Allocating Conservation Resources under the Endangered Species Act

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Abstract

The necessity to develop a priority system to guide the allocation of resources to the conservation of endangered species is widely recognized. The economic theory of biodiversity has established a framework to do so, and has identified priority criteria that should be considered when making conservation decisions. This paper uses a random-effects ordered probit model of endangered species recovery to simulate the effects of reallocating conservation funds among species listed under the Endangered Species Act according to these criteria. Our results suggest that if the goal of conservation policy is to preserve a diverse set of species, reallocating conservation funds according to criteria identified by economic theory would yield an improvement over actual spending patterns without significant tradeoffs in terms of overall species recovery.

Keywords: Endangered Species Act, endangered species, recovery plans, U.S. Fish and Wildlife Service, biodiversity, critical habitat.

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1. INTRODUCTION

A recent issue of the prestigious journal, *Science*, lists the 125 most pressing scientific knowledge gaps under the title "What we don't know" (Kennedy and Norman 2005).[1] On this list was the following: "Can we prevent extinction?" The suggested goal is to "[Find] cost effective and politically feasible ways to save many endangered species…" (Anonymous 2005). To accomplish this goal, we must probe the determinants of successful extinction prevention efforts and the consequences of alternative methods of allocating scarce resources to species' recovery. This paper does both.

From 1989 to 2003, U.S. state and federal agencies spent at least $9.5 billion in real terms[2] to promote the recovery of threatened and endangered (T&E) species in compliance with the Endangered Species Act (ESA)[3] (U.S. FWS 2003). Nevertheless, the number of successful recoveries of T&E species under the ESA remains small (Rohlf 1991, U.S. FWS 1996a, Dobson et al. 1997, Foin et al. 1998, Beissinger and Perrine 2001, Abbitt and Scott 2001, Stokstad 2005). Furthermore, the number of listed T&E species grows faster than the available funds and hence, many observers claim, the U.S. Fish and Wildlife Service's (FWS) enforcement and implementation of the ESA is perennially under-funded (Bean 1991, Smith et al. 1993, Mann and Plummer 1995, Brown and Shogren 1998, Stokstad 2005). Therefore, it is important to develop priorities

[1] The 125 questions were chosen based on the following ground rules: "Scientists should have a good shot at answering the questions over the next 25 years, or they should at least know how to go about answering them." (Kennedy and Norman 2005).
[2] Expenditures are adjusted using the Consumer Price Index.
[3] This amount understates total spending by states and the federal government because, up to 2001, it only includes funds that can be allocated to specific endangered species listed under the ESA. Furthermore, for the most part it only accounts for explicit expenditures, and does not include opportunity costs generated by the law through, for instance, land use restrictions.

to guide scarce resource allocations among T&E species (Pimm et al. 1994, Metrick and Weitzman 1998, Hughey et al. 2002).

Many priority criteria have been proposed, including endemism centers, biodiversity hotspots, and flagship species[4]. Carroll et al. (1996) and Restani and Marzluff (2001) argue that the risk of extinction in the absence of intervention should drive spending decisions. FWS assigns listed T&E species priority ranks based on degree of threat, recovery potential, genetic distinctiveness, and conflict with construction, development, or other economic activity (Simon et al. 1995). Several economists have formulated this problem as one of maximizing expected biodiversity or minimizing biodiversity loss subject to a budget constraint (e.g. Solow et al. 1993, Weitzman 1993, 1998, Metrick and Weitzman 1998, Polasky and Solow 1999). Weitzman (1998) derives a ranking criterion based on distinctiveness, utility, survivability, and cost of recovery of T&E species.

Empirical analyses of actual FWS decisions find only weak correspondence between T&E spending and either the criteria derived from FWS' priority rankings or economic theory. Simon et al. (1995) find that, although some of the individual components making up the FWS ranking are correlated with funding decisions, the actual ranking is not. Restani and Marzluff (2001) find that FWS' spending on birds is correlated with FWS priority rank, but rank explains less than five percent of the variation in spending. Metrick and Weitzman (1996, 1998) find that visceral characteristics such as size and taxonomic class have larger influences on FWS spending decisions than more science-based characteristics, such as uniqueness. The authors conclude that, of the four factors identified by an economics-based priority ranking, only

[4] See Hughey et al. (2002) for a review of this literature.

utility (proxied by preferences for charismatic megafauna) plays a role in funding decisions, whereas survivability, diversity, and costs do not, and conflict with economic activity seems to play a larger role than its relative importance in priority rankings warrants. Finally, Dawson and Shogren (2001) update Metrick and Weitzman's analysis using panel data and controlling for species-specific characteristics. They find that time-variant factors such as endangerment and conflict with development have no effect on FWS spending, whereas time-invariant factors such as size, taxonomic category, charisma, or the underlying ecosystem explain species-specific spending patterns. In summary, the existing literature suggests that actual spending patterns are only weakly consistent with FWS's rankings and generally inconsistent with theory-based criteria. However, the implications of these inconsistencies for the outcome of conservation policy, namely the recovery of T&E species and the prevention of extinctions have not yet been examined. In this paper, we address two questions. First: is it possible to improve biodiversity conservation outcomes by allocating resources according to the priority criteria suggested by economic theory? Second: given that the goal of the FWS is not explicitly to conserve the most diverse set of species possible[5], but rather to achieve recovery of endangered species in general, does imposing allocations based on the diversity-preserving priorities suggested by economic theory result in poorer recovery outcomes for species in general?

To address these questions, we start by estimating an econometric model of endangered species recovery, with spending as the focus explanatory variable. Then, we use the resulting estimates to simulate the effect of reallocating funds according to the

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[5] The relative distinctiveness of a species (whether it belongs to a monotypic genus, is a full species, or a subspecies) is taken into account in the FWS's priority system, but this is the least important component of the ranking.

various criteria identified by economic theory. We compare the estimated recovery outcomes with baseline outcomes corresponding to actual spending patterns. We also compare the estimated outcomes with simulated outcomes resulting from reallocating funds according to the FWS priority system. Our results suggest that, if the goal of conservation policy is to preserve a diverse set of species, reallocating funds according to economics-based criteria yields an improvement over actual spending patterns, as well as over the FWS priority ranking. Furthermore, such reallocations do not imply significant tradeoffs in terms of overall species recovery.

