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## AN ASSESSMENT OF MONITORING EFFORTS IN ENDANGERED SPECIES RECOVERY PLANS

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**Abstract.** Recovery efforts for threatened and endangered species often must be initiated with incomplete data. The outcomes of such efforts are difficult to predict, which makes monitoring the progress of recovery efforts an integral part of the recovery process. We evaluated the role of monitoring in recovery plans for 181 species listed as threatened and endangered under the U.S. Endangered Species Act. We considered both the extent to which monitoring tasks were proposed as part of the recovery effort and the extent to which the tasks proposed were actually implemented. In general, tasks devoted to tracking the species' population trend were more likely to be proposed and implemented than were other monitoring activities (e.g., those devoted to the species' demographics, its habitat requirements, or the impact of predators, competitors, and exotics). We found that the extent and nature of the monitoring proposed and implemented appeared to reflect taxonomic biases that exist throughout the recovery process and were little influenced either by the level of understanding of the species' biology or by the recovery priority assigned to the species. In particular, monitoring efforts did not adequately address the specific threats affecting species. Proposals for, and implementation of, monitoring progress toward recovery goals were independent of the type of criteria defined in the plans (e.g., population level and habitat extent), although population-related criteria were disproportionately common. Based on these findings, we caution against an overemphasis on focal species monitoring, especially when such an emphasis leads to the reduction or exclusion of other types of monitoring. We also recommend that species-specific attributes factor more prominently in the development of monitoring to avoid monitoring action that is otherwise unnecessary.

**Key words:** *endangered species; Endangered Species Act; monitoring; recovery criteria; recovery plans; threatened species.*

### INTRODUCTION

The Endangered Species Act of 1973 (ESA) and its subsequent amendments are arguably the most important legislation passed by the U.S. Congress for the protection of imperiled species and their habitats. The ESA requires that a recovery plan be prepared and implemented for each species listed as threatened or endangered by either the U.S. Fish and Wildlife Service (USFWS) or the National Marine Fisheries Service (16 U.S.C. §1533(f)(1)). This is a critical provision of the ESA, because recovery planning is specifically intended to increase the population of each listed species, as opposed to other provisions (e.g., designation of critical habitat) that simply strive to prevent further decline of the species (Foin et al. 1998).

The recovery of threatened and endangered species often must be initiated with incomplete biological knowledge and in the face of multifaceted and often intractable ecological, political, economic, and social obstacles. Therefore, good recovery plans should make provision for monitoring to track the species throughout the recovery process. First and foremost, monitoring should be undertaken to assess the current status of the population. Many recovery plans do not contain population estimates, and those that do are often based on guesses rather than on census or survey data (Tear et al. 1995). Second, monitoring can provide critical biological data that are lacking for most species (Schemske et al. 1994). Third, given the limited information often available to agency personnel conducting recovery efforts for most species, it is difficult to predict with confidence the outcome of proposed management actions; monitoring the subsequent response of the species to management is therefore es-

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sential. Fourth, the ESA requires that recovery plans include "site-specific management actions as may be necessary to achieve the plan's goal [and] objective, measurable criteria which, when met, would result in a determination . . . that the species be removed from the list" (16 U.S.C. § 1533(f)(1)(B)(i) and (ii) (2001)). Without monitoring, these legal requirements for the recovery plan process cannot be met. Finally, and most importantly, threatened or endangered species should be carefully monitored because they are, by definition, in danger of extinction.

Given the importance of monitoring in the recovery process, we evaluated its role in recovery planning based on information derived from a detailed review of recovery plans for 181 federally listed threatened and endangered species. First, we described the types of monitoring proposed and the extent to which each was employed among the sample of plans. Next, we examined how well the proposed monitoring actions reflected species-specific characteristics such as threats facing a species, knowledge of a species biology, taxon, range size, and recovery priority. Finally, we investigated the types of criteria used to define recovery goals and their monitoring. We concluded with recommendations for improving monitoring in the recovery process.

