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POPULATION VIABILITY ANALYSIS IN ENDANGERED SPECIES RECOVERY PLANS: PAST USE AND FUTURE IMPROVEMENTS

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Abstract. Using the results of a survey of recovery plans for threatened and endangered species, we evaluated the role that Population Viability Analysis (PVA) has played in recovery planning and management of rare species in the United States. Although there was a significant increase over time in the percentage of plans presenting information on PVA and assigning recovery tasks to collect more such information, the use of PVA was still called for in less than half of the plans approved since 1991. Because scarcity of data for rare species may be limiting the application of PVA to endangered species, we also assessed how often recovery plans proposed to collect the full complement of data required to perform four general types of PVA. For most of the species in the database, proposed monitoring data would allow the simplest type of PVA method (i.e., analysis of total population counts) to be applied, but more complex PVAs would be possible for <25% of the species. We conclude with brief recommendations for how the use of PVA in endangered species recovery planning might be improved in the future.

Key words: *endangered species; monitoring; population viability analysis; PVA; recovery plans.*

INTRODUCTION

Population Viability Analysis (PVA) is the use of quantitative methods to predict the likely future status of a population or collection of populations of conservation concern. There is good evidence that interest in PVA in the academic conservation biology literature is growing exponentially (Groom and Pascual 1998, Beissinger and McCullough 2002), but we currently lack a clear picture of whether PVA is being used where it matters the most, namely in on-the-ground management of rare species. Here, we use a survey of endangered species recovery plans (Hoekstra et al. 2002) to evaluate how often PVA is being used in actual conservation practice. The survey included several questions that focused explicitly on PVA. We analyzed responses to those questions to determine the frequency with which PVA has played a role in endangered species recovery planning over the 18-yr interval from the earliest to the most recently approved plan in the database.

It is not reasonable to expect that PVA should appear in every recovery plan. For critically endangered species, a PVA will probably be superfluous, both because the data necessary to perform one are virtually certain to be lacking and because immediate ''life support'' efforts must take precedence over all other measures. However, for species not on the very brink of extinction, PVA can serve three useful functions. First, simply by yielding an estimate of the probability of extinction by a specified future time, PVA can indicate how urgently recovery efforts need to be initiated in specific populations. Second, a PVA can be the focal point for synthesizing monitoring data into an assessment of recovery success. For example, a quantitative population model may be needed to determine whether an increase in a species' birth rate detected by monitoring actually suffices to reverse population decline. Third, PVA can identify particular life stages or demographic processes that should be the primary targets for management (Crouse et al. 1987, Beissinger and Westphal 1998). Given the potential value of these PVA ''products,'' two recent assessments of the use of science in endangered species management have advocated increased use of PVA (National Research Council 1995, Carroll et al. 1996).

Viability assessments can be quite accurate when sufficient data are available to build a quantitative population model (Brook et al. 2000). However, to capitalize on the advantages that PVA offers, managers often will need to begin by collecting such data, which are typically unavailable at the time a recovery plan is created. Recovery plans frequently propose monitoring tasks to assess whether a species' status is changing or management efforts are succeeding, and these tasks represent an ideal opportunity to collect the data needed for PVA. Hence, we also used the database to ask whether approved recovery plans included proposals

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to collect the complete set of information needed to perform a PVA. We assessed the completeness of data collection for four general types of PVA (see *Methods*) that span the range of complexity and data requirements of previously published viability analyses.

In summary, our analysis was designed to address three questions. First, how often has PVA been used in planning recovery efforts for threatened and endangered species? Second, what factors (e.g., year of plan approval, original vs. revised plans, taxonomic group and conservation status of the focal species, organizational affiliations of the plan's authors, geographical region) help to predict how often PVA has or has not been used? Third, do recovery plans call for the collection of the full complement of data needed to make future PVAs possible?

Methods

Use of PVA in recovery planning and recovery efforts

We extracted information from the survey about past, desired, and planned future use of PVA (see Appendix for the exact survey questions used in each analysis, and their interpretation). For past usage, we tallied responses to a question that asked whether information on PVA was presented in the plan, not presented because the plan stated that such information did not exist, or not mentioned. Desired usage was assessed by a survey question that asked whether the plan indicated that ''some or more information on PVA would be beneficial for recovery efforts.'' To evaluate planned future usage of PVA, we examined the assignment of items specifically related to PVA in the list of recovery tasks that appears at the end of each recovery plan. We used log-linear models (*G* tests, Sokal and Rohlf 1995) to test whether these three indicators of PVA usage were associated with other variables in the database.

