Using Focal Species in the Design of Nature Reserve Networks

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THE ESTABLISHMENT AND MANAGEMENT OF NATURE RESERVES is one of a variety of methods promoted to help conserve biological diversity. Over the past couple of decades, the number of protected natural areas has increased dramatically worldwide, and the theory and practice of reserve design has developed into a sub-discipline of conservation biology.

In designing a reserve or reserve network (a regional system of connected reserves), conservationists generally use some combination of three tactics. Those approaches are: 1) mapping special elements (i.e., sites of high value such as Wilderness Areas, roadless areas, location of rare species, etc.), 2) seeking representation (i.e., including all habitat types in a region as a "coarse filter" approach to protecting biodiversity), and 3) evaluating the requirements of selected focal species (Noss 1996).

Relying on only one of these approaches will not provide sufficient protection, so understanding the strengths and weaknesses of the three will aid decisions about integrating them into a more comprehensive reserve plan. Obviously, ecological, political, and socio-economic conditions will change from region to region, and consequently the goals and purposes of various reserves will differ. Because much of present reserve theory has not been tested empirically, individuals will differ in their opinions over the weight that should be granted to each tactic in a given plan. These discussions should enhance—not detract from—the overall goal of establishing protected areas.

In this paper, we present *some* ideas for using focal species in conservation actions (we stress that the list is not comprehensive and that local biologists should be consulted in any reserve planning that uses this approach). We focus primarily on biological considerations; the socio-economic considerations in reserve planning and implementation deserve attention as the prime topic of another paper and are beyond the scope of this manuscript. The focus of the techniques we present is terrestrial and largely drawn from experience in North America (north of the Yucatan Peninsula).

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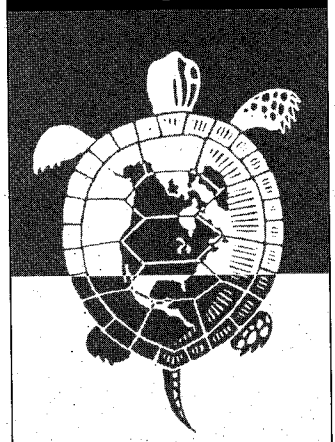

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Focal Species and Reserve Design

Focal species are organisms used in planning and managing nature reserves because their requirements for survival represent factors important to maintaining ecologically healthy conditions. Ultimately, questions about ecological patterns and processes cannot be answered without reference to the species that live in a landscape (Lambeck 1997). Representation and special elements themes point to which areas should be included in reserves, but focal species analysis identifies additional high-value habitats and addresses the questions:

- What is the quality of habitat?
- How much area is needed?
- In what configuration should we design components of a reserve network?

One of the first steps in using focal species as a basis for planning a reserve network is a clear description of the process. What species are chosen and why? How will the particular focal species contribute to the general goals and objectives of the reserve network? What assumptions are made in the selection of those species and in the models that are developed from their data? What are the potential weaknesses of the assumptions? What type and quality of data from each species are available? It is essential to be honest about what is known, what is assumed, and what is uncertain.

All of the terms used should be carefully defined to prevent misinterpretation. Many popular terms remain disturbingly ambiguous; "ecosystem management" and "sustainable development," for example, are used casually and can promote a wide range of political agendas. Terms germane to focal species are *keystone species*, *umbrella species*, *flagship species*, and *indicator species*. It is important not to confuse the purposes of these different categories when selecting focal species. In this paper, we follow the definitions of various focal species recently popularized by Noss and Cooperrider (1994), Lambeck (1997), and Meffe and Carroll (1997). We also add some of our own.