#### METHODS

Our analyses rely on a large database derived from a questionnaire-based review of recovery plans for 181 species listed under the Endangered Species Act. The review was initiated by a project jointly funded by NCEAS (National Center for Ecological Analysis and Synthesis), the Society for Conservation Biology, and the USFWS. We discuss the details of the design and methodology of this review only where they are directly relevant to our own analyses. For a complete description of the review, database, and questionnaire see Hoekstra et al. (2002) and the project web site.<sup>8</sup>

Within the questionnaire, 24 questions addressed how the recovery plan provided for monitoring the species concerned, and 48 questions focused on criteria used in the plan to identify progress toward successful recovery. Within each question (a row in the questionnaire), different columns allowed for a multi-attribute answer. For example, for a question about monitoring the number of individuals of the species, reviewers identified how many explicit tasks in the plan were related to monitoring population size; the priority the plan attached to these tasks; the extent to which such monitoring had a clear and species-specific biological rationale; and the extent to which the proposed monitoring activities were completed. For each analysis described in this paper, the specific questions and col-

umns of questions from the questionnaire and database are referenced in parentheses (e.g., Q9 or col. EE).

We considered two aspects of monitoring within the recovery process. The first was whether any monitoring tasks were specified in the recovery plans as needing to be undertaken as part of the recovery efforts. The second was whether such tasks were then implemented. Consideration of implementation was important because the proposal of a task does not automatically lead to its implementation; tasks can only be implemented when financial resources, time, and personnel are made available to do so.

We distinguished between two classes of monitoring described in the questionnaire: monitoring of the biological and ecological factors relevant to the species' current decline, and monitoring of criteria used to measure successful recovery. The latter class of monitoring, although obviously related to the former, was addressed as a separate issue because it specifically tracks whether management actions are having the desired effect.

#### *Monitoring of biological and ecological factors*

Monitoring of biological and ecological factors was divided into three categories: monitoring of each plan's focal species, monitoring of associated species, and monitoring of habitat (addressed in the questionnaire by Q347–359, Q360–365, and Q366–370, respectively). Focal species monitoring was divided into four subcategories depending on whether it involved actions to determine presence/absence, to track population size and trend, to obtain demographic information, or to examine other miscellaneous information (Table 1). The associated species category included the monitoring of predators, competitors, prey, and exotic species. Finally, habitat monitoring included the monitoring of trends in habitat quality and quantity. For each category of monitoring and subcategory of focal species monitoring, we quantified the extent to which monitoring tasks were proposed (col. OO) and subsequently implemented (col. WW).

Factors threatening a species' persistence need to be carefully monitored because their continued influence may cause sudden declines in the species. We therefore examined the extent to which each plan proposed tasks to monitor threats to habitat and from exotic species, as well as the extent to which these tasks were then implemented (Q366–370 and Q364 for monitoring of habitat and exotic species, respectively). We considered habitat destruction, degradation, and fragmentation (Q294–296), and the presence of exotic species (Q299) as threats only if plan evaluators determined (subjectively) that they were among the three most important threats to the species.

When baseline information on species biology is absent, it is difficult to know what biological parameters are relevant to monitor. For such species, therefore, one

<sup>8</sup> URL: <http://www.nceas.ucsb.edu/recovery>

TABLE 1. Monitoring of biological and ecological factors relevant to species' current decline, categorized by the subject of the monitoring effort: focal species, associated species, and habitat.

Subject of monitoring	Factors relevant to species' decline
Focal species†	
Presence/absence monitoring	presence/absence
Population monitoring	number of individuals; trends in population size; number of populations; trends in number of populations; extinction/persistence of populations
Demographic monitoring	reproductive rates; mortality rates; age/stage structure; genetic parameters; movement patterns; health/physiological condition
Other monitoring	other focal species monitoring
Associated species	prey species; predator species; competitor species; parasites/pathogens; exotic species; other
Habitat	habitat quantity; trends in habitat quantity; habitat quality; trends in habitat quality; other

† Focal species monitoring was divided into subcategories based on the type of information about the focal species that was monitored.

would expect the monitoring proposed to focus on determining basic distribution or abundance. In contrast, when a species' biology is better understood, the clearer understanding of its demography, species interactions, habitat needs, etc., is more likely to enable recovery specialists to propose monitoring tasks directly focused on these attributes. By the same reasoning, well-studied species should be more likely to have such tasks implemented. To examine this issue, we compared the complexity of monitoring actions as proposed and implemented to the extent to which the biology of the species was understood (Q168). The extent of biological knowledge was ranked by plan evaluators into one of five categories (1, excellent; 2, well; 3, moderate; 4, poor; and 5, not at all).

