoration: a critique. Conservation Biology **16**: 338–345.

Lindscombe, G., N. Kinler, and R. J. Aulerich. 1982. Mink (*Mustela vison*). Pages 627–643 in J. A. Chapman and G. A. Feldhamer, editors. Wild mammals of North America. The Johns Hopkins University Press, Baltimore, Maryland.

Lindzey, F. G. 1982. Badger (*Taxidea taxus*). Pages 653–663 in J. A. Chapman and G. A. Feldhamer, editors. Wild mammals of North America. The Johns Hopkins University Press, Baltimore, Maryland.

Mace, R. D., and J. S. Waller. 1997. Spatial and temporal interaction of male and female grizzly bears in northwestern Montana. Journal of Wildlife Management **61**: 39–52.

MacNally, R., and E. Fleishman. 2002. Using 'indicator' species to model species richness:

model development and predictions. Ecological Applications **12**: 79–92.

Mattson, D. J., S. Herrero, R. G. Wright, and C. M. Pease. 1996. Designing and managing protected areas for grizzly bears: how much is enough? Pages 133–164 in R. G. Wright, editor. National parks and protected areas: their role in environmental protection. Blackwell Science, Cambridge, Massachusetts.

McCord, C. M., and J. E. Cardoza. 1982. Bobcat and lynx (*Felis rufus* and *F. lynx*). Pages 728–766 in J. A. Chapman and G. A. Feldhamer, editors. Wild mammals of North America. The Johns Hopkins University Press, Baltimore, Maryland.

Melquist, W. E. 1981. Ecological aspects of a river otter (*Lutra canadensis*) population in west-central Idaho. Ph.D. Thesis, University of Idaho, Moscow.

Merrill, T., D. J. Mattson, R. G. Wright, and H. B. Quigley. 1999. Defining landscapes suitable for restoration of grizzly bears *Ursus arctos* in Idaho. Biological Conservation **87**: 231–248.

Messick, J. P. 1981. Ecology of the badger in southwestern Idaho. M.S. Thesis, University of Idaho, Moscow.

Miller, B., R. Reading, J. Strittholt, C. Carroll, R. Noss, M. Soulé, O. Sánchez, J. Terborgh, D. Brightsmith, T. Cheeseman, and D. Foreman. 1999. Using focal species in the design of nature reserve networks. Wild Earth **8**: 81–92.

Noss, R. F., and A. Y. Cooperrider. 1994. Saving nature's legacy: protecting and restoring biodiversity. Island Press, Washington, D.C.

Powell, R. A., and W. J. Zielinski. 1994. Fisher. Pages 38–73 in L. F. Ruggiero, K. B. Aubry, S. W. Buskirk, L. J. Lyon, and W. J. Zielinski, editors. American marten, fisher, lynx, and wolverine in the western United States. U.S. Forest Service General Technical

Report RM-254.

Rosatte, R. C. 1987. Striped, spotted, hooded, and hog-nosed skunk. Pages 598–613 in M. Nowak, J. A. Baker, M. E. Obbard, and B. Malloch. Wild furbearer management and conservation in North America. Ontario Ministry of Natural Resources, Ontario.

Rounds, D. E. 1979. Status of the bobcat in Idaho. M.S. Thesis, University of Idaho, Moscow.

Samuel, D. E., and B. B. Nelson. 1982. Foxes (*Vulpes vulpes* and allies). Pages 475–490 in J. A. Chapman and G. A. Feldhamer, editors. Wild mammals of North America. The Johns Hopkins University Press, Baltimore, Maryland.

Scott-Brown, J. M., S. Herrero, and J.-A. Reynolds. 1987. Swift fox. Pages 432–441 in M. Nowak, J. A. Baker, M. E. Obbard, and B. Malloch. Wild furbearer management and conservation in North America. Ontario Ministry of Natural Resources, Ontario.

Shaffer, M. 1987. Minimum viable populations: coping with uncertainty. Pages 69–86 in M. E. Soulé, editor. Viable populations for conservation. Cambridge University Press, New York.

Sheldon, J. W. 1992. Wild dogs: the natural history of the nondomestic canidae. Academic Press, San Diego, California.

Shrader-Frechette, K. S., and E. D. McCoy. 1993. Method in ecology: strategies for conservation. Cambridge University Press, New York.

Silva, M., and J. A. Downing. 1994. Allometric scaling of minimal mammal densities. Conservation Biology **8**: 732–743.

Silva, M., and J. A. Downing. 1995. CRC handbook of mammalian body masses. CRC Press, Boca Raton, Florida.

Suter, W., R. F. Graf, and R. Hess. 2002. Capercaillie (*Tetrao urogallus*) and avian biodiversity: testing the umbrella-species concept. Conservation Biology **16**: 778–788.

Svendson, G. E. 1982. Weasels (*Mustela* species). Pages 613–628 in J. A. Chapman and G. A. Feldhamer, editors. Wild mammals of North America. The Johns Hopkins University Press, Baltimore, Maryland.

Todd, M. C. 1980. Ecology of badgers in southcentral Idaho, with additional notes on raptors. M.S. Thesis, University of Idaho, Moscow.

Toweill, D. E., and J. E. Tabor. 1982. River otter (*Lutra canadensis*). Pages 688–703 in J. A. Chapman and G. A. Feldhamer, editors. Wild mammals of North America. The Johns Hopkins University Press, Baltimore, Maryland.

Trombulak, S. C., and C. A. Frissell. 1999. Review of ecological effects of roads on terrestrial and aquatic communities. Conservation Biology **14**: 18–30.

Verts, B. J. 1967. The biology of the striped skunk. University of Illinois Press, Urbana.

Weaver, J. L., P. C. Paquet, and L. F. Ruggiero. 1996. Resilience and conservation of large carnivores in the Rocky Mountains. Conservation Biology **10**: 964–976.

Whitman, J. S. 1981. Ecology of the mink (*Mustela vison*) in west-central Idaho. M.S. Thesis, University of Idaho, Moscow.