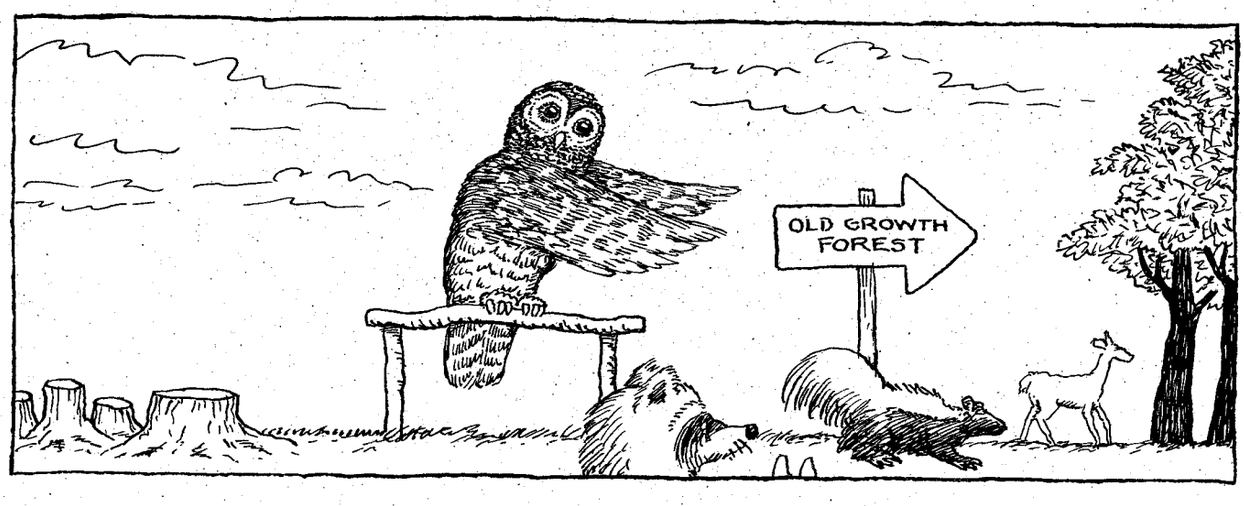
Keystone species enrich ecosystem function in a unique and significant manner through their activities, and the effect is disproportionate to their numerical abundance (Paine 1980, Terborgh 1988, Mills et al. 1993). Their removal initiates changes in ecosystem structure and often a loss of diversity. Examples of animals that significantly regulate ecosystem processes include beaver (*Castor canadensis*) (Naiman et al. 1988), large carnivores (Terborgh 1988), and prairie dogs (*Cynomys* spp.) (Miller et al. 1994). Because of the pronounced effect keystone species have on the integrity of an ecosystem, making them a target of management efforts provides an excellent opportunity to maintain or restore ecosystem processes through actions directed at a single species (Miller et al. 1994).

Umbrella species generally cover large areas in their daily or seasonal movements (Frankel and Soulé 1981). Protecting enough habitat to assure a viable population of these organisms benefits many other species more restricted in their range. Large mammalian carnivores are often proposed as umbrellas because they are wide-ranging and ecological generalists, but large herbivores and raptors can also fill this role (Noss and Cooperrider 1994, Noss et al. 1996, Meffe and Carroll 1997).

Flagship species are charismatic creatures—such as giant pandas (*Ailuropoda melanoleuca*) or sea turtles—that have wide appeal and thus draw attention to a conservation objective. They are the foundation of public relations and education campaigns, and the outreach built around flagships may be critical to building popular support for a protected area (Noss and Cooperrider 1994, Meffe and Carroll 1997).

Indicator species are tightly linked to specific biological elements, processes, or qualities; are sensitive to ecological changes; and are useful in monitoring habitat quality. Ideally, they would provide an early warning system and act as a surrogate for the integrity of the ecosystem they inhabit. Examples of indicator species include spotted owls (*Strix occidentalis*) for old-growth forests (Verner et al. 1992) and river otters (*Lutra* spp.) for rivers systems (Sánchez 1992). The choice of indicator species depends on the desired goals; they can represent an element as narrow as stream temperature or as broad as wilderness quality. When choosing indicator species it is important that the relationship between the species and the predicted effect is crystal clear.