2. BACKGROUND: SETTING PRIORITIES FOR PRESERVING DIVERSITY

The basic question underlying the economic approach to preserving biodiversity suggested by Weitzman (1998) (see also Metrick and Weitzman 1998) is "how to determine basic priorities for maintaining or increasing diversity." Weitzman develops a cost-effectiveness framework to rank priorities among biodiversity-preserving projects and guide the allocation of scarce resources to T&E species protection.

From this framework, Weitzman derives two important results that will guide our empirical analysis. First, he suggests an "extreme policy" in which all available resources are allocated to maximize protection for a selected subset of species, leaving all remaining species with minimal protection. The underlying intuition is that this strategy allows the decision-maker to "pin down" valuable characteristics (e.g. medically useful genetic information) common to the selected subset of species and the remaining species[6]. The practical policy implication is that a conserving agency should concentrate

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[6] More specifically, an extreme policy allows the decision-maker to preserve characteristics that are unique to the selected subset of species, plus the characteristics they share with the remaining species, and only

limited resources instead of spreading them out thinly. Second, he derives a simple priority ranking for the allocation of scarce conservation resources based on four criteria for each species i: how unique or distinct the species is (D_i), the direct utility derived from protecting it (U_i), by how much the probability of survival of the species can be improved (Δp_i), and the cost of improving its survivability (C_i). The ranking can then be written as $R_i = (D_i + U_i)(\Delta p_i/C_i)$. Weitzman recognizes that, given the practical difficulties inherent in quantifying these variables and combining them into R_i, this ranking is not meant to be directly implemented in actual conservation decisions. Rather, it is intended to provide a framework to think about biodiversity preservation and to highlight criteria that should be considered when making conservation decisions in the name of preserving diversity. We use these criteria as a basis to reallocate conservation expenditures. Before doing so, we describe the econometric model of species recovery underlying our analysis.

3. AN ECONOMETRIC MODEL OF SPECIES RECOVERY

3.1 *Econometric Model and Data*

A species' recovery status depends on a combination of factors, including resources allocated to the species, the management of the species by the FWS, and characteristics of the species. A recovery model can be specified in general terms as $S_{it} = f(r_{it}, \boldsymbol{m}_{it}, \boldsymbol{c}_{it})$, where S_{it} is the recovery status of species i in period t, r_{it} measures conservation resources allocated to the species, $\boldsymbol{m}_{it}$ is a vector of management variables, and $\boldsymbol{c}_{it}$ is a vector of species characteristics. To move from this general framework to a

risk the characteristics specific to the remaining species from being lost. On the other hand, if the resources are spread thinly to attempt to protect both subsets of species, there is a higher likelihood that the unique characteristics of both subsets, plus their shared characteristics, will be lost.

statistical model that can be estimated with available data, we define specific measures for the relevant variables. We have constructed an unbalanced panel data set of these variables for 275 vertebrates on the ESA's endangered species list for the years t = 1990, 1992, 1994, 1996, 1998, 2000, 2002.[7]

To measure recovery status we rely on population status reported by the FWS, which reflects species numbers and the threats they face and is determined by field and regional staff based on the best available information from recovery planning and implementation efforts, consultation with other Federal and State agencies, and the FWS' permitting program (FWS 2002a). The FWS status has been used in the ecological and economics literature for similar purposes (Rachlinski 1997, Beissinger and Perrine 2001, Abbitt and Scott 2001, Hatch et al 2002, Miller et al. 2002, Taylor et al. 2005). Although not ideal, it is the only broad-based measure of recovery status available over a time frame long enough to meaningfully discuss species recovery[8]. The FWS classifies each listed species into one of seven categories: Extinct (E), Declining (D), Stable (S), Improving (I), Recovered (R), found only in captivity (C), and Uncertain (U) (U.S. FWS 1990a-2002a). Based on this classification, we construct a measure of recovery status as a discrete, ordered variable: $STATUS_{it} = 0$ if species i's status at time t is E, $STATUS_{it} = 1$ if status is D, $STATUS_{it} = 2$ if S, or $STATUS_{it} = 3$ if status is I or R. We exclude status C because only two species are in this class, so the model cannot be estimated if it is included as a separate category. Similarly, we set $STATUS_{it} = 3$ for species in both the I

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[7] We limit ourselves to vertebrates because of data availability.

[8] Two other well-known measures are the classification from the Red List compiled by the International Union for the Conservation of Nature (IUCN) and the status scores provided by Natureserve. We are not able to use these for our purposes because the Red List classification methodology changed in the year 2000 and the scores are not consistent over time, and past Natureserve scores are not made available for trend analysis. Furthermore, Hatch et al. (2002) argue that measures such as these may be biased depending on the reporting agency.

and R categories because only nine species have R status. Finally, we leave out the uncertain (U) status because it cannot be ordered among the other categories meaningfully[9].

The focus independent variable in the model is r_{it}, the resources spent to prevent extinction and promote recovery. We measure r_{it} as spending by federal and state governmental agencies on T&E species recovery, as reported by the FWS (U.S. FWS 1989-2002b). Agencies are required to report all "reasonably identifiable expenditures" that can be traced back to specific species[10]. This includes species-specific funding for items such as refuges, land acquisition, law enforcement, research, surveys, listing, recovery, and consultation. Opportunity costs such as the value of unsold power, timber, or water are generally not included[11]. Thus, these reported expenditures understate the true amount of resources allocated to endangered species recovery. Nevertheless, Metrick and Weitzman (1998) argue these expenditures provide "the most direct and least noisy measure of preservation attention." Expenditures are reported on a yearly basis, but our data on recovery status is available only biennially, so we construct $SPENDING_{it}$ by

[9] This raises the possibility of sample-selection bias if factors that determine whether the status of a species is uncertain are correlated with factors that determine recovery scores. We tested for this possibility by defining a dichotomous recovery score variable (*STATUS II* = 1 if *STATUS* > 2 and *STATUS II* = 0 otherwise) and estimating a bivariate probit selection model, where selection is based on the Uncertain status. There is no evidence of sample selection, and the results of the recovery model carry through.

