Conservation triage or injurious neglect in endangered species recovery

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Listing endangered and threatened species under the US Endangered Species Act is presumed to offer a defense against extinction and a solution to achieve recovery of imperiled populations, but only if effective conservation action ensues after listing occurs. The amount of government funding available for species protection and recovery is one of the best predictors of successful recovery; however, government spending is both insufficient and highly disproportionate among groups of species, and there is significant discrepancy between proposed and actualized budgets across species. In light of an increasing list of imperiled species requiring evaluation and protection, an explicit approach to allocating recovery funds is urgently needed. Here I provide a formal decision-theoretic approach focusing on return on investment as an objective and a transparent mechanism to achieve the desired recovery goals. I found that less than 25% of the $1.21 billion/year needed for implementing recovery plans for 1,125 species is actually allocated to recovery. Spending in excess of the recommended recovery budget does not necessarily translate into better conservation outcomes. Rather, elimination of only the budget surplus for "costly yet futile" recovery plans can provide sufficient funding to erase funding deficits for more than 180 species. Triage by budget compression provides better funding for a larger sample of species, and a larger sample of adequately funded recovery plans should produce better outcomes even if by chance. Sharpening our focus on deliberate decision making offers the potential to achieve desired outcomes in avoiding extinction for Endangered Species Act-listed species.

endangered species | conservation triage | conservation prioritization | return on investment | cost

The magnitude of issues influencing global biodiversity dwarfs the resources available to mitigate impacts and sustain biodiversity. Thus, we are faced with making hard choices and striving for efficient conservation resource allocation. The US Endangered Species Act (ESA), now 40 years old, mandates protection of endangered species through identifying at-risk species and then implementing conservation strategies that ameliorate threatening activities and stabilize or increase abundances. The agencies responsible for implementing the ESA, the US Fish and Wildlife Service (FWS) and National Marine Fisheries Service, have been successful in preventing extinction, but recovering species to the point where they can be delisted has proven more difficult. At present, responsible agencies lack resources to implement all recovery plans and are faced with making difficult decisions about which species and which actions are of highest priority.

Each year, agencies face the challenge of deciding whether and how to invest in the recovery of ∼1,500 listed species. Among species found in the United States, ∼50% of ESA-listed species continue to decline or remain at high risk for extinction, and the FWS is mandated to evaluate ∼800 more candidate species by 2018. This capacity challenge is acutely problematic, given the potential impacts of human activity on the wildlife and plants that the ESA's protections are intended to benefit.

In light of the growing list of imperiled species requiring evaluation and protection, an explicit decision framework to facilitate the setting of recovery priorities and allocation of recovery funds is urgently needed. Listing endangered and threatened species under the ESA is presumed to offer a defense against extinction and a solution to achieve the recovery of imperiled populations (1), but only if effective conservation action ensues after listing occurs.

The amount of government funding available for species protection and recovery is one of the best predictors of successful recovery (2–7); however, government spending is both insufficient and highly disproportionate among groups of species (8). Most species recovery plans include cost estimates—a proposed budget for meeting recovery goals. Previous work has demonstrated a significant discrepancy between proposed and actualized budgets across species (9). Furthermore, the literature on formal decision theory and endangered species conservation suggests that the most efficient allocation of resources to conserve species is not always intuitive; for example, the level of investment should not necessarily reflect the level of threat, and is dependent on whether the time frame is short term or long term (9, 10).

Resource managers are increasingly relying on formal decision theory and return on investment (ROI) approaches as a societally relevant scale to facilitate management of natural resources. ROI analysis has been applied to a number of conservation contexts, including resource allocation spatial prioritization and weighing of alternative conservation actions. Approaches based on ROI and grounded in decision theory offer promise in identifying cost-effective investments and efficiency in achieving conservation goals. In this paper, I consider recovery expenditures using a formal decision-theoretic approach that considers ROI to quantitatively examine the relationship between level of investment and level of threat (11). This approach includes the following elements: (*i*) identify a well-defined and measurable objective; (*ii*) evaluate conservation opportunities; (*iii*) include estimates of benefits;

Significance

Although government funding available for species protection and recovery is one of the best predictors of successful recovery, government spending is both insufficient and highly disproportionate among groups of species. Here I demonstrate that expenditures for recovery in excess of the recommended recovery budget would not necessarily translate into better conservation outcomes. More importantly, elimination of the budget surplus for "costly yet futile" recovery plans can provide sufficient funding to offset funding deficits for more than 180 species. Using a return on investment analysis, I show that triage by budget compression provides better funding for a larger sample of species, and that a larger sample of adequately funded recovery plans should produce better outcomes even if by chance.