Similarly, because some taxonomic groups are better studied than others, an association between taxon and type of monitoring proposed and implemented may also exist. To test for this association, we considered whether the monitoring of plants and animals differed and, separately, whether monitoring patterns differed among mammals, birds, fish, and invertebrates (Q66). The plant group included all members of the plant kingdom and one species of lichen. Because our sample of plans included only three reptile species and three amphibian species, we excluded these six species from comparisons among animal taxa.

The spatial scale at which species occur may influence the extent to which monitoring is conducted. Species with small ranges (e.g., a plant species consisting of only a few known individuals) may be thoroughly monitored, whereas species with large ranges may require considerably more monitoring effort to assess their status. To see if monitoring differed among species occupying different-sized areas, we related range size (Q71) to monitoring effort. Range size was classified into one of six categories (1, <1 km<sup>2</sup>; 2, <100 km<sup>2</sup>; 3, <10 000 km<sup>2</sup>; 4, <50 000 km<sup>2</sup>; 5, <1 000 000 km<sup>2</sup>; and 6, >1 000 000 km<sup>2</sup>).

The USFWS (1983) assigns each listed species a score to signify its priority for recovery. In brief, these

scores range from 1 (highest priority) to 18 (lowest priority) and reflect a combination (in decreasing order of importance) of (1) the degree of threat that the species faces (high, moderate, and low); (2) recovery potential (high and low); and (3) taxonomic distinctness (monotypic genus, species, and subspecies). Because these scores are based on attributes that may also be important determinants of monitoring, we related USFWS recovery priority scores (Q62) to monitoring.

#### *Monitoring of recovery criteria*

The factors that most critically imperil endangered species differ markedly from one species to another. Recovery plans, therefore, vary in their specifications of criteria for recovery. For a species threatened largely by habitat destruction, for example, achieving some minimum of completely protected habitat may be a sufficient criterion to ensure the persistence of the species. For a species threatened by an introduced species, control or elimination of the exotic would be the relevant criterion. In our study, we divided recovery criteria into five categories of metrics: population, demographic, habitat, securement, and other metrics (Table 2). The individual metrics within and across these five groups represent the range of measurements used in setting recovery goals for the species. In brief, population metrics (Q405–410) define the size and number of populations or subpopulations required for recovery. Demographic metrics (Q415 and 418) indicate the ability of the recovered population to be self-sustaining. Habitat metrics (Q411–413) index the quality and quantity of available habitat, and securement metrics (Q417 and 419) demonstrate that legal rights to the habitat have been acquired to ensure the long-term protection of the species. These different criteria require different types of monitoring and may also differ in the ease with which they can be monitored. Therefore, we examined the patterns of monitoring proposed (col. WWW) and implemented (col. ZZZ) for each type of recovery criterion specified (col. EEE and FFF) in the recovery plans.

TABLE 2. Criteria used to assess the extent to which monitoring efforts track progress toward recovery goals.

Metrics	Criteria
Population	total population size; number of subpopulations; number of individuals in each subpopulation; trends in total population size; trends in number of subpopulations; trends in number of individuals in each subpopulation
Demographic	age structure of population; productivity/net recruitment rates
Habitat	total range; quality of habitat; quantity of habitat
Securement	securement of water rights; securement of habitat
Other <sup>†</sup>	existence/significance of threats; implementation of post-delisting management programs; other metrics

Note: Criteria were grouped into five metrics based on the similarity of the recovery goals that they measure.

<sup>†</sup> The "other" category was used for those criteria not contained in the former categories.

### Statistical analyses

We collapsed the variables for task proposal and implementation to a dichotomy, indicating either that at least one relevant monitoring task was proposed in the recovery plan or that no relevant monitoring was proposed. We dichotomized the implementation of monitoring tasks in a similar manner (i.e., underway/completed or not started). We considered a monitoring category to have a task or to have a task that was implemented if at least one of the constituent monitoring actions did (see Tables 1 and 2). With this approach, monitoring categories that had only one action associated with a task or only one task implemented were given the same weight in the analyses as those categories that had many actions with tasks or many tasks implemented. This approach was conservative, in that we were more likely to show that monitoring was done to a greater extent than was actually the case.