To review, these four categories of focal species (keystone, umbrella, flagship, and indicator) can be briefly summarized by their functional context—the way they contribute to reserve planning. A keystone species is defined by



ecological value. An umbrella species is a basis for management decisions, particularly about size, shape, and spatial distribution of protected areas. A flagship species is charismatic and used in public relations and fundraising. Finally, an indicator species is useful in assessing and monitoring quality of habitat.

Despite functional differences, it is possible to choose species that occupy more than one category. Grizzly bears (*Ursus arctos*) and jaguars (*Panthera onca*) could represent (1) keystone species as top carnivores, (2) umbrella species because of their large area requirements, (3) indicators of wilderness quality, and (4) flagships. Wolves can represent categories 1, 2, and 4, but can also indicate a level of human persecution. The capacity of animals to represent more than one factor in reserve design demonstrates the need to be clear in terminology, objectives, and assumptions.

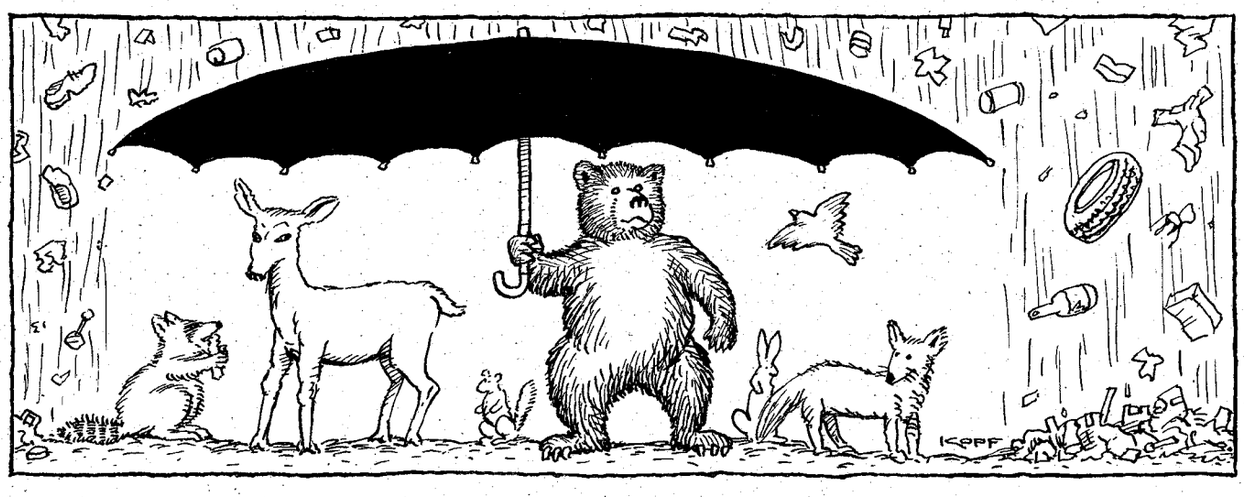
As a general guideline for selecting focal species, we suggest preparing a list of threatened, ecologically important, economically important, and endemic organisms for the target area. This may suggest likely candidates for indicator and flagship species. In addition, many of the carnivores—particularly large ones—can be excellent candidates for the umbrella category. We argue that any conservation plan that fails to include the needs of native carnivores is incomplete (Noss and Cooperrider 1994). Large carnivores are keystone species that make substantial contributions to ecosystem function; to exclude their presence may result in a protected area with highly altered and unstable systems (Terborgh 1988). If a local carnivore has been extirpated, after careful analysis it can still be included in reserve design under a future reintroduction plan. Large herbivores can also be good umbrella species, particularly if they require specialized habitat or make predictable seasonal movements.

From such lists, potential focal species can be placed in their respective categories. Some species will be nested under the needs of another species or simply duplicate those needs. Obviously, duplicative species should be eliminated from a category as it is important to keep the focal species list as short as possible (each species will require research and monitoring).