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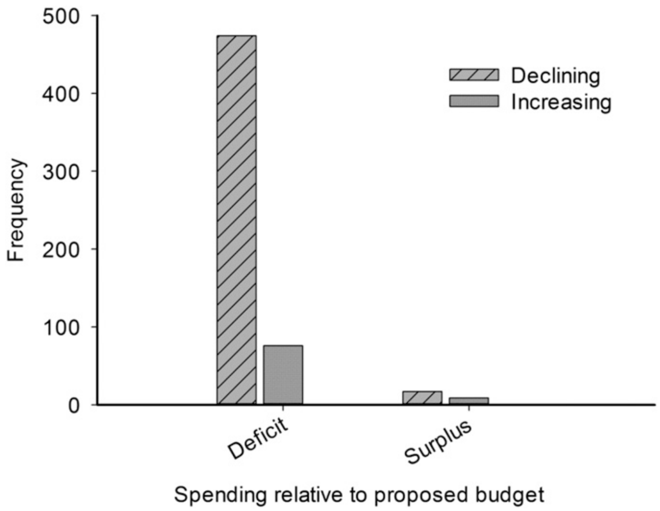

Fig. 1. Frequency of ESA-listed species showing the relationship between their status (declining or increasing) and proportion of proposed funding that the species has received for recovery (deficit, less than proposed by the recovery team; surplus, more than proposed by the recovery team). The two are negatively correlated; funding influences the relative frequency of success (i.e., increasing population) or failure (i.e., decreasing population) with greater relative success with more funding (Kendall rank correlation, $T = 0.05$, $z = 1.39$, $n = 84$, $P = 0.049$).

(*iv*) incorporate estimates of costs; and (*v*) allocate portfolio. This simple application demonstrates the potential relevance of ROI to achieving recovery objectives for a fixed conservation budget.

Results

The ESA requires agencies to produce a recovery plan for listed species and to include an estimate of cost of and time to recovery in each plan (12, 13). Separately, species status and dollars spent by government agencies for species recovery are reported in annual reports to Congress. With data on population status and government spending for 1,125 listed species, I found that 271 listed species (24%) are in a state of "injurious neglect," defined here as species that are both in decline and for which recovery efforts are underfunded.

Contrary to previous work suggesting that the most efficient allocation of resources to conserve species is not intuitive, I found a strong correlation between recovery funding and status. In particular, funding influences the relative frequency of success (i.e., increasing population) and failure (i.e., decreasing population) for listed species. As expected, the relative recovery success of underfunded species is lower than that of overfunded species recovery plans. This result is significant across a broad range of taxa (Kendall rank correlation, $\tau = 0.05$, $z = 1.39$, $n = 1124$, $P = 0.049$) (Fig. 1).

To address the potential bias associated with a single metric for status, I performed a rank correlation analysis on two alternate datasets. The first of these included the rank sum of annual status measures as a composite measure of recovery success (values ranging from −9 to 9), and the second had the same composite measure of recovery but removed plans in which species had a recovery status of 0. In both cases, our result was unchanged. The relative recovery success of underfunded species recovery plans is still lower than that of overfunded species recovery plans for this subset of our data (Kendall rank correlation, $\tau = 0.08$, $z = 3.26$, $n = 1124$, $P = 0.001$ and $\tau = 0.06$, $z = 2.16$, $n = 927$, $P = 0.03$, respectively).

Only ∼12% (140 of 1,125) of species are receiving as much or greater funding than prescribed in their recovery plan. For this small percentage of species for which spending recommendations are met, recovery goals are 2.5 times more likely to be met (Fig. 1); however, a large number of these species with adequate or surplus funding are still in decline (Fig. 2). The declining species within the top 50 spending surpluses command a (surplus) budget of more than $17 million/year. In contrast, among species in a state of injurious neglect, more than 100 species are receiving less than 10% of the investment needed as defined by their recovery plans.

Conservation triage is the process of prioritizing the allocation of limited resources to maximize conservation returns (3, 14). Explicit triage systems have received criticism that they encourage governments to abandon species (i.e., make a conscious decision to deny any of the conservation resources needed by a species). Here I refer to a more nuanced definition of triage: a reallocation of surplus spending from the top 50 costly but heretofore futile recovery efforts to efforts that are grossly underfunded. "Overfunded" species are defined as those with a budget at least two-fold greater than that proposed, and "underfunded" species are defined as those with a budget of 90% or less of that proposed. Adequately funded species are those in between (proportional budget between 0.9 and 2.0).

As a thought exercise, I examined how triage—budget compression of the top 50 most expensive, but failing, recovery efforts—would translate into funding for species that are declining but underfunded (i.e., injurious neglect). Reallocation of surplus funding from these 50 recovery efforts would erase deficits in funding for up to 182 species (Fig. 3). Of these 182 species, more than one-half (96) are plants, and the majority of the remaining 86 species (63) are invertebrates and lower vertebrates (fishes, reptiles, and amphibians) (*SI Appendix*, Table S1). These proportions do not differ vastly from those of species whose surplus funding would be triaged and reallocated (*SI Appendix*, Table S2).