Given this treatment of the data, all analyses involved categorical data and consisted primarily of chi-square tests of independence and Fisher's exact tests where samples were small. When binary variables were cross-tabulated (e.g., task proposal with task implementation), we computed phi ( $\phi$ ) coefficients as a measure of association between the two variables (Zar 1996). The coefficient ranges from  $\phi = +1$ , when there is complete agreement between the presence of the two variables (e.g., all tasks proposed were also implemented and where tasks were not proposed there was no implementation), to  $\phi = -1$  for the converse. The metrics for knowledge of a species' biology, range size, and recovery priority were ordinal variables and were tested for linear associations using the Cochran-Armitage trend test (SAS 1989, Agresti 1996).

Species in multi-species plans or in ecosystem plans probably share the same within-plan biases and elicit similar proposals for monitoring because they are often afflicted by similar threats. In our sample of 181 species, 59 species were addressed in 14 plans. To check for biases that may result from treating all 181 species as if they were independent, we reanalyzed the data using only the 122 plans from which only one species was sampled. Only in rare instances did this restricted set yield different conclusions from the full analyses.

Although we conducted numerous tests, we did not control for experiment-wise error rates (e.g., Bonferroni-adjusted  $P$  values), because we were not making inferences to the population of all recovery plans, but were only interested in identifying any differences among the 181 species. Our  $P$  values for the rejection of null hypotheses were therefore kept at 0.05 for all tests. Consequently, our conclusions indicate only that any biases identified exist in the plans for the 181 species in the sample. Given that these species are a substantial percentage (19%) of threatened and endangered species with recovery plans, any differences identified need to be considered in the recovery planning process, even if the remaining plans are without these biases.

## RESULTS

### Monitoring of biological and ecological factors

In the sample of 181 species, 98.3% proposed at least one task devoted to monitoring focal species, 64.6% had tasks that addressed monitoring of habitat, and 49.7% had tasks related to monitoring associated species (Table 3A). Some 33.7% of the species had tasks proposed in all three categories, 29.8% of the species proposed only focal species and habitat monitoring, 16% specified only focal and associated species, and 18.8% involved only focal species monitoring.

When focal species monitoring was proposed ( $n = 178$  species), provision was typically made to monitor population trend (Table 3B). Monitoring of population levels was proposed for 91% of the species, monitoring of demographic information for 66.9%, and tracking of presence/absence for 56.7%. Monitoring tasks were proposed in all three of these subcategories for 37.1% of the species, in population and demographic subcategories for 25.8%, in population and presence/absence subcategories for 16.3%, and in only the population subcategory for 11.8%. Notably, presence/absence alone was monitored in only 2.8% of the species, indicating that most focal species monitoring went beyond merely recording presence/absence data.

These percentages relate to the proposal of monitoring activities without regard to whether or not they were ever implemented. The percentages of species that had at least one of the proposed tasks implemented for

TABLE 3. (A) Proportions of species that had at least one task proposed within each category of monitoring, the proportions of these species for which at least one task was implemented, and the association between task proposal and implementation, as measured by the phi ( $\phi$ ) coefficient. (B) As for (A), but for subcategories of focal-species monitoring.

Task type	Proportion of species with task implementation			Association	
	Proposal present	Proposal present	Proposal absent	$\phi$	$P$
A) All monitoring categories ( $n = 181$ species)					
Focal species	0.983	0.815	0.000	†	†
Habitat	0.646	0.761	0.031	0.697	<0.001
Associated spp.	0.497	0.656	0.000	0.699	<0.001
B) Focal species monitoring ( $n = 178$ species)					
Population	0.910	0.796	0.000	0.510	<0.001
Demographic	0.669	0.773	0.000	0.728	<0.001
Presence/absence	0.567	0.733	0.000	0.737	<0.001
Other	0.180	0.531	0.000	0.694	<0.001

† The phi coefficient was not reported because there were only three species without tasks in this category.

focal species, habitat, and associated species monitoring were 81.5%, 76.1%, and 65.6%, respectively (Table 3A). In a very few cases (two of 64 species), habitat monitoring activities were underway even though they were not formally proposed in the recovery plan as a task (Table 3A); there was otherwise considerable consistency between the proposal and implementation of monitoring tasks ( $\phi = 0.697$  for habitat,  $\phi = 0.699$  for associated species). Similarly, proposed tasks were typically implemented (>73%) across subcategories of focal species monitoring: population level, demographic, and presence/absence (Table 3B).