Using Indicator Species to Assess Quality of Habitat and Connections

Monitoring indicator species can be useful to assess degree of threat, and they provide an excellent means to gauge the success or failure of conservation actions. Although a hands-off approach to management would be preferable, there are simply too few natural regions in North America that are large enough to hold viable populations of all native species and exhibit naturally regulated patterns of disturbance and recovery. Indeed, many regions will require restoration programs to heal past wounds (e.g., regions where carnivores have been eliminated, fires have been suppressed, prairies overgrazed, riparian quality destroyed, exotics introduced, beaches removed, wetlands drained, etc.). Management will be essential to prevent further declines of native species and systems, and vigilant monitoring of carefully selected indicator species can provide information to help restore and protect natural processes.

illustrations by L.J. Kopf



UMBRELLA SPECIES

Focal species denoting wilderness quality could indicate such factors as vulnerability to human presence, roads, and hunting (both legal and illegal). Grizzly bears, jaguars, and quetzals (*Pharomachrus mocinno*) would be examples of animals that require the protection of a wilderness core area, as opposed to wolves (*Canis lupus*) which can exist in both a wilderness core and surrounding buffer zones (if tolerated by humans). Microendemic species are also good indicators of ecosystem quality. For example, there are areas in México where nearly each mountain holds distinct species of an arboreal lizard genus (*Abronia*), which are flawless indicators of habitat quality in mesophyll mountain humid forest (Good 1988, Sánchez pers. obs.).

Individuals of resource-limited species (nectarivorous birds, cavity-nesting birds) require certain relatively rare or patchy resources; those resources determine the carrying capacity at the time of lowest availability (Lambeck 1997). A process-limited species is sensitive to an ecological process such as fire, flood, or grazing, and it could be utilized to monitor such events (Lambeck 1997). Individuals of dispersal-limited species are restricted in their ability to move between patches of habitat; the linkages they require should be ranked according to the minimum width, length, and vegetation structure necessary for animals to use those biological connections successfully (Lambeck 1997). This implies definition by function and not just by the presence of a particular vegetation structure.

Biological connections should permit movement of animals, energy, and materials over long distances. For example, salmon returning to Idaho from the Pacific Ocean are important sources of protein that help improve productivity of grizzly bear populations (as well as other animals). Biological connections provide for natural dispersal of individuals within an area, seasonal migration of groups, genetic exchange between populations, and ability to shift natural ranges in response to climate change. Thus, issues of scale come into play in planning connections (and issues of scale can be among the most difficult to understand).

In general, biological connectivity is a convoluted topic. Different species can react to the same habitat corridor as a travel conduit, a permanent home, a sink with insufficient resources to maintain long-term persistence, an agent in disease transmission, a vehicle that promotes contact with an exotic competitor, or an avenue that provides increased contact with a predator. This panorama of effects has produced criticism of the corridor concept (Simberloff and Cox 1987, Simberloff et al. 1992), in particular around the negative effects of edges (Wilcove 1985, Simberloff and Cox 1987, Yahner 1988). Some species, such as songbirds, are more susceptible to the negative effects of edges than are other species, such as deer, which often benefit.

Despite those complicating factors, connectivity in some form is essential for many species, especially large animals, which cannot maintain viable populations in small, isolated areas (Frankel and Soulé 1981, Noss and Harris 1986, Beier 1993, Soulé 1991, Noss and Cooperrider 1994). We should remember, however, that whereas large animals may be excellent for estimating reserve size (as an umbrella), they should not be the sole choice for planning connections because they can move across gaps in habitat

that are inhospitable to smaller species. Corridor design and management should consider width requirements necessary for movement of the larger focal species, but planners should also consider the degree of connectivity that the least vagile focal species needs to maintain viability. For example, pine martens (*Martes americana*) do not cross treeless expanses much wider than 100 meters in winter (Koehler and Hornocker 1977), a distance easily traversed by most other carnivores.

