

Viability Analysis in Biological Evaluations: Concepts of Population Viability Analysis, Biological Population, and Ecological Scale

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Abstract: *Environmental protection strategies often rely on environmental impact assessments. As part of the assessment process biologists are routinely asked to evaluate the effects of management actions on plants and animals. This evaluation often requires that biologists make judgments about the viability of affected populations. However, population viability analyses that are analytically comprehensive require extensive ecological data. Such data are usually unavailable and impossible for wildlife managers to collect given limitations of time and money. In this paper we present a conceptual framework to help managers assess population viability given the reality of limited information and resources. Our framework includes a series of steps that facilitate assessment of management impacts on population viability while stressing the importance of reconciling disparities between the geographic scale of management actions and the scale of ecological responses. We argue that a gross mismatch of scale between local management actions (e.g., timber sales) and geographically extensive ecological responses (e.g., species viability) reduces the reliability of environmental analyses. Our framework stresses "biological populations" as the most appropriate level of ecological organization for conducting impact analyses. We argue that in most cases environmental analyses of local management actions should assess the ecological responses of populations rather than the responses of entire species, as is now commonly the case. We also present ecological concepts that*

Análisis de viabilidad en evaluaciones biológicas: Conceptos del análisis de viabilidad poblacional, poblaciones biológicas y escala ecológica

Resumen: *Las estrategias de las agencias de protección ambiental se basan frecuentemente en las evaluaciones del impacto ambiental. Como parte del proceso de evaluación, se pide rutinariamente a los biólogos que evalúen los efectos de acciones de manejo sobre plantas y animales. Esta evaluación requiere frecuentemente que los biólogos juzguen acerca de la viabilidad de las poblaciones afectadas. Sin embargo, los análisis de viabilidad poblacional que son analíticamente comprensivos requieren datos biológicos extensivos. Tales datos no están usualmente disponibles y son imposibles de coleccionar para los administradores de vida silvestre debido a las limitaciones de tiempo y dinero. En este trabajo nosotros presentamos un encuadre conceptual para ayudar a los administradores a evaluar la viabilidad de las poblaciones en vista de la realidad de las limitaciones de información y recursos. Nuestro encuadre incluye una serie de pasos que facilitan la evaluación de los impactos del manejo sobre la viabilidad de poblaciones mientras que enfatiza la importancia de reconciliar las disparidades entre la escala geográfica de las acciones de manejo y la escala de las respuestas ecológicas. Nosotros sostenemos que un desfase de la escala entre acciones de manejo local (e.g. venta de madera) y respuestas ecológicas geográficamente extensivas (e.g. viabilidad de especies) reduce la confiabilidad del análisis ambiental. Nuestro encuadre enfatiza a las "poblaciones biológicas" como el nivel más apropiado de orga-*

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have been used effectively by biologists in making judgments about management effects and in developing conservation plans. Although not completely generalizable we believe these concepts, summarized from the conservation biology literature, can aid in evaluating population viability: (1) connected habitats are better than disjointed habitats; (2) suitable habitats in close proximity to one another are better than widely separated habitats; (3) late stages of forest development are often better than younger stages; (4) larger habitat areas are better than smaller areas; (5) populations with higher reproductive rates are more secure than those with lower reproductive rates; and (6) environmental conditions that reduce carrying capacity or increase variance in the growth rates of populations decrease persistence probabilities.

Introduction

Current environmental protection strategies rely heavily on environmental analyses. Environmental analyses are intended to support decision-making processes by evaluating the potential environmental effects of alternative management actions. For example, federal regulations and agency policy stemming from the National Environmental Policy Act (NEPA) and the National Forest Management Act (NFMA) require U.S. Forest Service biologists to evaluate whether or not management actions contribute to the loss of species' viability on National Forest lands. Species classified as threatened or endangered under the Endangered Species Act and species classified as "sensitive" by the National Forest System are often emphasized in environmental analyses.