#### Monitoring and species' characteristics

The types of threats affecting the species did not have a strong influence on monitoring proposals and implementation in recovery plans. Although most species (92.3%) faced habitat destruction, degradation, or frag-

mentation as a principal threat, habitat monitoring was proposed for only 65.9% of the species thus affected and was implemented for only 52.1%; the  $\phi$  coefficients were correspondingly low (Table 4). Similarly, only 48.2% of the species threatened by exotics had tasks proposed to address these threats, and for only 26.5% of the species were exotics actually monitored (Table 4).

For all 181 species, proposals for, and implementation of, monitoring tasks were independent of the extent to which a species' biology was known. However, consideration of only the 119 plans for which a single species was sampled suggested that demographic information was slightly more likely to be monitored when the biology of the species was better understood (for task proposal, Pearson correlation = 0.192,  $P = 0.037$ ; for task implementation, Pearson correlation = 0.201,  $P = 0.029$ ).

The taxon of the species appeared to have some effect on the proposal of monitoring tasks. There were few differences between plants and animals (Fig. 1). However, the extent to which monitoring of associated species was proposed varied among the animal taxa ( $\chi^2_3 = 9.525$ ,  $P = 0.023$ ,  $n = 90$ ). Considerably more mammal species (66.7%) had such tasks proposed than did invertebrate species (19.1%; Fig. 1). Additionally, monitoring of demographic information was proposed most frequently for birds (87.5%) and least frequently for invertebrates (38.1%), with other taxa intermediate (mammals 72.2% and fish 66.7%) ( $\chi^2_3 = 12.652$ ,  $P = 0.005$ ,  $n = 87$ ).

Monitoring efforts were largely unrelated to range size. Across all categories and subcategories of monitoring, the proposal of monitoring tasks and their subsequent implementation showed no pattern with regard to the range size of the species being monitored ( $n = 148$ ; 33 lacked information on range size).

TABLE 4. Proportion of 181 species for which (A) at least one task was proposed to monitor either habitat modification or exotic species, and (B) at least one task was implemented to monitor either of these two threat types.

Threat type	Proportion of species		Association	
	Threat present	Threat absent	$\phi$	$P$
A) Monitoring task proposed				
Habitat modification	0.659	0.500	0.089	0.233
Exotic species	0.482	0.102	0.423	<0.001
B) Monitoring task implemented				
Habitat modification	0.521	0.286	0.126	0.091
Exotic species	0.265	0.061	0.281	<0.001

Notes: The association between presence of the threat and task proposal and implementation is measured by the phi ( $\phi$ ) coefficient. Recovery plans identified the principal threat as (1) habitat modification (i.e., destruction, degradation, and fragmentation) for 167/181 species (proportion = 0.923) and (2) exotic species for 83/181 species (proportion = 0.459).