If connections are designed for avenues of long-distance dispersal, we recommend that consideration be given to corridors wide enough to house residents of the focal species (Noss and Cooperrider 1994). Such corridors more closely resemble historical conditions of connectivity. Many species of vertebrates allow dispersing juveniles to pass through their territories. In addition, the typical dispersal pattern for many polygynous mammals is for females to remain fairly close to the area where they were raised, whereas males make the long-distance movements (Greenwood 1980, Dobson 1982). Areas wide enough to house residents would allow females to disperse, which could be important for natural restocking of extirpated colonies in a metapopulation. In addition, wide connections would diminish the ratio of edge to core, which could reduce the spread of those exotics that move via disturbed conditions.

The management complexity of connectivity becomes progressively more complicated as scale increases (Sánchez 1996). Whereas connections within a single protected area may be relatively simple, movement that crosses agency, state, and international boundaries increases the number of managing partners. Connecting two protected areas that are already separated by roads and human settlements increases the number of social, economic, and enforcement dimensions (Sánchez 1996). These considerations should not be taken lightly and must be addressed.

For practical purposes, preserving existing corridors is preferable to trying to reconstruct them. Natural habitat should not be changed to create artificial corridors, as that could produce deleterious effects in a highly heterogeneous landscape where two subspecies exist in close proximity geographically but still may be separated genetically by a million years or more (Sánchez 1996).

Alternatives to restoring biological connections have been presented (Simberloff and Cox 1987, Simberloff et al. 1992). For example, areas large enough to hold residents could be linked like stepping-stones between reserves. Stepping-stones, however, could easily become habitat sinks that increase mortality. Small populations that cannot move between habitat islands would have a higher probability of inbreeding depression or demographic problems than connected populations (Simberloff and Cox 1987). Those isolated habitat patches would also be more susceptible to poaching.

Another alternative suggests that managers capture and translocate animals between isolated populations. Although it may be physically possible to move animals between sites, there may or may not be a functional benefit. Homing behavior and excessive movement from the release site have been a major problem in carnivore translocations, resulting in drastically reduced survival (Linnel et al. 1997). Several pumas (*Felis concolor*) translocated over 400 kilometers returned to their original territories (Logan et al. 1996). A young male tiger (*Panthera tigris*) translocated to a new area was quickly killed by the resident male (Seidensticker 1976).

Most important, neither of these alternatives is a viable attempt to restore ecologically healthy expanses of land. Indeed, both tactics may perpetuate existing patterns of habitat fragmentation. Thus, large animals may persist in patches—at least over the short term—but their numbers may remain too small for natural selection to act, and they would have little impact on ecosystem processes. Additionally, processes such as fire, nutrient cycling, grazing, and flooding would remain altered by isolation and reduced scale. At our present level of knowledge, we believe protecting and restoring connections is a better step toward restoring ecological integrity.

Using Umbrella Species for Reserve Design

Some biologists have recommended using a suite of focal species because no single species can assess habitat quality or quantity necessary for all other organisms of the reserve network (Noss and Cooperrider 1994). For example, the percentage of species diversity protected under a single umbrella species will likely decline as one moves from a homogeneous to a heterogeneous landscape with high beta diver-

sity (Sánchez 1996). The latter condition, typical of many tropical areas, often includes many locally adapted endemic species. An endemic plant requiring specific conditions may be restricted to a small area that is not necessarily included in the movements of a single umbrella species. A heterogeneous landscape may therefore require a larger suite of focal species than a more homogeneous system.

Umbrella species can be used to protect a substantial fraction of a region's species diversity. If the umbrella species is also sensitive to human disturbance, it might serve as both an umbrella and a wilderness indicator species. Considering the needs of a species that is both an umbrella and wilderness indicator could increase the chances of protecting enough high-quality land for an intact system.

A frequently cited problem is that umbrella species such as wolves, pumas, and black bears are not truly wilderness indicator species, as they can exist in human manipulated areas if hunting pressure is controlled. They can even survive a level of forest perturbation that will cause other, more specialized, species to decline. This points to the need for carefully defining the purpose of focal species. The wolf is an umbrella that provides an idea of how much land to include in a reserve system, and it is both a core and buffer species. It is an indicator of the level of human persecution, but it is not an indicator of wilderness quality per se. If the wolf is used as an umbrella, it may be necessary to choose indicator species to represent quality of the core (perhaps species such as lichens, songbirds, cavity-nesting birds, pine martens, wolverines, etc.) and to establish an acceptable level of compatible use in the buffer.