One specific type of environmental analysis conducted by Forest Service biologists is the Biological Evaluation. Biological Evaluations are usually directed at the effects of individual management actions (e.g., a specific timber sale) on plants and animals that occur on a management site. In Biological Evaluations biologists must provide written documentation of their judgments about whether or not a proposed management action will increase the likelihood of sensitive species becoming threatened or endangered. Accordingly, the Biological Evaluation process provides important information to decision makers, and biologists are held accountable for their judgments. These judgments are formalized in "determination of effect" documents.

The basis for the determination of effect in a Biolog-

nización ecológica para conducir el análisis del impacto. Nosotros mantenemos que en la mayoría de los casos, el análisis ambiental de acciones de manejo locales debería evaluar las respuestas ecológicas de las poblaciones antes que las respuestas de la especie en su totalidad, como es actualmente el caso. Nosotros también presentamos conceptos ecológicos que han sido usados efectivamente por biólogos en el juzgamiento de los efectos del manejo y en el desarrollo de planes de conservación. Creemos que si bien estos conceptos, resumidos de la literatura de conservación biológica, no son completamente generalizables, pueden ayudar a evaluar la viabilidad poblacional: 1) hábitats conectados son mejores que hábitats inconnexos; 2) hábitats apropiados cercanos entre si son mejores que hábitats separados por grandes distancias; 3) estadíos tardíos de desarrollo forestal son usualmente mejores que estadíos más jóvenes; 4) áreas de hábitats más grandes son mejores que áreas más pequeñas; 5) poblaciones con tasas reproductivas más altas son más seguras que aquellas con tasas reproductivas más bajas; y 6) condiciones ambientales que reduzcan la capacidad de carga o incrementen la varianza en las tasas de reproducción de las poblaciones disminuyen la probabilidad de persistencia.

ical Evaluation or other impact analysis necessarily involves some kind of population viability analysis (PVA). Gilpin and Soulé (1986) described PVA as a complex process of considering all factors that affect the processes of species extinction. In a formal PVA (one that is analytically comprehensive) it is necessary to integrate those factors that influence the likelihood of extinction, such as demographic, genetic, and environmental stochasticity, as well as life history and habitat-use parameters. In addition, basic ecological processes like dispersal, competition, and predation also need to be understood as they influence population persistence. In other words, a formal PVA (whether qualitative or quantitative) is comprehensive and requires considering the entirety of a species' (or population's) ecology. In formal PVAs ecological relationships and demographic parameters are often incorporated into a mathematical model that helps predict population trends and extinction probabilities.

Appreciating the complexity involved in the PVA process is useful because it serves as a measure of our general ecological understanding for a given species. But when biologists are routinely required to make judgments about population viability with extremely limited data and resources, they face numerous professional and personal difficulties. In this paper we hope to aid biologists faced with conducting viability analyses when local demographic, habitat use, and life history data are unavailable.

To make viability assessments more practical for resource managers, we discuss the basic characteristics of

PVA and attempt to dispel the theoretical mystique surrounding PVA by placing the concept in a practical framework. We also present a discussion of "biological populations" and "ecological scale," concepts we feel must be carefully addressed for meaningful impact assessment. To place the problems of ecological scale in a practical framework we suggest a stepwise process to formalize major decisions that must be made when conducting an impact assessment. The process outlined can be generalized to plants, invertebrates, or other taxa and is not limited to the assessment procedure used by any single agency. Finally, we present basic ecological ideas that can aid biologists when local ecological information is limited. The ideas we present have been effectively incorporated into biological evaluations.

We are not attempting to provide readers with a cookbook approach to viability analysis. We have not specified suggested acreages associated with each spatial scale we discuss because of the wide variety of scales involved. Rather, we hope to provide biologists with a conceptual framework to help them address population viability given limited information and resources. Biologists will, in turn, have to adapt our suggestions to their own management situations.