Although the objective of this thought exercise was focused on bringing the most plans to full funding by compressing budgets from species categorized as "costly failures," the general framework allows for consideration of alternative objectives. For example, to identify a threshold for minimum funding level for success, I analyzed funding (i.e., proportion of proposed budget allocated) as a function of status (Fig. 4). The cost–success curve is convex; funding surpluses were common for the species least

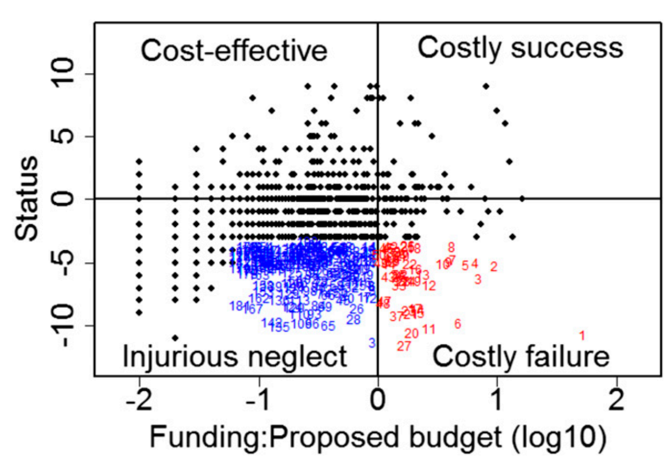

Fig. 2. Framework for conservation triage. Shown is the index of recovery as a function of the proportion of the proposed budget actually allocated and spent on conservation for all species with conservation plans (black points). The index of recovery is the sum of years in which the population increases (+1), decreases (−1), or remains constant (0). Blue numbers represent species experiencing injurious neglect (*SI Appendix*, Table S1), and red numbers show species with recovery efforts that cost more than the budget proposed in their recovery plan (*SI Appendix*, Table S2). By increasing expenditures for injurious neglect species (blue numbers) and reducing expenditures for costly failure species (red numbers), recovery funding objectives are met for 182 species.

likely and most likely to recover. For the subset of species with positive status (i.e., increasing more than decreasing on average across years), the relationship between status and funding was positive and linear. In other words, for those species not in critical decline, status increased linearly with funding. Nevertheless, median funding was higher for recovering species (status >0) than for declining species. Median funding rates (as a proportion of proposed budget) were 0.27 for all recovering species and 0.41 for those species recovering for 6 or more years (Fig. 4). Thus, species receiving less than 41% of required funding are unlikely to recover, and funding and status are linearly correlated above this level of funding (blue bars in Fig. 4).

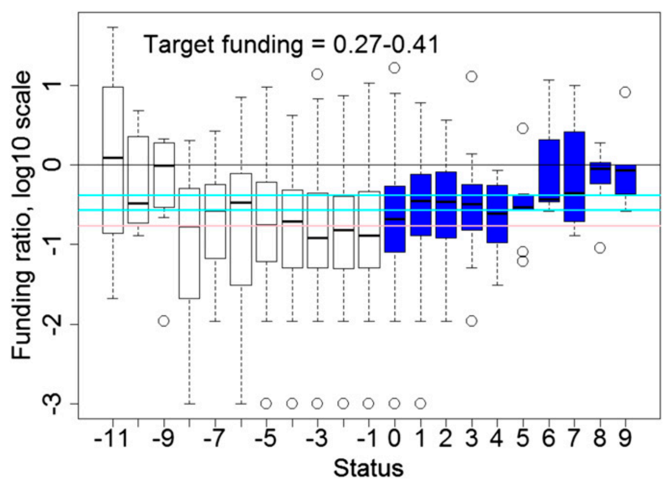

Fig. 4. Realized funding (expressed as a proportion of proposed budget) as a function of recovery status. Species with a positive status are depicted by solid blue boxes and declining species are open boxes. The light-blue lines represent median funding levels of species with plans that are on average stable or increasing and plans that are on average increasing during a majority of years (0.27 and 0.41 of the proposed budget, respectively). The pink line represents the median funding level of all declining species plans (status −9 to −11) except those with funding levels >1.

Discussion

Protection of species under the ESA is a challenging and often controversial task that requires input from various environmental, economic, social, and political interests. Required funding ($1.21 billion/year) should be allocated to recover all 1,125 listed species; however, given that less than 25% of this estimate is available for recovery plans, formal decision-theoretic approaches focusing on ROI offer an objective and transparent mechanism to achieve desired recovery goals. The analyses described in this paper represent potential mechanisms to better meet recovery objectives.