[10] Starting in 2001, FWS also started reporting expenditures related to endangered species conservation that cannot be traced back to particular species. Since the unit of observation in our model is an individual species, we do not use this data.

[11] The exceptions are revenues lost by the Boneville Power Administration in its efforts to conserve salmon and steelhead, which are reported starting in 2001. This may partially explain why reported spending on these species is much higher than spending on all other species, making the corresponding observations outliers and thus prompting us to exclude these species from our analysis. Furthermore, these species are managed by the National Marine and Fisheries Service, rather than the FWS, so many of the variables we use in our analysis are not reported. Nevertheless, the main qualitative result of the recovery model regarding the effect of spending on recovery status holds even when a partial version of the model is estimated to include salmon and steelhead.

adding the expenditures for the two-year period ending in year *t* (e.g. $SPENDING_{i1990}$ includes spending for 1989 and 1990) and adjusting by the Consumer Price Index.

The recovery status of an endangered species also depends on management actions taken by the FWS to promote its recovery, including designation of critical habitat, preparation of a recovery plan, and achievement of recovery objectives. To account for the effect of critical habitat designation, we include $TIME\ HABITAT_{it}$, the length of time that species *i* has had critical habitat designated at time *t*.[12] To account for the effect of a recovery plan, we include two dummy variables: $SOME\ PLAN_{it} = 1$ if some level of recovery plan preparation has taken place by time *t*, but the plan is not yet complete (e.g. a draft or revision), $SOME\ PLAN_{it} = 0$ otherwise; and $FINAL\ PLAN_{it} = 1$ if a final plan has been approved by time *t*, $FINAL\ PLAN_{it} = 0$ otherwise (the benchmark is no plan preparation whatsoever by time *t*).

Finally, to account for recovery actions taken on behalf of species *i* we include the percentage of recovery objectives achieved for species *i* by period *t*. Recovery objectives comprise specific goals for each species. For example, one of the objectives for the Atlantic coast piping plover is to "increase breeding pair numbers and productivity across the Atlantic coast". Progress in attaining these objectives is measured on the basis of specific criteria, such as "a five-year average productivity of 1.5 fledged chicks per pair", and specific recovery actions, such as fencing nest sites, support these objectives (FWS 2002a). Thus, although recovery objective achievement is not a direct measure of the specific recovery actions completed, we consider that it provides a good proxy. We include the percentage of recovery objectives achieved by defining three dummy

[12] We also estimated the model using a dummy variable which was set equal to one if species *i* had critical habitat designated at time *t*, and to zero otherwise. This does not affect the results of the recovery model.

variables[13]: $RECOVERY2_{it}$ = 1 if 25%-50% of recovery objectives for species *i* are achieved by time *t* and $RECOVERY2_{it}$ = 0 otherwise, $RECOVERY3_{it}$ = 1 if 50%-75% of recovery objectives are achieved, and $RECOVERY4_{it}$ = 1 if 75%-100% of objectives are achieved (the benchmark is 0%-25% of objectives achieved). These variables are reported every two years by the FWS (U.S. FWS 1990a-2002a).

We control for a number of species' biological characteristics that may affect recovery status. We include dummy variables to account for taxonomic differences: $MAMMAL_i$, $BIRD_i$, $REPTILE_i$, and $AMPHIBIAN_i$ are set equal to one if species *i* corresponds to that taxonomic group (fish is the benchmark group). We control for the distinctiveness of the species by including the variable $DISTINCT_i$ = 1 if the species is monotypic (the only species in its genus) or belongs to a small genus (2 – 5 species), and $DISTINCT_i$ = 0 otherwise. Additionally, the conservation biology literature suggests that species recovery (or decline) probably depends on population size, longevity, reproductive rate, and the variability of the growth rate and the population density (Goodman 1987, Pimm et al. 1988). Data on most of these variables is not available for most U.S. vertebrates, but longevity and growth rate are highly correlated with body size, which is readily available (Cash et al. 1998). Hence, we include the variable $BODY\ LENGTH_i$ as well as its square to allow for the possibility of a non-linear relationship (Johst and Brandl 1997).

Finally, we control for two additional factors that may affect a species' recovery status. Species that are in conflict with economic activity may be less likely to recover, so we include the dummy variable $CONFLICT_{it}$ = 1 if species *i* is considered by the FWS to be in conflict at time *t*. To control for location-related features that could affect recovery,

[13] This is how the information is reported by the FWS. A continuous measure is not available.

such as regional administrative differences or geographic factors, we include dummies for the FWS's administrative regions (*REGION1*$_i$ – *REGION6*$_i$, with region 7 as the benchmark). These variables are reported every two years by the FWS (U.S. FWS 1990a-2002a). Biennial means for all the variables appear in Table 1.

Given that our dependent variable, $STATUS_{it}$, is a discrete, ordered variable, the correct method of estimation is an ordered probit. Let S_{it}^* be the true measure of recovery status: $S_{it}^* = \boldsymbol{\beta}'\boldsymbol{x}_{it} + \alpha_i + \varepsilon_{it}$, where $\boldsymbol{x}_{it}$ is a vector containing the variables described above and a constant, $\boldsymbol{\beta}$ is a vector of parameters to be estimated, $\varepsilon_{it} \sim$ N[0,1] is an error term, and α_i is a term that captures unobserved species-specific effects. We cannot observe S_{it}^*; instead, we observe $STATUS_{it} = j$ if $\mu_{j-1} < S_{it}^* \leq \mu_j$, j = 0, 1, 2, 3, where $\mu_0 = 0$, $\mu_3 = +\infty$, and the remaining μ_j are parameters to be estimated. The corresponding probability that species i is in category j at time t is:

$$P_{it}^j \equiv \text{Prob}[STATUS_{it} = j] = \text{Prob}[\mu_{j-1} < \boldsymbol{\beta}'\boldsymbol{x}_{it} + \alpha_i + \varepsilon_{it} \leq \mu_j]$$

$$= \Phi(\mu_j - (\boldsymbol{\beta}'\boldsymbol{x}_{it} + \alpha_i)) - \Phi(\mu_{j-1} - (\boldsymbol{\beta}'\boldsymbol{x}_{it} + \alpha_i)) \qquad (1)$$

where $\Phi(\cdot)$ is the c.d.f. for the standard normal distribution.