Important Concepts

Population Viability Analysis as Part of Routine Impact Analysis

Population viability analysis can be a complex process involving the integration of a wide range of information; but, simply put, PVA is about birth, death, immigration, and emigration rates and how environmental and ecological factors affect these rates over time. Models employed in PVA may be sophisticated mathematical constructs, elaborate word models, or simple narratives. However, in each case the model is employed principally to evaluate the long-term balance between individuals coming into the population and leaving the population. Thus the essential question to be asked by wildlife managers is simply, "Can I reasonably infer this proposed action will alter the balance between the rate of recruitment and the rate of loss such that the probability of persistence for the population in question is diminished?" In this context it is important to understand that a reduction in carrying capacity or an increase in the variance associated with growth rates can also have a negative effect on the probability of population persistence (Goodman 1987; Boyce 1992). This framework also suggests that a population that persists due to an influx of individuals from an adjacent population is not as secure as a population that persists based on the strength of its own reproductive and survival rates.

This emphasis on persistence leads us to focus on the critical importance of time and changing environmental conditions over time (Ruggiero et al. 1988). Viability assessments must address both population persistence within acceptable habitat and the dynamics of the habitat network itself (Shaffer 1990). Hence, the cumulative effects of management actions and changing environmental conditions (past and future) need careful evaluation.

Ecological Scale in Impact Analysis

The concept of scale must be a central theme when evaluating population viability. The disparity between the scale of a local management action (e.g., a timber sale) and the scale of the ecological response (e.g., species viability) is a fundamental problem in assessing population viability. For example, consider the biologist who has to determine the effects of a series of clearcuts on the viability of Northern Goshawks (*Accipiter gentilis*). The scale of the response—species' persistence over its geographic range (millions of hectares)—is inconsistent with the scale of the management action (usually only hundreds of hectares). In the Biological Evaluation process, as a specific example, a biologist's job is to evaluate the effects of local management actions on species persistence.

The term ecological scale implies hierarchical levels of ecological organization: individuals, demes, subpopulations, populations, metapopulations, subspecies, and species. Higher levels of ecological organization generally occupy larger geographical areas. Disparity between the scale of a proposed management action and the scale at which the corresponding ecological response is evaluated can result in viability analyses that are questionable. This mismatch in scale can easily lead to an erroneous conclusion regarding the impact of management actions if one confuses the inability to measure an effect with the absence of an effect per se. To make the scales of management action and analysis compatible, either scale up the area used to analyze management effects (including all related actions) or scale down the response unit by moving from species-level to some lower level of ecological organization. Reconciling scales alone will not necessarily make the job of assessing viability possible; data on species' ecology are still needed. However, recognizing (and eliminating) significant disparities in scale is the first step toward ensuring that conclusions about effects will be meaningful and useful in the decision-making process.

Populations as the Focus of Impact Analysis

Reconciling mismatched scales between management actions and ecological responses usually involves focusing analyses on biological populations rather than on

entire species. A biological population is a cluster of individuals with a high probability of mating with one another as compared with the probability of mating with members of other populations (Pianka 1983). Biological populations represent a real level of ecological organization that occurs in nature (as opposed to arbitrarily defined populations that are often used to facilitate sampling or mathematical analysis). Although the geographic or physiographic boundaries that demarcate different populations are often difficult to define, it is nonetheless important to attempt a biologically meaningful delineation. In some rare cases a species with a very limited distribution may be restricted to a single population (e.g. *Hemignathus parvus* and other birds of the Hawaiian islands, Scott et al. 1986; desert fishes, Minckley et al. 1991), but usually a species exists as multiple populations throughout its range (Andrewartha & Birch 1984). It is clear that species usually differ from populations, and failure to make this distinction is one of the primary sources of confusion when biologists conduct viability analyses. By focusing impact analyses on populations mismatches in scale between management actions and the geographic scale of the ecological response can sometimes be mitigated. The results from the analysis should not be extended to an entire species without careful consideration of the ramifications.

In addition to its importance in addressing issues of scale, the concept of biological population is important in impact analysis because individual populations evolving under the unique conditions present in a given locale may have acquired characteristics important for that population's persistence. Therefore, maintaining a diversity of natural populations is important for species conservation.