Types of PVA

The types of quantitative methods that fall under the heading of PVA are quite varied, both in terms of the complexity of the underlying models and the quantity of data needed to parameterize them (Burgman et al. 1993, Morris et al. 1999, Beissinger and McCullough 2002). As a result, the question of whether the appropriate combination of data needed for PVA is to be collected under proposed monitoring schemes must be asked in the context of a particular PVA method. We examined four general classes of PVA approaches, which we term ''count-based,'' ''structured,'' ''metapopulation,'' and ''spatially explicit'' PVAs. The first (and simplest) class uses time series data on total population size to parameterize models (typically derived using diffusion approximations) that predict extinction risk. This method requires data on both current population size and trends in population size over time, but does not require age- or stage-structured data or spatially explicit information. Examples of PVAs using this method are Dennis et al. (1991), Stacey and Taper (1992), and Middleton and Nisbet (1997). Structured PVAs use life tables or projection matrix models, which track changes in the numbers of individuals in different stages (e.g., age or size categories) in a population. Such structured models allow more detailed analysis of critical life stages or demographic processes that are potential targets for management (Caswell 2001), but they require data on stage-specific fecundity rates, stage-specific mortality rates, and the current stage structure of the population in order to be used to predict viability. Examples of PVAs using projection matrices are Crouse et al. (1987), Menges (1990), Beissinger (1995), Nantel et al. (1996), and Kareiva et al. (2000). The third class, ''metapopulation'' PVAs, follows the fates of multiple subpopulations and attempts to determine whether the rate of establishment of new subpopulations through colonization is sufficiently high to counter the extinction of subpopulations, thus allowing the entire metapopulation to persist (for an example, see Hanski et al. 1996). Such PVAs require information on the number of subpopulations, trends in the number of subpopulations or the rate of subpopulation extinction, and the colonization rate, typically as reflected in patterns of dispersal. The fourth, and most data-intensive, class of PVA methods (''spatially explicit'' PVAs) typically involves simulating the behavior of individual organisms on detailed landscapes upon which the sizes and locations of suitable habitat patches are mapped. In addition to requiring information about birth and death rates of individuals and their movement patterns, this type of PVA also requires data on the degree of isolation and fragmentation of suitable habitat patches. Examples of spatial PVAs are Lamberson et al. (1992) and Liu et al. (1995). We examined the assignment of recovery tasks to monitor population size, trends in population size, fecundity and mortality rates as functions of stage, stage structure, number and trends in the number of subpopulations, rates of subpopulation extinction, dispersal and movement rates, and habitat fragmentation/isolation to get a sense of how often each of the four types of PVA would be possible, given the types of data that planned monitoring efforts would yield.

Results

How often do recovery plans make use of PVA?

Only 14.4% of the plans presented information on PVA, and an additional 6.8% stated that such information did not exist. The portion of plans stating that more information on PVA would be beneficial (24.3%) and the portion assigning specific recovery tasks to collect more information on PVA (31.1%) were somewhat higher, but still below one-third of all plans. Although these statistics indicate that use of PVA has been uncommon in recovery planning, there is an encouraging trend toward increased use over time (Fig.