To estimate the model, it is necessary to make an assumption about the species-specific effect, α_i. The econometrics literature suggests that there is no consistent estimator of $\boldsymbol{\beta}$ for fixed-effects probit models, and hence the standard assumption is that α_i is an unobserved random variable, distributed normally with mean 0 and variance σ_α^2. A conditional maximum likelihood approach is used to estimate the parameters $\boldsymbol{\beta}$, μ_j, and σ_α^2. Because the α_i are not observed, it is necessary to integrate them out to get the joint distribution of ($STATUS_{i1990}$, …, $STATUS_{i2002}$) conditional on $\boldsymbol{x}_{it}$. Given the normal distribution of α_i, for each i this is given by

$$f(STATUS_{i1990}, \ldots, STATUS_{i2002}|\boldsymbol{x}_i; \boldsymbol{\beta}, \mu_j, \sigma_\alpha^2) = \int_{-\infty}^{+\infty}\left[\prod_{t=1}^{T} P_t^j\right]\frac{1}{\sigma_\alpha}\phi\left(\frac{\alpha}{\sigma_\alpha}\right)d\alpha \quad (2)$$

where P_t^j is defined in (1) and $\phi(\cdot)$ is the standard normal p.d.f. Taking the log gives the conditional log likelihood function for each i. The resulting log-likelihood function for the entire sample is then maximized with respect to $\boldsymbol{\beta}$, μ_j, and σ_α^2 (Wooldridge 2002, Hsiao 2003).

3.2 *Results*

The estimated coefficients for the recovery model are shown in Table 2, along with marginal effects for each of the variables (with the remaining variables evaluated at the sample mean)[14]. The results in Table 2 suggest that our main explanatory variable, $SPENDING_{it}$, has a positive effect on recovery status. Specifically, an increase in spending decreases the probability that a species is classified as Extinct and Declining, and increases the probability that it is classified as Improving. This result is robust to a variety of alternative specifications, such as including the level of threat faced by a species, its recovery potential, its degree of endangerment (whether it is listed as endangered or threatened)[15], and lagged spending and management variables, or controlling for FWS management using the length of time a species has been listed rather

[14] The marginal effects for dummy variables are estimated as P[$STATUS = j \mid x = 1, z$] – P[$STATUS = j \mid x = 0, z$], where x is the dummy variable and z includes all other variables evaluated at the sample mean.
[15] These variables were left out of the final specification because of their potential endogeneity.

than the management variables used here[16]. We conducted an additional robustness check of this result by estimating models that use the status categories from the IUCN's Red List and from Natureserve as dependent variables (in place of the status provided by the FWS). Although it is difficult to compare results due to the different classification systems and the different samples used in each of the models, the main results regarding the effect of spending on recovery status holds in these models as well.

Achievement of recovery objectives decreases the probability that a species is classified as Declining and increases the probability that it is classified as Improving[17]. The effects of time since critical habitat designation and recovery planning are not statistically different from zero[18], which agrees with some previous empirical findings (Abbitt and Scott 2001, Hoekstra et al. 2002, Clark et al. 2002)[19]. Possible explanations are that habitat may generally not be a decisive factor in determining extinction when

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[16] A possible concern with the results presented here is that the $SPENDING_{it}$ variable may be endogenous. We have controlled for this possibility in three ways. First, we conducted a Hausman endogeneity test by estimating a spending model, obtaining predicted values for spending, and including the difference between $SPENDING_{it}$ and its predicted value as an additional regressor in the recovery model. We cannot reject the null hypothesis of exogeneity at a 5% confidence level. Second, we used the predicted values of $SPENDING_{it}$ to implement an instrumental variables approach and estimated the recovery model using these predicted values. Finally, we estimated a model of recovery status as a function of lagged spending, which is exogenous. In the latter two models, the results are qualitatively and quantitatively very similar to those presented here.

[17] The achievement of recovery objectives variables could be endogenous as well. We do not have adequate instruments for these variables to be able to perform a Hausman test or estimate a model using instrumental variables. However, we did estimate the recovery model with lagged values of the RECOVERY dummies, which are exogenous, and the results are the same as those presented here. Additionally, we estimated a version of the model that excluded the RECOVERY variables, and the results corresponding to the focus variable, SPENDING, remain the same, as do most of the remaining results. However, the model does not perform as well in terms of correctly predicting outcomes as the one presented here.

[18] In alternative versions of the recovery model that include lagged spending variables, recovery plan preparation does have a statistically significant effect on recovery status. However, because the main objective of the recovery model in this paper is to simulate the effects of reallocations of spending, we do not discuss this any further here.

[19] Taylor et al. (2005) find that recovery trends are positively correlated with the duration of critical habitat designation, but they analyze a different sample that includes plants and invertebrates, use arbitrary weights to aggregate biennial recovery scores into a single measure, and use fewer control variables. Rachlinski (1997) also analyzes a sample that includes plants and finds that species with critical habitat are less likely to be Declining and more likely to be Stable, but he uses a different statistical technique and focuses only on the 1994 FWS recovery scores.

populations are already small (Belovsky et al. 1994), that critical habitat is redundant to other protections provided by the ESA (U.S. FWS 1999c), that legislative requirements limit critical habitat designations to the subset of potential habitat located on federal land that does not conflict with economic interests (Hoekstra et al. 2002). FWS has been reluctant to designate critical habitat, contending that the process is expensive, contentious, and provides no additional protection (Stokstad 2005). Recovery plans may be subject to lengthy delays in preparation and implementation, may not include biological data essential for recovery, may overemphasize economic considerations, or may fail to address political realities (Smith et al. 1993, Tear et al. 1995).