The focus of viability analyses should be on biological populations; however, it is also important to remember that few populations exist in demographic isolation. Some populations act as sources by contributing immigrants to less stable populations, whereas others act as sinks by attracting individuals that will be unable to survive. A collection of interacting populations, linked through dispersal, is known as a metapopulation. It is especially important that cumulative effects analyses, which extend beyond the direct effects of individual management actions, examine ecological consequences within the metapopulation. By considering how management actions affect metapopulation structure, the analysis will further explore how a proposed action affects the persistence of local populations.

Viability Assessment: A Guide for Land Managers

We have formalized a series of steps into a flow chart (Fig. 1) that may help biologists assess the impacts of management actions on population viability. It is impor-

tant to stress that our approach focuses on biological populations, not on subspecies or species. However, we understand that certain analyses are conducted pursuant to the Endangered Species Act and are constrained to address the viability of species or subspecies. Even so, we hope the steps in our general viability assessment process are useful in thinking about all impact assessments.

Step 1

In step 1 (Fig. 1A) delineate the management area as the immediate area in which management actions will occur. Actions might include a series of clearcuts, a live-stock allotment plan, or some other proposed management action. In project-level planning (the planning level where Biological Evaluations are typically conducted), management areas are small (often fewer than 4000 ha) relative to the size of most national forest ranger districts (typically greater than 100,000 ha).

Steps 2 and 3

In step 2 identify the species to be addressed in the analysis. Once species are identified, gather information concerning their natural history, usually through literature reviews. This information might include dispersal capabilities, habitat requirements, mortality agents, home-range size, predators, competitors, productivity, and obligate ecological relationships.

For each species of concern, delineate the population(s) that occupy the management area (step 3). Identifying the geographic extent of a population is possible, but usually difficult. In the case of an amphibian restricted to a small wetland the extent of the population is clear. However, for wide-ranging species, like the Northern Goshawk, the extent of a given population is unknown and impossible to determine. To mitigate the problem and to identify reasonable, even if uncertain, boundaries consider vegetative structure, physiographic characteristics, and documented dispersal distances.

Steps 4 and 5

In step 4 define an analysis area. The analysis area is the geographic site where biologists consider how the direct effects of management actions will influence population viability. Depending on the geographic extent of a target population(s) the analysis area may be equal to or larger than the management area (Fig. 2). Because the biological population is the fundamental demographic unit involved in extinction, we suggest that, when practical, the analysis area include all biological populations existing in whole, or in part, in the management area.

If the management area subsumes one or several biological population(s) of some target species (Fig. 1B),