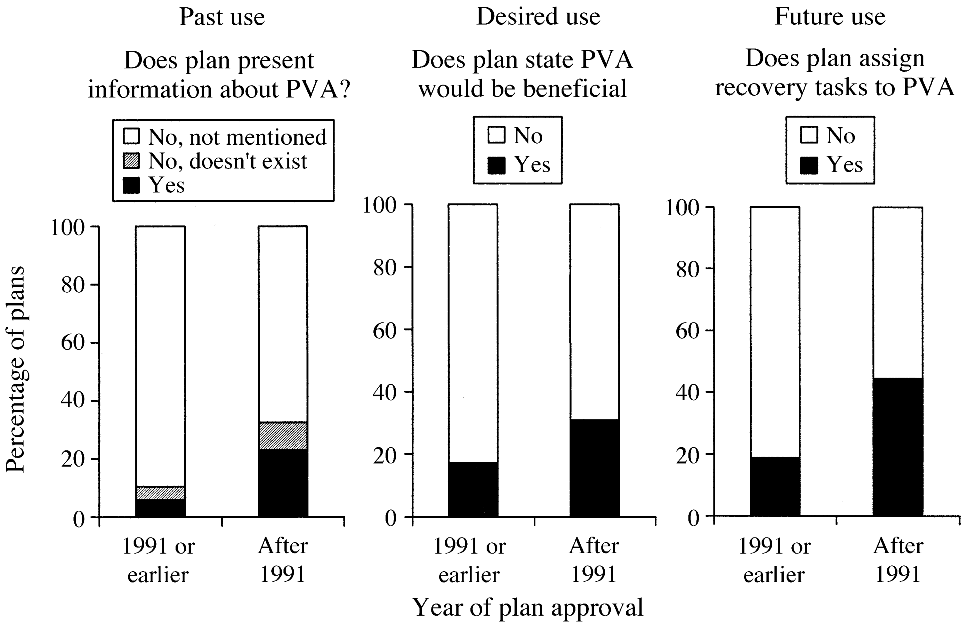

FIG. 1. Percentage of recovery plans, pre- and post-1991, categorized by PVA (population viability analysis) content. Indices of past, desired, and planned future use of PVA show that it has played a small but increasing role in recovery planning.

1). Plans approved after the median year of approval for plans in the database (1991) were over three times more likely than earlier plans to present information on PVA ($G = 9.77$, df = 1, $P = 0.002$), and there was a more than twofold increase in the percentage of plans assigning recovery tasks to collect information on PVA ($G = 10.23$, df = 1, $P = 0.001$).

What factors (if any) are correlated with the use of PVA?

All three measures of PVAs influence on recovery plans (i.e., past, desired, and planned future usage) were statistically independent of whether the plan was an original or revised version, the institutional affiliation of the lead author of the plan (i.e., recovery team, government scientist, academic scientist, private consultant, etc.), the presence of either nonfederal or academic scientists on the recovery team, and the U.S. Fish and Wildlife Service (USFWS) region in which the plan was approved. Thus the only factor associated with the use of PVA is the year of plan approval.

Do recovery plans call for collection of the right combination of data to perform PVA?

Given that PVA has been used only infrequently to date, how often have recovery plans proposed to collect the kinds of data that would allow PVA to be used more frequently in the future? The good news is that the majority of plans have assigned tasks to collect at least some of the right types of data. Specifically, plans assigned monitoring tasks to collect some of the data needed to do count-based, structured, metapopulation, and spatially explicit PVAs for 93.9, 69.1, 83.4, and 83.4% of the species, respectively. However, when we asked how often plans assigned monitoring tasks to collect *all* of the data needed to do a PVA, these numbers dropped to 77.9, 22.7, 16.0, and 7.2%, respectively (Fig. 2). In one sense, these numbers may actually be optimistic, in that, even if a recovery plan did assign monitoring tasks in a general category such as ''reproductive rates,'' the full set of data needed to do a PVA might still not be collected. For example, all steps in the recruitment process might not be quantified, or censuses might not be performed for a sufficient number of years to enable an accurate PVA to be performed (Fieberg and Ellner 2000).

We also tested for associations between the likelihood that the right combination of data would be collected and the following factors: whether the plan was a revised or original version, whether the plan was a single- or multi-species plan, the participation of nonfederal and academic scientists as either recovery team members or team leaders, the Endangered Species Act listing status of the species (threatened vs. endangered), the USFWS region in which the plan was approved, and the taxonomic affiliation of the species (animal vs. plant or lichen). None of these factors was significantly associated with the intention to collect all of the data needed to perform any of the four types of PVA, with the exception that revised plans were significantly *less* likely to specify the right data to perform a metapopulation PVA ($G = 5.03$, df = 1, $P = 0.025$).

Despite the significant increase that we noted in the percentage of plans assigning recovery tasks to perform

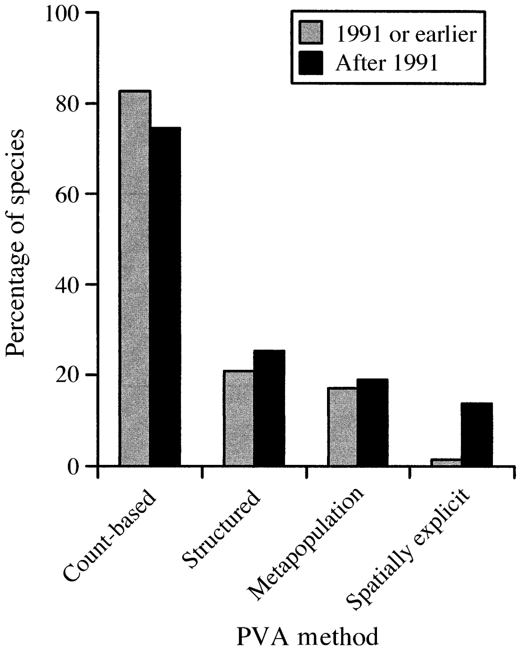

FIG. 2. Percentage of species for which the recovery plan called for the collection of all the necessary data needed to perform four types of population viability analysis (see *Methods* for a description of PVA types). Only for spatially explicit PVAs was there a significant improvement over time in the completeness of data collection (see *Results*).