Table 2 also suggests that species characteristics play a role in recovery status. All taxonomic groups are more likely to be classified as Extinct and Declining and less likely to be classified as Stable than fish. Body length has a negative but decreasing effect on the probability of being classified as Extinct or Declining. Species in a monotypic or small genus are more likely to be classified as Extinct. As for our remaining control variables, the results in Table 2 suggest that conflict with economic activity increases the likelihood of being classified as Extinct and that species managed by Regions 4 and 5 (Southeast and Northeast) have a smaller chance of being classified as Declining and a larger chance of being classified as Improving. In the following section we use these results to simulate the effects of reallocations of funds among endangered species.

4. REALLOCATING CONSERVATION SPENDING

4.1 *Procedure*

The estimates reported above provide a means of accomplishing the second purpose of the paper—shedding light on changes in recovery outcomes likely to result if recovery spending were reallocated. We proceed in three steps. First, we choose the species-specific criteria we might use to reallocate spending and tailor these criteria to utilize the available data. Second, we decide precisely how to reallocate spending. Third, we choose the standards by which we might judge the predicted recovery outcomes.

Weitzman's (1998) rank for each species is based on four criteria: species' distinctiveness, direct utility, survivability, and recovery cost. This rank might be used to allocate constrained spending among all species. However, our data are insufficient to construct this rank. Instead, we allocate spending separately according to each of the criteria in Weitzman's theoretical rank, using the proxies identified by Metrick and Weitzman (1998). For distinctiveness, we use the size of a species' genus as a proxy and classify species *i* as "Distinct" if it belongs to a monotypic (one species) or small (2 – 5 species) genus. Between 1990 and 2002, on average 34% of species in our database satisfy the Distinctiveness criterion. For direct utility, we rely on the empirical result that conserving charismatic megafauna may generate more direct utility. Specifically, Metrick and Weitzman (1998) find that mammals and birds are more likely (relative to amphibians, reptiles, and fish) to receive conservation attention (i.e. to be listed and allocated funds), as are larger species. Hence, we classify species *i* as meeting the "Direct Utility" criterion if it is a mammal or a bird whose body length is greater than the sample mean for all species (41.86 cm). On average, 17% of species in our panel satisfy the Direct Utility criterion. We proxy the recovery cost criterion using FWS' classification of whether or not species' recovery is in conflict with economic activity, since protecting species not in conflict implies lower opportunity costs. A species satisfies the "Low Recovery Cost" criterion if FWS classified it as not in conflict with economic activity. About 60% of species satisfy the Low Recovery Cost criterion. We proxy a species' survivability by its degree of endangerment, because the species that are most endangered may be the ones that benefit the most from small conservation projects (Metrick and Weitzman 1998). Species *i* meets the "Survivability" criterion if it is listed as endangered, rather than threatened, by FWS. On average, 72% of species in our data satisfy the Survivability criterion. Average spending over the years 1990-2002 on species meeting these four criteria was distributed as follows: Distinct species received 36% of spending, species satisfying the Direct Utility criterion received 43%, species satisfying Low Recovery Cost received 27%, and those meeting the Survivability criterion received 66%[20].

In addition to the four criteria suggested by Weitzman's ranking, we want to examine the effects of redistributing resources according to the criterion based on the FWS priority rank. We classify a species as a "High Priority Rank" species if its FWS priority ranking is between 1 and 6 on a scale of 1 to18.[21] On average, 63% of species satisfy this criterion, receiving 62% of spending.

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[20] A breakdown per period is available from the authors upon request.

[21] The FWS' ranking is based on, in lexicographic descending order of importance, degree of threat, recovery potential, and taxonomy, with smaller numbers indicating higher priority. Additionally, species in conflict with economic activity are given higher priority.

To simulate the effects of reallocation, we uniformly redistribute the total amount spent to the species meeting each criterion. This yields five separate simulations. An alternative would be reallocation proportional to actual spending levels, but this would preserve some of the criteria used to determine the actual spending, and our objective is to examine the effects of a reallocation based *exclusively* on the criteria we have defined. For example, $ 97.3 million was spent in 1989-1990 on 195 species. The 68 species classified as "Distinct" received $29.6 million. This group includes the Little Mariana Fruit Bat, which received $12,098, and the Virginia Big Eared Bat, which received $138,900, more than ten times as much. With a proportional reallocation, the 68 Distinct species receive the entire $97.3 million, but the criteria that determined the original proportions remains: the Little Mariana Fruit Bat receives $42,500 and the Virginia Big Eared Bat receives $457,600. With a uniform reallocation, $1.4 million is spent on each of these bat species.

The third step needed to evaluate changes in recovery outcomes is to choose the standards by which outcomes are judged. We choose two standards, based on two assumptions about the goal of conservation policy. First, we assume that the goal of policy is diversity preservation, and hence focus on status changes only for species classified as "Distinct"[22]. We term this the "Diversity Preservation" standard. Second, we assume that the goal of policy is to promote the recovery of all, as opposed to only Distinct, species. Hence, we focus on changes in the status of all species. This is consistent with the fact that the main goal of the ESA "… is the conservation of

[22] Improving the population trends for Distinct species protects a more diverse set of species, and hence arguably improves biodiversity conservation outcomes as well. This very coarse notion of diversity is not the same as that discussed in the biodiversity economics literature, which is based on measures of dissimilarity between species, such as genetic distance (Weitzman 1993, 1998; Solow et al. 1993), but it is the only one available for the relatively large number of species in our database.

endangered and threatened species (listed species) …" (FWS 2002a); that is, the FWS is charged with the task of preventing the extinction and promoting the recovery outcomes of all T&E species (see U.S. FWS 1990a-2002a). Moreover, Tilman's (1999) conclusion that ecosystem services, including ecosystem stability, productivity, and resistance to invasion, increase with biodiversity at the same trophic level may argue for not distinguishing between species. We term this the "Overall Recovery" standard. Applying these two standards, we examine changes in the percentages of species classified as Improving, Stable, Declining, and Extinct. The latter two outcomes may be of particular interest if, as Bean (1991) and Smith et al. (1993) argue, preventing species from sliding further towards extinction is the main achievement of the ESA.