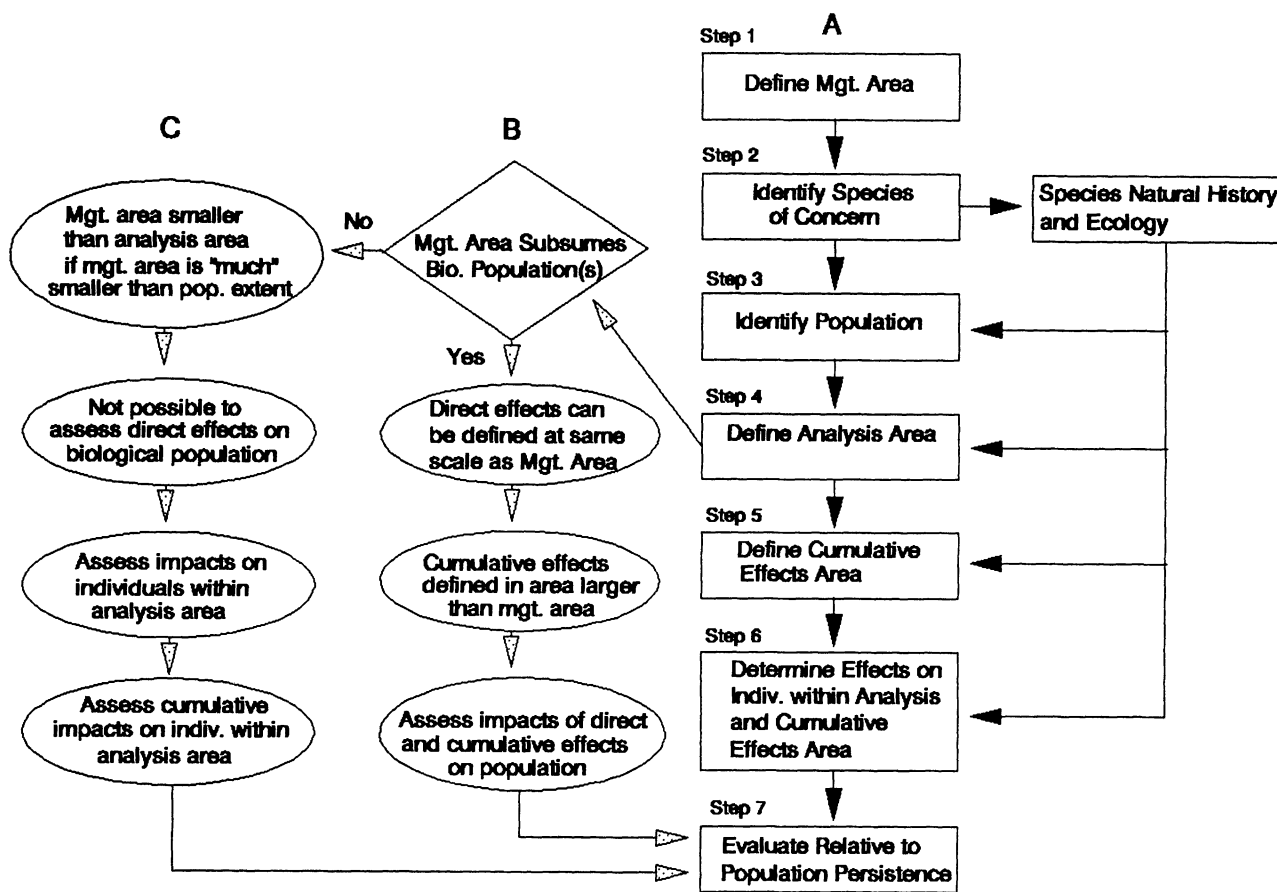


Figure 1. Flow chart of steps in a population viability impact assessment.

then the scale of management action and the scale of ecological response are congruent and thus comparable. All pertinent direct impacts can be evaluated within the management area. Accordingly, the management area and the analysis area are identical.

More often the management area will include only a portion of a population that is directly affected by the management action (Fig. 1C). In these cases population boundaries will extend beyond the management area and the definition of the analysis area becomes considerably more difficult. While we recommend the analysis area include all directly affected biological populations, we also stress that the geographic size of the analysis area and the management area cannot be grossly mismatched.

Because this potential mismatch represents one of the central difficulties in the assessment process, we suggest some guidelines for dealing with the problem. When the area occupied by the biological population(s) is less than ten times the area occupied by the management area, the population boundaries should be used to define the analysis area. For species with large home ranges, like the Northern Goshawk or American marten (*Martes americana*), populations may extend well beyond the area defined as ten times the management area.

Population structures for these species are often poorly understood and may occur at geographic scales that encompass millions of hectares. For these species the scale of the management action and the population boundaries are so disparate that they are not comparable. In such instances it is reasonable to define the analysis area as an administrative unit (e.g., ranger district). Delineating an analysis area based on an administrative area may be justified either by agency regulation or as a means of rendering the scale of management action more comparable to the scale of ecological response. Alternatively, define an analysis area so it includes a small portion of the biological population. This requires assessing the impacts of management on individuals (or groups of individuals) rather than on populations. When using this approach the size of the analysis area can be based on species mobility. For example, mammals typically disperse less than five home-range diameters (Chepko-Sade & Halpin 1987), and information like this should be considered when using this approach. Regardless of whether the analysis area is defined administratively or by species mobility, it is imperative that the scale of a proposed management action and the scale of the corresponding analysis area be comparable, even for species of high vagility.