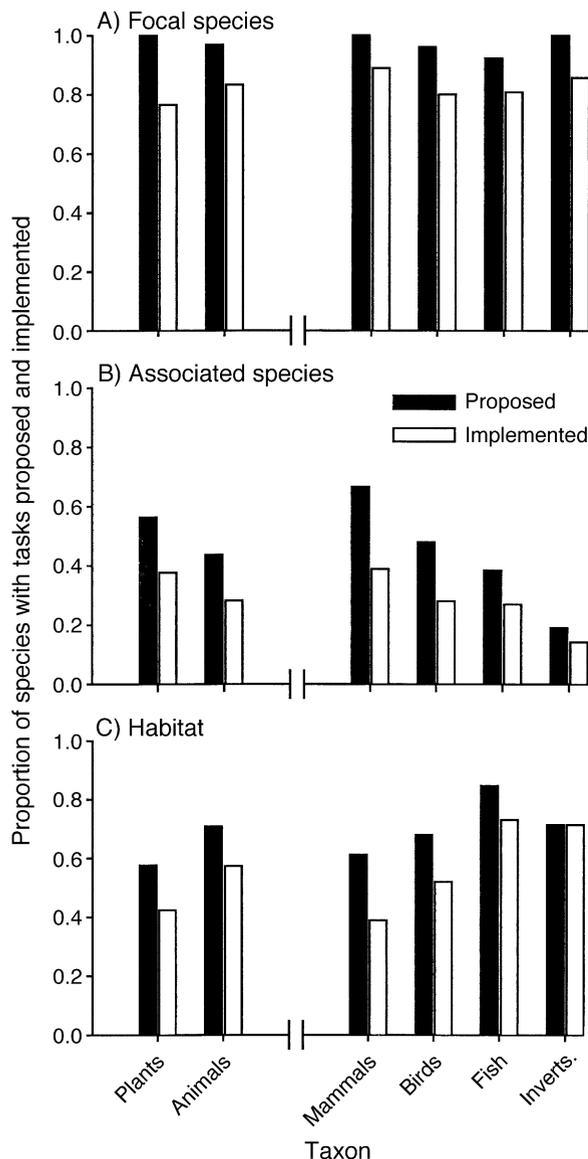


FIG. 1. Proportions of species in each taxon that have proposed (solid bars) and implemented (open bars) tasks for the monitoring of (A) focal species, (B) associated species, and (C) habitat specified in their recovery plans. In the taxonomic comparisons, there are 85 plant species and 96 animal species. Within the animal taxon, there are 25 mammal, 26 bird, 21 fish, and 18 invertebrate species.

Likewise, USFWS priority scores had negligible influence on monitoring. Proposals for, and implementation of, monitoring tasks for all categories of monitoring and subcategories of focal species monitoring were independent of recovery priority ( $n = 166$ ; 15 species lacked priority scores).

#### *Monitoring of recovery criteria*

Recovery criteria were most frequently specified with respect to population (82.3% of the species) and

much less so with respect to recovery of habitat (45.3%), legal protection (securement) of habitat (35.9%), and demographic viability (24.9%; see Table 5A). Plans that specified such criteria also typically ( $\phi \geq 0.604$ ,  $P < 0.001$  in all categories) proposed specific monitoring of progress toward these criteria (Table 5A), more so for population, habitat, and demographic criteria (91.3%, 81.7%, and 80.0% of the species, respectively) than for securement criteria (67.7%). Even where recovery criteria were not stated explicitly, plans often contained proposals for monitoring that were relevant to recovery criteria. For example, nine of the species (28%) proposing tasks to monitor population level and 14 of the species (14%) proposing tasks to monitor habitat did so when criteria were not specified (Table 5A). Where recovery criteria were specified, proposed monitoring tasks were uniformly (60–75%) likely to be implemented (Table 5B).

#### DISCUSSION

A major issue in the recovery of threatened and endangered species is how to divide limited resources among the tasks necessary for species recovery. Our results indicate that monitoring is less thoroughly considered in the recovery process than is appropriate, possibly because it does not directly benefit the species in terms of increased abundance in the way that other recovery efforts such as threat mitigation or captive breeding do. However, recovery efforts that incorporate monitoring can lead to more efficient recovery of a species, both in terms of time and money, because recovery actions that are closely monitored can be modified to ensure the desired results. In essence, a well-planned and implemented monitoring program provides the basis for effective adoption of adaptive management of rapidly changing populations of threatened and endangered species and their habitats.

Cook and Dixon (1987), Dixon and Cook (1989) suggest that recovery plans are written as if following a standardized template and are not species-specific. Several of our results suggest that their assertion may be particularly true of the monitoring component of plans. First, neither habitat nor exotic species were well monitored, despite the prevalence of threats to habitat and of threats from exotics among endangered species (Ehrlich and Ehrlich 1981, Ehrlich and Wilson 1991, Noss and Cooperrider 1994, Wilcove et al. 1998, Czech et al. 2000, Lawler et al. 2002). Threats to species should guide the development and implementation of monitoring actions. For species facing threats to habitat and from exotic species, it may be as important to monitor habitat and exotic species as it is to monitor the focal species. In this context, a bias toward monitoring of focal species is particularly undesirable, because problems with exotics and habitat loss that have immediate and dire consequences are deprived of attention and resources.

TABLE 5. Proportions of species ( $n = 181$ ) for which (A) at least one task was proposed to monitor the attainment of each type of recovery criterion when that criterion was either present or absent; and (B) monitoring tasks were implemented when tasks were or were not proposed.