To establish baseline outcomes, we use the parameter estimates from the econometric model and sample values for spending and all other variables to simulate the probabilities that each species is classified as Extinct, Declining, Stable, or Improving. We report a species' status according to the category with the highest predicted probability and calculate the percentage of species in each category. We do this separately for Distinct species and for all listed species to report results for both the Diversity Preservation and Overall Recovery standards[23]. We then repeat this process for each reallocation. The results of each spending reallocation model are compared to the baseline outcomes.

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[23] Since it is necessary to account for the random effect term α_i, predicted probabilities cannot be obtained directly from (1). The following transformation is necessary: Prob[$STATUS_{it} = j$] = $\Phi(\mu_j^* - \boldsymbol{\beta}^{*\prime}\boldsymbol{x}_{it}) - \Phi(\mu_{j-1}^* - \boldsymbol{\beta}^{*\prime}\boldsymbol{x}_{it})$, where $\mu_j^* = \mu_j/(1 + \sigma_\alpha^2)^{1/2}$ and $\boldsymbol{\beta}^{*\prime} = \boldsymbol{\beta}'/(1 + \sigma_\alpha^2)^{1/2}$ (see Hsiao 2003 for details).

4.2 *Results and Discussion*

We report the simulation results for 2002, the most recent year in our database, in Table 3. By the Overall Recovery standard, baseline outcomes predict 8.7% of all species classified as Improving, 40.3% as Stable, 51% as Declining, and no species as Extinct[24] (thus this category is omitted from our results). Using the Diversity Preservation standard, baseline outcomes are somewhat worse for Distinct species: 7.3% are Improving, 30.5% are Stable, and 62.2% are Declining[25].

Consider first the results judged by the Diversity Preservation standard. Spending reallocations devoted to Distinct species lead to unambiguous improvements: the percentage of Distinct species classified as Improving increases from 7.3% to 8.5%, Stable species increase from 30.5% to 37.8%, and species classified as Declining decrease from 62.2% to 58.5%. Similar results are obtained when spending is allocated to species satisfying the Low Recovery Cost criterion, although the improvements over the baseline are somewhat smaller. A reallocation to species satisfying the Direct Utility Criterion yields a higher proportion of species classified as Stable and a lower proportion of species classified as Declining relative to the baseline, and no change in the percentage of species classified as Improving. A reallocation to species satisfying the Survivability criterion yields no substantive changes relative to the baseline. Finally, a reallocation to species satisfying the High Priority Rank criterion arguably leads to a deterioration, since the percentage of species classified as Improving does not differ from the baseline, but Stable species decline from 30.5% to 29.3% and Declining species increase from 62.2%

[24] Otherwise, the predictions are somewhat "conservative" relative to the actual outcomes for this sample: compared to the data, the model predicts a higher proportion of Declining species and lower proportions of Stable and Improving species.
[25] This is true for this subsample of species in the data as well, although the differences are not as large as those in the simulation.

to 63.4%. Overall these results suggest that reallocations of funds according to the criteria identified by economic theory will yield improvements over the baseline if outcomes are judged by the Diversity Preservation standard. The exception is the Survivability criterion, but even here the reallocation does not yield a worse outcome. Conversely, a reallocation according to the FWS High Priority criterion does yield worse outcomes than the baseline. Judged by the Diversity Preservation standard, all criteria based on economic theory perform better[26].

The simulation results judged by the Overall Recovery standard appear in the bottom three rows of Table 3. A reallocation to Distinct species result in a slight improvement relative to the baseline, with a small increase in the percent of Stable species (from 40.3% to 41.5%), a small decrease in the percent of species classified as Declining, and no change in species classified as Improving. Reallocation to Direct Utility species leads to no change in the percentage of species classified as Declining relative to the baseline, a small decrease in the proportion of species classified as Stable, and an increase from 8.7% to 9.1% for species classified as Improving. Reallocation to Low Recovery Cost species yields no change in the fraction of species classified as Stable, a decrease in species classified as Declining, and an increase from 8.7% to 9.1% of Improving species. Reallocating funds to Survivability species results in inferior results relative to the baseline, since there is no change in Increasing species, but the fraction of Stable species decreases and that of Declining species increases. Finally, reallocation to High Priority species also yields inferior outcomes relative to the baseline.

[26] We also conducted simulations with less "extreme" reallocations. Instead of reallocating 100% of funds to the selected subsets of species, we reallocated 80% and 90% of funds, with the remainder allocated as in the baseline. The results are consistent with those presented here, but better outcomes for the Diversity Preservation standard are achieved when 100% of funds are reallocated.

These results suggest that reallocating funds according to the criteria identified by economic theory to improve the status of Distinct species would not lead to a decline in overall conservation outcomes for all species. In fact, the reallocations that yield improvements according to the Diversity Preservation standard are predicted to lead to small improvements using the Overall Recovery standard as well[27].

What drives these results? The reason behind the improvements judged by the Diversity Preservation standard is straightforward: under each of the reallocations spending on Distinct species increases relative to the baseline. This is, of course, what we would expect for the reallocation to Distinct species, where 2001-2002 spending on this subset increases from $98.5 million in the baseline to $ 287.1 million. This is also the case for the other criteria yielding improvements based on the Diversity Preservation standard. Distinct species are allocated $113.3 million under the Direct Utility criterion and $104.8 million under Low Recovery Cost. On the other hand, when the Survivability criterion is used to reallocate funds, spending on Distinct species is $ 97.4 million, slightly less than in the baseline.