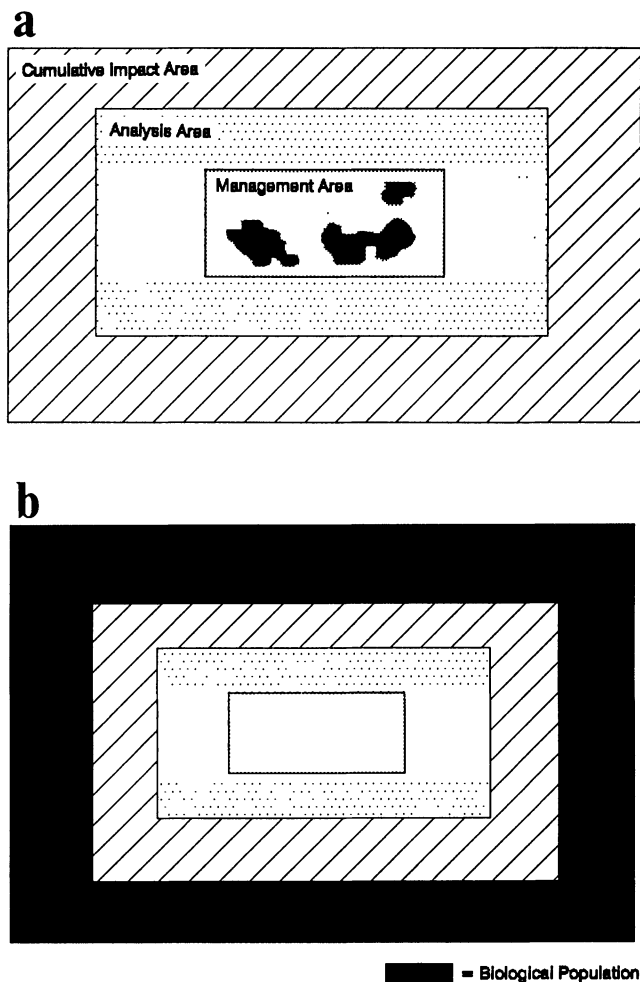


Figure 2. Spatial relationships among (a) management areas that subsume biological populations and (b) management areas that do not subsume the biological population.

In addition to examining the direct affects of management, cumulative effects—the long-term impact of management over time—must be addressed. The first step, in the difficult process of reconciling scales when addressing cumulative effects, is to delineate a cumulative impacts area (Fig. 1A5). The cumulative impacts area usually extends beyond the analysis area and includes populations that are not directly affected by current management actions. Thus, cumulative effects analyses usually consider the indirect effects of proposed actions.

When management effects are examined at broader, cumulative-impact scale the metapopulation structure is a preferred scaling unit for the analysis. Ideally, the cumulative impacts area includes all populations adjacent to the population directly affected by the management action. Cumulative impact analyses ought to examine how changes from past, present, and future management actions may alter metapopulation structure and affect the persistence of the population under study.

Unfortunately, as was the case in defining the analysis area, the broad geographic extent of populations of wide-ranging species will again lead to a mismatch in scale when relating the management area to the cumulative impacts area. This may be true even when only a single population is involved and there are no metapopulation considerations. When considering wide-ranging species depart from strict adherence to the metapopulation framework for analysis. This recommendation is an attempt to correct the extreme mismatch in scale between management actions and the vast geographic areas used by highly mobile species. In these cases use administrative boundaries (e.g., Ranger District) as suggested for defining the analysis area for highly mobile species. Delimiting cumulative impact areas in this way is consistent with regulations that mandate maintaining viable populations on planning units (e.g., National Forests). Because population viability on National Forests or other comparable land units depends on the persistence of individuals on relatively large subunits, the District framework suggests a reasonable size for cumulative impact areas. In addition, the data needed for viability assessments (e.g., management plans, vegetation, and other maps, etc.) is most likely to be available in these field-oriented, administrative units.