PVA per se, plans approved after the median approval year (1991) were no better at specifying the proper sets of data needed to actually build a count-based, structured, or metapopulation PVA ($P = 0.189$, 0.496, and 0.750, respectively; Fig. 2). However, the percentage of species for which the necessary data to perform a spatially explicit PVA were to be collected did increase from 1.5% before the median year to 13.8% after ($G = 8.79$, df = 1, $P = 0.003$). The database also recorded whether the plans explicitly stated that monitoring data were to be ''incorporated into a model for predictive analyses.'' For only 18 of the 181 species did the plans specifically state that *any* monitoring data potentially useable in PVAs of any kind were to be incorporated into models. However, explicit plans to incorporate monitoring data into models were more frequently found when the plan also stated that PVA would be beneficial ($G = 7.70$, df = 1, $P = 0.006$). Thus there is a subset of plan authors that both see a value to PVA and call for its use in analyzing monitoring data, but this subset represents only 4.4% of the plans sampled.

DISCUSSION

Our evaluation of the use of population viability analysis in endangered species recovery plans yielded two causes for concern. First, the frequency with which recovery planners use PVA, although increasing over time, remains low, with <50% of recent plans explicitly assigning recovery tasks to collect information about PVA. The second, more worrisome, concern is that, despite strong evidence of a desire on the part of recovery managers to make greater use of PVA (Fig. 1), recovery plans rarely propose to collect complete sets of data, without which PVA will continue to be underutilized in future recovery planning and the management of endangered species. By not considering fully how ongoing data collection efforts can be made to serve the needs of PVA, we may be missing the opportunity to make the monitoring of endangered species do ''double duty.'' Monitoring data not only can be used to answer the simple question: ''is a population of an endangered species recovering or declining,'' but when used to parameterize viability models, can also form the basis for more sophisticated quantitative analyses that would allow us to ask, for example, which of several management interventions has the greatest chance of success in the future. Making such analyses possible requires that monitoring provide the full complement of information needed to construct viability models.

Given the type of monitoring data that recovery plans are proposing to collect, count-based models are more likely to form the basis of future PVAs than are more complex models (Fig. 2). Such simple models are both easier to parameterize and less informative. For example, models of total population size cannot provide guidance about which life stages or demographic rates are crucial management targets, nor can they be used to integrate changes in stage-specific vital rates to determine if a population's status is improving. Structured models are more informative in both regards (Caswell 2001), yet only ~25% of recent plans proposed to collect complete demographic data (Fig. 2). Considering the recent conservation successes of structured viability models (e.g., Crouse et al. 1987, Lande 1988), managers should seriously consider whether the benefits of such models might justify the added complication of monitoring multiple life stages.

Recommendations for improving the use of PVA in recovery planning

We close with three recommendations that follow from our review of recovery plans.

Enhance appreciation for PVA among recovery planners.—Federal agencies responsible for managing endangered species (USFWS and the National Marine Fisheries Service) should, through courses and workshops, continue to increase the level of awareness among those charged with developing recovery plans that quantitative methods such as PVA can provide useful tools for evaluating risk and developing management strategies.

Involve population viability analysts directly in the recovery planning process.—Even when plans proposed that some of the variables needed to do PVA be monitored, they showed very little awareness that models could be used to inform the interpretation of such data. Involving quantitatively trained biologists in recovery planning would broaden the array of tools that could be used to analyze monitoring data. Rather than asking population biologists to review recovery plans only after they are written, agencies should invite and encourage them to take part in plan creation. For their part, academic population biologists need to ''put their money where their mouths are'' by agreeing more often to serve on recovery teams when invited to do so.

Fill the gap between the design of monitoring protocols and the needs of PVA.—Increased involvement in plan development of individuals with PVA expertise would also help to assure that proposed monitoring will yield the right kinds and combinations of information to develop quantitative models for endangered species. In this way, even if insufficient data now exist to use PVA for a particular threatened or endangered species, routine monitoring could make the construction and parameterization of population models feasible in the future. In many cases, population viability analysts may be able to improve the appropriateness of monitoring schemes for modeling purposes without significantly increasing the cost of monitoring.

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[4] URL: ⟨http://www.nceas.ucsb.edu/recovery/acknowledgments⟩

APPENDIX

A table presenting interpretations of survey responses pertaining to the use of Population Viability Analysis (PVA) in endangered species recovery plans is available in ESA's Electronic Data Archive: *Ecological Archives* A012-007-A1.