Understanding why these reallocations do not have a negative effect on Overall Recovery is more difficult. First, note that the marginal effects of spending on species status are small. Second, in the 2002 baseline all species except one receive some amount of funding. When funds are reallocated according to the different criteria prescribed by

[27] We chose the Overall Recovery standard as a basis for comparison because it is consistent with the FWS goal of promoting recovery of all species. A "stricter" standard would compare the effects of reallocations on changes in recovery status for Distinct and non-Distinct species (i.e. those belonging to a medium or large genus). Using this standard, the reallocations do yield slightly worse outcomes for non-Distinct species, but the changes are small, particularly relative to the improvements achieved for Distinct species. Overall, the results suggest that reallocating funds according to the criteria identified by economic theory to improve the status of Distinct species would not lead to significant declines in conservation outcomes for non-Distinct species. The results are available from the authors upon request.

economic theory, resources are concentrated on smaller subsets of species. If the subset of species receiving funds is small enough, i.e. if funds are sufficiently concentrated, then overall the gains by species receiving more funding exceed the losses of species whose funding is taken away. Because marginal effects are small, the positive effects of the relatively larger increases in funding dominate the negative effects of the smaller decreases in funding, yielding overall improvements in status. However, if the subset of species receiving funds is not small enough, then on average losses may exceed gains, yielding an overall decline in status. For example, funds in the baseline are allocated to 240 species, but under the Distinctiveness criterion reallocation, the same amount of resources is apportioned to only 82 species. As a result, species who receive more funding gain $3.13 million on average relative to the baseline, whereas species who receive less funding lose only $0.97 million on average. On the other hand, under the Survivability criterion reallocation, funds are divided up among 171 species and the average gain is $1.45 million, but the average loss is $1.52 million.

Finally, note that the improvements in Diversity Preservation outcomes reported so far would be achieved without any additional spending on species recovery, since all our results are based on reallocations of actual spending. As a test of the robustness of our general results, we consider what would happen if total spending in each period were to increase and the additional funds were allocated according to the different priority criteria considered above. Table 4 shows the results of increasing spending in each period by 100% over the baseline, and allocating the additional funds in proportion to the existing allocation or evenly according to the different priority criteria. The results in Table 4 suggest that an increase in spending would improve both Diversity Preservation and Overall Recovery outcomes. Allocating additional funds according to any of the criteria suggested by economic theory has a positive effect on Diversity Preservation and, with the exception of the Survivability criterion, the outcomes are better than what could be achieved with a proportional allocation. Furthermore, as before, there are no significant tradeoffs in terms of Overall Recovery. Although the proportion of all species classified as Improving would increase more with a proportional allocation, the improvements in terms of species classified as Stable and Decreasing are greater for the other allocation criteria (except for Survivability). On the other hand, allocating the additional funds according to the High Priority Ranking criterion has almost no effect on Diversity Preservation outcomes, and a small effect on Overall Recovery. In fact, better results would be obtained with a proportional distribution. Thus, our main results hold for an increase in funding as well as with a reallocation of a given amount of resources.

5. SUMMARY AND CONCLUSION

Economic theory has been used to establish a number of criteria for setting priorities in allocating scarce conservation resources. In this paper we examine whether reallocating resources according to these criteria would yield improvements in biodiversity conservation outcomes and, if so, whether these improvements would come at the cost of inferior outcomes for the overall recovery of endangered species. We use the parameter estimates of an econometric model of endangered species' recovery status to simulate the effects of reallocating spending by state and federal governmental agencies according to these criteria.

Our results suggest that if the goal of conservation policy is to enhance the recovery status of Distinct species, a reallocation according to criteria identified by economic theory would yield an improvement over the original allocation, and would also outperform the priority ranking proposed by the FWS. Furthermore, such reallocation does not appear to entail significant tradeoffs in terms of overall species recovery. We also find that an absolute increase in funding would have a positive effect on both Diversity Preservation and Overall Recovery outcomes, but that better results for Diversity Preservation would be achieved if additional funding is allocated according to the criteria suggested by economic theory.

The variables we use to define our criteria and conduct our analysis are coarse proxies of the underlying measures. Nevertheless, the data used in this paper is not altogether different from the information available to FWS and others responsible for making conservation decisions. Hence, the objective of this paper is not to prescribe a particular priority criterion to guide the allocation of scarce conservation resources, but rather to suggest that, by taking into account the criteria suggested by economic theory when allocating scarce resources, it may be possible to preserve a more diverse set of species, without negatively affecting the goal of overall recovery.

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TABLE 1 – Sample Means

Variable	1990	1992	1994	1996	1998	2000	2002
TOTAL NUMBER OF SPECIES IN SAMPLE	195	208	226	237	238	241	241
SPENDING (*$ millions*)[a]	0.50	1.14	0.83	0.80	0.77	1.03	1.19
TIME HABITAT (*days*)	774	1107	1137	1411	1659	1814	1816
SOME PLAN	0.44	0.50	0.44	0.47	0.40	0.48	0.29
FINAL PLAN	0.44	0.47	0.54	0.52	0.57	0.50	0.68
RECOVERY2	0.22	0.23	0.21	0.18	0.26	0.26	0.25
RECOVERY3	0.10	0.09	0.09	0.12	0.12	0.13	0.13
RECOVERY4	0.03	0.05	0.04	0.03	0.03	0.03	0.03
MAMMAL	0.21	0.20	0.18	0.17	0.17	0.17	0.19
AMPHIBIAN	0.03	0.03	0.03	0.05	0.04	0.05	0.05
BIRD	0.36	0.33	0.35	0.32	0.31	0.31	0.30
REPTILE	0.09	0.10	0.10	0.10	0.12	0.12	0.10
BODY LENGTH (*cm.*)	41.11	42.83	40.99	42.66	40.88	41.12	42.98
DISTINCT	0.35	0.34	0.36	0.34	0.35	0.34	0.34
CONFLICT	0.36	0.41	0.39	0.41	0.41	0.41	0.43
REGION 1 (*Pacific*)	0.44	0.43	0.42	0.41	0.38	0.40	0.40
REGION 2 (*South west*)	0.15	0.14	0.14	0.16	0.17	0.17	0.17
REGION 3 (*Great Lakes*)	0.04	0.04	0.03	0.03	0.04	0.05	0.04
REGION 4 (*South east*)	0.24	0.26	0.29	0.30	0.30	0.31	0.30
REGION 5 (*North east*)	0.06	0.05	0.05	0.04	0.04	0.04	0.03
REGION 6 (*Mountain*)	0.08	0.08	0.08	0.07	0.07	0.07	0.07
ENDANGERED	0.77	0.75	0.73	0.71	0.71	0.70	0.71

[a] Includes total spending for the two-year period ending in that year.