Step 6

To determine the effects of a management action (Fig. 1A6) on population viability four major questions need to be addressed: (1) Has habitat amount or condition been changed over time and space relative to the extent of the population (or individuals) of interest? (2) What is known about the ecology of the species under investigation, and how does this knowledge relate to the current management situation? (3) How will recruitment and death rates be directly (e.g., habitat loss, roads) and indirectly (e.g., by increasing the probability that stochastic events will affect population dynamics) affected by management activities? (4) Given all available information, is it possible to make an informed judgment on the effects of the management action?

Step 7

In step 7 evaluate what is known about species' ecology, habitat changes within the area of concern, and the interaction of these two bodies of information. Consider the results of this evaluation within the context of basic ecological concepts and principals, and make the best possible judgment about the effects of management actions on the survival of individuals and persistence of population(s). Professional judgment regarding population viability will certainly involve a degree of biological uncertainty. However, it is important to recognize the

considerable body of ecological understanding we do possess. We can offer some general considerations for use as guidelines when making judgments about effects. Our intent is to provide a basis for thinking about potential effects. These are guidelines and not principles which have been tested extensively in a variety of geographic regions and found to be generalizable. Accordingly, biologists should apply these guidelines critically with full consideration of the unique circumstances associated with each analysis. We believe these guidelines are indicative of current knowledge and are therefore appropriate as tools to help formulate judgments about population persistence (Thomas et al. 1990).

CONNECTED IS BETTER THAN DISJOINTED

Few vertebrate populations occur in demographic isolation. Productive populations contribute immigrants to less productive populations, thus rescuing them from local extinction. The degree of isolation influences population persistence (Brown & Kodric-Brown 1977). Even large populations, existing in complete isolation, may have low persistence probabilities over time frames as short as 100 years (E. O. Garton, unpublished data). Over time a given population may act as a source or sink depending on environmental and demographic variability. Thus, population persistence, especially in landscapes that have been modified by management activities, may depend on habitat linkages.

In this context, wildlife corridors serve two major functions in biological conservation: (1) they provide habitat for plants and animals; and (2) they act as conduits for movement (Noss 1993). Travel corridors that link populations may minimize local extinction and genetic isolation of wildlife populations (Noss & Harris 1986; Harris & Scheck 1991). Many studies, both empirical (Johnson & Adkisson 1985; Henderson et al. 1985; La Polla & Barret 1993; Saunders & de Rebeira 1991; Wegner & Merriam 1979; Catterall et al. 1991; Bennett 1990; Merriam & Lanoue 1990; Dmowski & Kozokiewicz 1990) and computer simulated (Henein & Merriam 1990; Fahrig & Merriam 1985), stress the importance of corridors to wildlife. However, corridors are not a panacea for maintaining population viability and there are associated costs (Simberloff & Cox 1987; see Noss 1987 for reply). Corridors may serve as conduits for fire or predators, allow entrance for weedy, edge-tolerant species, and may have significant economic costs that expend limited conservation dollars.

The critical question is not if corridors are good or bad, but whether protected, interconnected habitats better protect biological diversity compared with dispersed protected areas with no connections (Harris & Scheck 1991). In our opinion adequately designed corridors have an important role to play in species conservation.

CLOSER IS BETTER THAN FARTHER

The theory of insular biogeography predicts that the persistence of species occurring on islands is a result of a dynamic equilibrium between immigrations and extinctions (MacArthur & Wilson 1967). The theory suggests that a number of factors influence persistence: extinction rate is a decreasing function of area while immigration is inversely related to the distance to potential colonists. Although empirical investigations suggest that extinction and colonization are complex functions of many factors (see review by Wiens 1989) the importance of distance in determining immigration rates has been shown in several investigations (Abbott 1980; Diamond & Mayr 1976; Williams 1981). Brown and Kodric-Brown (1977) suggested that islands located close to a source may be frequently rescued from extinction by continuing inputs of individuals. Models have also shown that dispersal may have a positive effect on persistence in subdivided populations (Reddingius & den Boer 1970; Burkey 1989).