Type of criterion or task	Criterion or task presence	Proportion of species with monitoring tasks proposed		Proportion of species with task implementation		Association	
		With criterion	No criterion	With proposal	No proposal	$\phi$	$P$
A) Recovery criterion							
Population	0.823	0.913	0.281			0.604	<0.001
Habitat	0.453	0.817	0.141			0.676	<0.001
Demographic	0.249	0.800	0.052			0.760	<0.001
Securement	0.359	0.677	0.078			0.632	<0.001
Other	0.414	0.720	0.170			0.554	<0.001
B) Task proposal							
Population	0.801			0.738	0.056	0.557	<0.001
Habitat	0.448			0.741	0.050	0.716	<0.001
Demographic	0.238			0.605	0.007	0.714	<0.001
Securement	0.293			0.755	0.047	0.740	<0.001
Other	0.398			0.583	0.037	0.615	<0.001

*Notes:* Part (A) indicates the proportions of species that had each type of recovery criterion specified in their recovery plans, the proportions of these species for which at least one task was proposed to monitor the attainment of the criterion, and the association of criterion presence with task proposal. Part (B) indicates the proportions of species for which at least one task was proposed to monitor attainment of a recovery criterion, the proportions of these species for which the tasks were implemented, and the association of task implementation with task proposal for each type of criterion. Associations are given by phi ( $\phi$ ) coefficients.

Second, the level of knowledge about each species' biology should inform the design of monitoring efforts. For well-understood species, biological information should clarify which types of monitoring are most relevant to ensuring recovery. For more poorly understood species, "template" monitoring efforts stand a high chance of being wasted if directed to aspects of the species that are not particularly important to why they are threatened or endangered. Such an approach for less understood species is therefore undesirable, despite its widespread occurrence in the plans reviewed in this study.

Third, taxonomic differences in monitoring efforts were consistent with other systematic biases in the treatment of taxa in the recovery process. Specifically, there is a persistent bias toward animals in the recovery process (i.e., from candidacy for listing to recovery plan revision), and some bias is also apparent toward vertebrates, particularly mammals and birds (Tear et al. 1995). Thus, the higher levels of monitoring that we observed for these taxa are more likely to result from this process-wide disparity than from anything peculiar to monitoring.

Finally, recovery priority of the species had little influence on the allocation of monitoring efforts. This lack of relationship was somewhat surprising because species facing a higher degree of threat and a higher likelihood of extinction should be more intensely monitored. At critically low levels, a population needs to be carefully tracked to indicate when intrusive man-

agement actions such as captive breeding or translocation become necessary to avert extinction. This may reflect the template approach described by Cook and Dixon (1987), but one possibility that we cannot reject and that also has implications for recovery planning is that priority scores do not, in fact, reflect the ordinal index of risk presumed of them.

Our analysis regarding the monitoring of criteria used to define recovery goals showed that criteria for habitat goals were defined for less than one-half of the sampled species. This lack of attention to habitat criteria seems shortsighted, given that the principal threats to most species are habitat-related and that adequate quality habitat is needed for long-term recovery of the species. Similarly, criteria for population recovery goals were lacking in almost 20% of the species examined, which calls into question how recovery is being monitored in these species, if it is at all.

Unless monitoring addresses the specific situation of the species, resources allotted to monitoring tasks are likely to be wasted. This point is especially important considering the recent increase in multi-species and ecosystem plans, an increase largely in response to criticisms that the species-by-species approach is inefficient (Hutto et al. 1987, Gibbons 1992, Clark and Harvey 2002). Species are grouped in these plans on the grounds that multiple species occurring in the same geographical areas can be managed simultaneously, leading to more effective recovery efforts. This assumption needs to be tested, because the application

of a generic monitoring program to multiple species may be inadequate for one or more of the species.