TABLE 2 – Recovery Model – Coefficient Estimates and Marginal Effects

		Marginal Effects			
Variable	*Coefficient* (*t statistic*)	*P*(*STATUS*=0) (*t statistic*)	*P*(*STATUS*=1) (*t statistic*)	*P*(*STATUS*=2) (*t statistic*)	*P*(*STATUS*=3) (*t statistic*)
Constant	3.31*** (6.35)				
SPENDING	0.08*** (3.47)	-0.15E-02** (-2.39)	-0.01*** (-3.34)	0.70E-02 (1.25)	0.89E-02* (1.93)
TIME HABITAT	-0.23 E-04 (-0.73)	0.43E-06 (0.70)	0.41E-05 (0.73)	-0.20E-05 (-0.63)	-0.25E-05 (-0.70)
SOME PLAN	0.55* (1.75)	-0.99E-02 (-0.83)	-0.10 (-1.55)	0.05 (0.56)	0.06 (1.63)
FINAL PLAN	0.39 (1.27)	-0.74E-02 (-0.69)	-0.07 (-1.11)	0.03 (0.47)	0.04 (1.02)
RECOVERY2	1.55*** (15.22)	-0.02 (-1.18)	-0.26*** (-3.55)	0.08 (0.56)	0.21*** (7.00)
RECOVERY3	2.23*** (17.01)	-0.02 (-1.20)	-0.35*** (-3.79)	0.02 (0.12)	0.35*** (10.34)
RECOVERY4	2.99*** (11.55)	-0.02 (-1.18)	-0.39*** (-3.60)	-0.10 (-0.82)	0.51*** (15.31)
MAMMAL	-0.60* (-1.77)	0.01*** (16.87)	0.10* (1.72)	-0.06*** (-4.15)	-0.06 (-0.80)
AMPHIBIAN	-0.73 (-0.92)	0.02*** (43.61)	0.12** (2.01)	-0.08*** (-5.34)	-0.07 (-0.89)
BIRD	-0.69** (-2.32)	0.02*** (42.95)	0.12** (2.04)	-0.07*** (-4.99)	-0.07 (-0.89)
REPTILE	-1.12*** (-2.41)	0.03*** (6.29)	0.18*** (2.86)	-0.12*** (-5.00)	-0.10 (-1.11)
BODY LENGTH	1.25*** (2.67)	-0.02** (-2.03)	-0.22*** (-2.60)	0.11 (1.29)	0.14 (1.46)
BODY LENGTH^2	-0.27* (-1.84)	0.51E-02* (1.64)	0.05* (1.79)	-0.02 (-1.19)	-0.03 (-1.23)
DISTINCT	-0.31 (-1.36)	0.62E-02* (1.81)	0.06 (0.93)	-0.03 (-1.18)	-0.03 (-0.50)
CONFLICT	-0.32* (-1.81)	0.62E-02* (1.92)	0.06 (0.96)	-0.03 (-1.26)	-0.04 (-0.52)
REGION 1	-0.09 (-0.20)	0.17E-02 (0.31)	0.02 (0.26)	-0.79E-02 (-0.21)	-0.99E-02 (-0.17)
REGION 2	-0.10 (-0.20)	0.19E-02 (0.33)	0.02 (0.28)	-0.85E-02 (-0.22)	-0.01 (-0.18)
REGION 3	0.39 (0.76)	-0.60E-02 (-0.69)	-0.07 (-1.10)	0.03 (0.43)	0.05 (1.02)

Table 2 – Cont.

REGION 4	0.86*	-0.01	-0.15**	0.06	0.10***
	(1.85)	(-1.01)	(-2.30)	(0.62)	(3.17)
REGION 5	0.80	-0.01	-0.14**	0.05	0.11***
	(1.28)	(-0.95)	(-2.02)	(0.51)	(2.65)
REGION 6	-0.20	0.40E-02	0.04	-0.02	-0.02
	(-0.34)	(0.83)	(0.57)	(-0.54)	(-0.34)
μ_1	4.11***				
	(20.26)				
μ_2	6.56***				
	(30.70)				
σ_α	1.75***				
	(18.05)				
Observations	1586				
Log Likelihood	-1186.45				
p value -LR Test [a]	0.00				
% Correct Predictions	58%	0%	72%	67%	17%

*, **, *** indicate parameter significance at α = 0.1, 0.05, and 0.01 respectively

[a] p - value for likelihood ratio test of joint significance of regressors.

TABLE 3: Simulation Results - Percentage of Species by 2002 Status

Status 2002	*Baseline*	*Distinct*	*Direct Utility*	*Low Recovery Cost*	*Survivability*	*High Priority Rank*
Diversity Preservation (*Distinct species*)						
Improving	7.3%	8.5%	7.3%	8.5%	7.3%	7.3%
Stable	30.5%	37.8%	32.9%	32.9%	30.5%	29.3%
Declining	62.2%	53.7%	59.8%	58.5%	62.2%	63.4%
Overall Recovery (*all species*)						
Improving	8.7%	8.7%	9.1%	9.5%	8.7%	8.7%
Stable	40.3%	41.5%	39.8%	40.3%	39.4%	39.0%
Declining	51.0%	49.8%	51.0%	50.2%	51.9%	52.3%

TABLE 4: Effects of a 100% Increase in Spending - Percentage of Species by 2002 Status

Status 2002	*Baseline*	*Proportional*	*Distinct*	*Direct Utility*	*Low Recovery Cost*	*Survivability*	*High Priority Rank*
Diversity Preservation (Distinct species)							
Improving	7.3%	8.5%	9.8%	8.5%	8.5%	8.5%	7.3%
Stable	30.5%	32.9%	41.5%	34.1%	35.4%	31.7%	31.7%
Declining	62.2%	58.5%	48.8%	57.3%	56.1%	59.8%	61.0%
Overall Recovery (all species)							
Improving	8.7%	12.0%	9.5%	10.4%	10.4%	10.4%	10.0%
Stable	40.3%	38.6%	44.0%	41.9%	41.5%	39.4%	39.4%
Declining	51.0%	49.4%	46.5%	47.7%	48.1%	50.2%	50.6%