Umbrella species can also be flagship and keystone species, but whether or not there are multiple purposes, we suggest the umbrella species should exhibit at least several of the following qualities: (1) large area requirements, (2) a defined habitat association, (3) a known life history, preferably through an ongoing study or monitoring effort, and (4) potential for regional viability or reintroduction. When calculating area requirements of umbrella species, we should think in terms of what is necessary for viable populations, whether viability is measured at local or regional scales (Berger 1997).

If terrestrial carnivores are used as umbrella species, we recommend considering females. Male carnivore movements can be extensive, highly variable, and related mainly to social status, behavioral spacing mechanisms, and hormonal production (Ewer 1973, Powell 1979). For example, the male weasel's (*Mustela erminea*) territorial system breaks down during the breeding season, and a class of super males trespass far beyond their home areas to reproduce (Sandell 1986). Female carnivores, on the other hand, are the base of a wild population. They are more valuable demographically and will raise their young in areas where critical resources are concentrated and easiest to obtain (Lindzey 1982, King 1989, Miller et al. 1996). They need to satisfy elevated energy requirements with minimal time away from their young, so they are more restricted to optimal habitat and their home range sizes more accurately represent the quality of that habitat (King 1989, Lindstedt et al. 1986). For those reasons, it is probably more practical to rely heavily on female movements and spatial needs. It should be noted, however, that in highly fragment-

ed or disturbed habitat, considering only female needs can result in low mating success (Beier 1993). In addition, the system will vary depending on the natural history of the species chosen, and in some cases the males may protect the breeding territories (e.g., raptors).

A defined habitat association, at least at some level, is also important. Some species can survive in many different environments (including human-dominated ones), and they will not provide as good a definition for reserve boundaries. Indeed, some species are now abundant in areas where they did not previously exist (e.g., coyotes), or where they previously existed only in low numbers, because they have exploited edges created by fragmentation. Thus, species richness does not measure the quality of an area (Sampson and Knopf 1982, Van Horne 1983, Soulé 1991, Noss and Cooperrider 1994). The maintenance of native species usually requires large areas of undisturbed habitat (Kitchener 1980, Noss 1983).

Choosing an umbrella species that has already been well-studied is very helpful. Many investigations conducted in natural systems with unpredictable and inherent fluctuation take five to ten years to produce solid data, but land-use decisions often cannot wait this long. An umbrella species with an existing data bank, at least from the general geographic area, would provide a huge advantage in time saved.

It is also important, however, to pay attention to the type of data that have been collected. We recommend integrating geographically local (intensive) and regional (extensive) data. In some cases only presence/absence data are available, which can be problematic. This type of information often says nothing about habitat preference, persistence, or animal needs for reproduction. In presence/absence databases, a juvenile male sighting can carry as much weight as that of an adult female holding territory. Yet, the juvenile may be dispersing over a long distance or may be living in habitat that represents a population sink (i.e., a habitat with higher rates of mortality than natality and thus only sustained by immigration; Gilpin 1991, Hanski and Gilpin 1991) because the prime habitat is already occupied. So, even if there are enough sightings in an area to conclude that a population exists, sightings still could be misleading. Alternatively, intensive demographic studies can often separate low-quality habitats, which may deceptively contain high densities (e.g., of dispersing subordinates that are unlikely to survive and reproduce), from high-quality habitat that supports stable and dependable adult populations (Van Horne 1983, Pulliam 1988).

A caveat about intensive data is that different investigative methods can influence results (Laundré and Keller 1984). Hence, different home range sizes calculated in different studies may be attributed to habitat quality, method of data collection, method of analyzing data, or simply sample size. And, the limited spatial scale of intensive demographic studies may miss important regional-scale dynamics. This suggests the need for integrating extensive data with intensive demographic studies.

