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 mesocamivore 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).
   cj 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) Mesocamivores 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 detections 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 mesocamivores. 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 mesocamivore 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 mesocamivore 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** using an atlas approach is a practical, yet useful, way to assess change in a mesocamivore 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 KIoeisewski 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 mesocamivores (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 detections over a smaller area. Either exercise is time-consuming and expensive so it is prudent to use these data fur 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 Schoenwaid 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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