It follows that the distance between suitable habitat and the nature of the intervening habitat matrix following management actions will likely influence the persistence of target species. In order to maintain demographic linkages, suitable habitat must be within a species' dispersal capabilities.

OLDER IS OFTEN MORE VALUABLE THAN YOUNGER

As a result of clearcuts, road construction, powerlines, natural burns, and other habitat alterations early-successional vegetation has increased at the expense of late-successional plant communities. Late-successional or old-growth communities have been reduced in extent while edge and early-successional communities have increased. Species of wildlife associated with edge communities may impede the movements of (Catterall et al. 1991) or exclude certain forest-dwelling wildlife (Ambuel & Temple 1983). Thus, conservation concerns are increasingly focused on species closely associated with late-successional vegetation (Ruggiero et al. 1991). Maintaining intact blocks of old-growth or mature (late-successional) forests, prairies, and desert communities may be important to conserving our most sensitive native wildlife.

BIGGER IS BETTER THAN SMALLER

Habitat fragmentation is considered the number one cause for declining biological diversity (Wilcox & Murphy 1985). As described previously, the theory of insular biogeography suggests the relationship between island size and extinction (MacArthur & Wilson 1967 and see review in Wiens 1989). The likelihood of population persistence, then, decreases with loss of habitat and the

resulting reduction in population size (Goodman 1987). Large habitat areas are also important for interior forest species because of the reduced influence of negative edge effects (e.g., Ambuel & Temple 1983).

HIGH REPRODUCTIVE RATES ARE MORE SECURE THAN LOW REPRODUCTIVE RATES

In general populations with low intrinsic rates of increase have higher extinction probabilities because of their slow recovery from low population levels (Pimm et al. 1988). Small populations are at risk due to environmental, demographic, and genetic stochasticity. Thus, habitat changes that reduce population size or productivity decrease persistence probabilities.

ENVIRONMENTAL CONDITIONS THAT INCREASE VARIANCE IN GROWTH RATES DECREASE PROBABILITY OF PERSISTENCE

Populations that experience high variance in growth rates have reduced probabilities of persistence when their population size is reduced (Goodman 1987). Furthermore, increased variability in reproduction, mortality, or dispersal will decrease the likelihood of persistence (Boyce 1992). If habitat changes increase the variability of these parameters and population growth becomes more variable, the population is less likely to persist, even if the mean reproductive rate remains constant over time. Habitat alterations can cause changes in population demographics either through direct effects on reproduction and survival or by affecting the stability of important prey (Garton et al. 1987).

Conclusions

Ideally, formal PVAs should be conducted for all populations when the potential impacts of management are a concern. But given the limited availability of demographic and ecological information this is unlikely to happen. Our word model for assessment of population viability makes the best of limited knowledge and resources.

There are sharp distinctions between reasonable and unreasonable questions concerning management impacts on wildlife. Questions posed at the wrong scale must be discarded. Furthermore, current ecological knowledge suggests it is unrealistic to expect simple answers to complex questions regarding species viability. We provide a process to aid managers in developing practical impact analyses: (1) a biologically based method of reconciling disparities between the scale of management actions and the scale of ecological response; (2) direct and cumulative effects assessed at the proper scale even when scales differ; (3) use of spatially explicit data for entire administrative units may be necessary when addressing questions about population vi-

ability; and (4) application of ecological rules of thumb, when data are lacking, to develop defensible impact assessments.

It is important that research scientists and management biologists work together to mold the science of viability assessment into a practical tool. Formal population viability analyses are complex and are impossible to conduct on a routine basis. But a process allowing managers to assess impacts of local management on wildlife is critical to conservation. We have described a framework that we hope makes this process more practical and more defensible.

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