Presence/absence data may be all that is available for many lesser-known species, and several approaches have been developed to make use of this type of information. For example, presence of animals in sink habitats is expected to be more variable over time than in higher-quality source habitats (Wiens 1989, Howe et al. 1991). Long-term survey and monitoring data sets, which may be available from land management agencies, could be used to distinguish source from sink habitats for conservation planning purposes. Records of presence/absence over time also allow measurement of the rate at which vacant habitat is colonized, a critical attribute for dispersal-limited species (Karieva et al. 1996). In fragmented habitats, "incidence function" models that relate the presence of a species in a patch to patch isolation and area may be useful in detecting critical connectivity thresholds for a particular species (Hanski 1996, Hanski et al. 1996).

Choosing an umbrella species that has a large number of individuals in its population will increase the likelihood that data are representative of natural circumstances. The larger the population, the less likely data will reflect the variability and complexities suffered by a small population (Soulé 1987, 1988). Alternatively, an extirpated species could be an umbrella if a future reintroduction is planned. If species are being added to the area, the resulting interspecific interactions may influence the type and amount of habitat used by existing focal species. Very few data exist on ecological interactions between species, so the plan should reflect the capacity for future adjustments. As an example, it will be important to monitor the ecological changes that occur as wolves return to Yellowstone National Park.

Several authors have reported problems using certain species as umbrellas. Berger (1997) reported that the spatial needs of a small herd of 28 black rhinos (*Diceros bicornis*) did not assure healthy populations for six other herbivores. Rainfall was highly variable, and other herbivores changed their ranges in response to precipitation patterns, whereas the black rhinos did not (Berger 1997). When he modeled spatial needs for a black rhino population of 100, the population numbers of the other herbivore species included under the umbrella increased significantly (Berger 1997). This indicates the need to consider area based on a viable (or at least large) population of the umbrella species. Preferably the viable population already exists, but if not, the area should be calculated to foster the recovery of the umbrella.

Kerr (1997) found that only four regions in North America still had a complete set of carnivores; he used those places as centers for reserves. These particular locations, however, did not significantly protect North American diversity in the taxa *Lasiolossum* (bee genus), Plusiinae (a moth subfamily), and Papilionidae (a butterfly family). Kerr concluded that the use of carnivores as an umbrella was unreliable for invertebrate conservation. We see a problem with this interpretation, however. The present distribution of many large carnivores is largely limited to areas inhospitable to humans; these areas probably do not represent historically prime habitat for either carnivores or invertebrates. Furthermore, three groups of invertebrates do not encompass biodiversity.

Kerr's (1997) study demonstrates the need to define the goals of a reserve clearly. The remaining population of a rare carnivore is an excellent location for protection under a "special elements" strategy, both for wilderness quality and as a source for restoring that carnivore to other areas. But, if the goal is protecting three taxa of invertebrates, the location of reserves should not be based on the present distribution of carnivores. In general, an umbrella/wilderness indicator species is more suitable to the question of how much high-quality land is necessary.