Although it is clear that no single monitoring program is going to work for all species, we can make some general recommendations about improving the design and rigor of monitoring efforts in recovery plans. A good monitoring program will gather current, accurate, and relevant information on the species of interest, which can then be used to assess the effectiveness of current recovery efforts, and direct and modify future efforts. To attain such a program, monitoring efforts must be tailored to the individual situation of each species. The ability to do this is probably influenced heavily by the extent of the knowledge of the species' biology. When a species' biology is fairly well known, it should be relatively easy to devise a narrowly designed monitoring program that provides only those data explicitly specified for tracking the parameter(s) most relevant to the species recovery. For poorly understood species, however, recovery plans should emphasize acquisition of basic knowledge as an early priority, with planning for more complex monitoring postponed until such acquisition. No matter how well a species' biology is understood, population monitoring should be present in plans for every species, because it is almost always pertinent to know the current status of the species population. However, an overemphasis on focal species monitoring at the cost of reduction or exclusion of other types of monitoring should be avoided. In particular, monitoring of the factors known to threaten each species should not be overlooked. Finally, criteria defining recovery goals must be clearly established in recovery plans, because it is these criteria that guide the monitoring of progress toward the recovery and eventual delisting of species.

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<sup>9</sup> URL: <http://www.nceas.ucsb.edu/recovery/acknowledgments>

#### LITERATURE CITED

- Agresti, A. 1996. An introduction to categorical data analysis. John Wiley, New York, New York, USA.
- Clark, J. A., and E. Harvey. 2002. Assessing multi-species recovery plans under the Endangered Species Act. *Ecological Applications* **12**:655–662.
- Cook, R. E., and P. M. Dixon. 1987. A review of recovery plans for threatened and endangered plants. Report to the World Wildlife Fund, Cornell Plantations, Ithaca, New York, USA.
- Czech, B., P. R. Krausman, and P. K. Devers. 2000. Economic associations among causes of species endangerment in the United States. *BioScience* **50**:593–601.
- Dixon, P. M., and R. E. Cook. 1989. Science, planning, and the recovery of endangered plants. *Endangered Species UPDATE* **6**:9–14.
- Ehrlich, P. R., and A. H. Ehrlich. 1981. Extinction: the causes and consequences of the disappearance of species. Random House, New York, New York, USA.
- Ehrlich, P. R., and E. O. Wilson. 1991. Biodiversity studies: science and policy. *Science* **253**:758–762.
- Foin, T. C., S. P. D. Riley, A. L. Pawley, D. R. Ayres, T. M. Carlsson, P. J. Hodum, and P. V. Switzer. 1998. Improving recovery planning for threatened and endangered species. *BioScience* **48**:177–184.
- Gibbons, A. 1992. Mission impossible: saving all endangered species. *Science* **256**:1386.
- Hoekstra, J. M., J. A. Clark, W. F. Fagan, and P. D. Boersma. 2002. A comprehensive review of Endangered Species Act recovery plans. *Ecological Applications* **12**:630–640.
- Hutto, R. L., S. Reel, and P. V. Landres. 1998. A critical evaluation of the species approach to biological conservation. *Endangered Species UPDATE* **4**:1–4.
- Lawler, J. J., S. P. Campbell, A. D. Guerry, M. B. Kolozsvary, R. J. O'Connor, and L. C. N. Seward. 2002. The scope and treatment of threats in endangered species recovery plans. *Ecological Applications* **12**:663–667.
- Noss, R. E., and A. Y. Cooperrider. 1994. Saving nature's legacy. Island Press, Washington, D.C., USA.
- SAS Institute. 1989. SAS/STAT user's guide. Volume 1, version 6, fourth edition. SAS Institute, Cary, North Carolina, USA.
- Schmidske, D. W., B. C. Hubbard, M. H. Ruckelshaus, C. Goodwillie, I. M. Parker, and J. G. Bishop. 1994. Evaluating approaches to the conservation of rare and endangered plants. *Ecology* **75**:584–606.
- Tear, T. H., J. M. Scott, P. H. Hayward, and B. Griffith. 1995. Recovery plans and the Endangered Species Act: are criticisms supported by data? *Conservation Biology* **9**:182–195.
- USFWS (U.S. Fish and Wildlife Service). 1983. Federal Register. Volume 48. Number 221, Page 51985, 15 November 1983.
- Wilcove, D. S., D. Rothstein, J. Dubow, A. Phillips, and E. Losos. 1998. Quantifying threats to imperiled species in the United States. *BioScience* **48**:607–615.
- Zar, J. H. 1996. Biostatistical analyses Third edition. Prentice-Hall, Englewood Cliffs, New Jersey, USA.