Flagship species

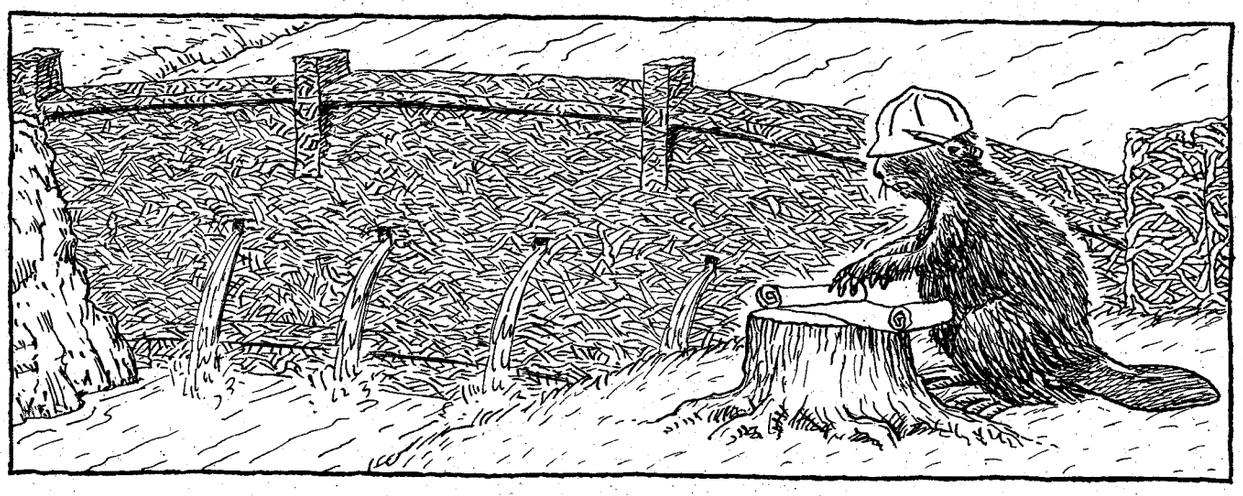
In addition to the biological considerations of selecting umbrella and indicator species, an array of important nonbiological variables should be examined. For example, what are the social, economic, and political ramifications of managing a focal species? What are the prevailing attitudes toward the focal species? Is the species commercially valuable? Is it prized by hunters or anglers? Which organizations are interested in the species or mandated to manage it? Are there any pertinent laws or regulations associated with the species (e.g., game species or species with special management status)? Which species can effectively educate the public about a conservation problem?

For example, using endangered species as flagships in reserve planning might stir our souls, but using *only* endangered species will make some members of the general public nervous or antagonistic. Including animals such as elk (*Cervus canadensis*), moose (*Alces alces*), pumas, black bears (*Ursus americanus*), and species of trout and salmon in the suite of flagship species will involve hunters and anglers, whose support can be critical to conservation efforts. Kellert (1990) found hunters supportive of wolf restoration in Michigan and recommended using this fact to counter antagonistic attitudes in the agricultural community. In many cases game and fish species also embody more than one category of focal species.

We are not recommending avoidance of endangered species in reserve design, but if employed, they should be used judiciously and not exclusively. Because of legal restrictions and small numbers, it can take longer to collect data on endangered species, and information may be influenced by artifacts of small population size. Still, many endangered species, such as sea turtles, inspire large sections of the public and help to educate people about conservation issues.

Keystone Species

Keystone species should be a pivotal part of reserve planning. Keystones contribute greatly to maintaining a biological system; their removal initiates changes in ecosystem structure, usually coupled with loss of diversity. Protection of keystone species gives managers an avenue to educate the public about the relationship between the various parts of an ecological system (a flagship role). Fiscally, it makes more sense to invest in management of a keystone species than to initiate individual management programs for all the species that depend on that keystone.



Managing keystone species therefore directs a gradual transition from traditional single-species management to management of ecosystems.

We must remember that keystone status is based on human perception of a species' role. All species contribute to ecosystem function in some way, and the charisma of some makes it easier to see their value. Yet, it is also clear that certain species contribute more than others to maintaining ecological health. Indeed, the same species may play different roles in different systems. For example, the activity of beavers in mountain-meadow streams plays a critical role in that ecosystem's structure, but beavers living in the banks of larger rivers have considerably less ecological impact (Naiman et al. 1994).

Conclusion

In this paper we have discussed the role of focal species in planning a reserve network. Focal species can contribute as keystones (ecological definition), umbrellas (management definition), flagships (public relations and fundraising), or indicators (monitoring quality). Although the categories are functionally different, a species may fall under more than one heading, which emphasizes the need to define the purpose of each focal species carefully. Focal species are an important component of reserve design, because protecting processes and patterns cannot be accomplished without a reference to the species that live in the area. Moreover, it will be difficult to assess the level of wilderness quality without reference to the species most sensitive to human presence. Our intention in this paper was to clarify some of the questions around using focal species in reserve design. We hope it contributes to a vision of how focal species can guide us closer to the goal of protecting and restoring wild areas.

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