In light of the high risk level and potentially unexpected consequences associated with triage, I suggest that these results be viewed as an example of applying an ROI approach to recovery planning. The results should not be used to definitively identify species for triage until more data allow for validation of the quantitative relationship between funding and success (i.e., improved status). In only a very small number of cases did plans lead to success or failure; a larger set of validation data would reduce the risk associated with triage.

Triage by budget compression provides a means for increasing the equitability of funding allocation among species recovery efforts. For example, the broad taxonomic groups could be further ranked by threat rather than by cost efficacy. Alternate approaches to efficient triage could be achieved first by ranking cost to benefit (potential success). Surplus funds could then be reallocated to maximize the number of species meeting spending targets (cost efficacy), to prioritize the most threatened (and most expensive) recovery plans or by relative threat. As data become available, it will be important to consider the species-specific probability of success associated with recovery funding. For example, some recovery plans will have relatively large budgets but may have little if any capacity to advance recovery, owing to factors beyond control (e.g., protected predators consuming protected prey).

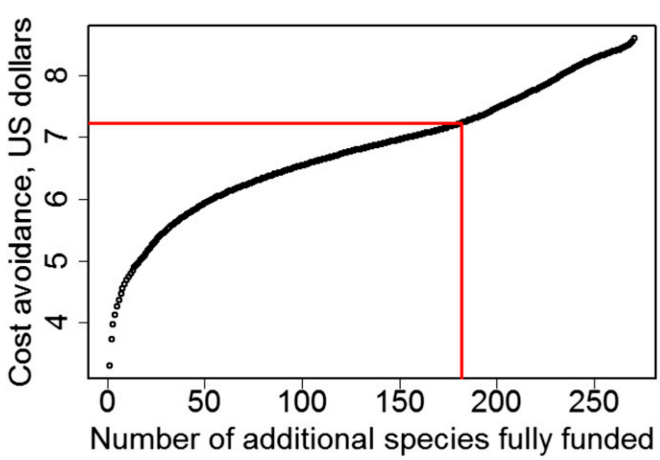

Fig. 3. Cumulative number of species categorized as injurious neglect (spending for recovery less than the budget recommended for recovery) whose project spending can be improved (spending equal to or greater than budget) by triaging the top 50 species in the "futile" category (where spending is greater than budget but the species has declined more than increased over the last decade). The horizontal red line is the fixed, inflation-adjusted cost of deliberate budget compression for 50 overfunded futile species. Species on the *x*-axis are rank-ordered by cost efficacy (from low to high spending deficits). Triage can provide funding for up to 182 species (intersection of two lines). The *y*-axis (cost) is on a log scale; the fixed cost of triage is ∼$17 million/year. The mean (1 SE) deficit in spending for species converted from injurious neglect to adequate is 93.5K (86.7K).

There is no fixed or transparent system that governs federal and state investments in endangered species. For example, each regional office of the FWS has discretion to allocate funds within the limits of the money they receive through a national allocation, which is in turn limited by appropriations from Congress. Geographic regions, staffing issues, potential for partnerships, and past funding patterns determine future funding levels. Currently, the FWS has a well-specified algorithm for allocation of funds from the national office to regional offices. Thus, applying this budgetary prioritization scheme at the regional level may be the appropriate scale for achieving recovery objectives.

Agencies responsible for recovery of listed species are faced with an increasing workload and decreasing resources. Furthermore, despite much attention on what is needed for species recovery, relatively little attention has been given to the question of whether research and management plans are actually implemented (15). The careful work that goes into creating recovery plans will be useful only if the recommended recovery actions are implemented and funded (16). In light of the growing list of imperiled species requiring evaluation and protection, an explicit decision framework to facilitate setting recovery priorities and allocating recovery funds is urgently needed (17). Sharpening our focus on deliberate decision making offers the potential to achieve desired outcomes in avoiding extinction for ESA-listed species.

Methods

The overall decision-theoretic framework represents an ROI approach consisting of five basic steps (11):

i) Identify a well-defined and measurable objective. The overarching goal is to minimize the number of species in the "declining" category given a fixed budget.

ii) Evaluate conservation opportunities. Conservation opportunity is defined as an improvement in species status for the largest number of species.

iii) Incorporate realistic estimates of cost. Actual dollar amounts as described above are used to incorporate estimates of cost. Overfunded species (*SI Appendix*, Table S1) are defined as those with a budget at least twice that proposed. Underfunded species are defined as those with those with a budget of 90% or less of that proposed. Adequately funded species (orange) are those in between (proportional budget between 0.9 and 2).

iv) Allocate portfolio. Our analysis provides guidance on differential impacts of rates of investment on species status using a "species investment curve" representing the cumulative number of species for the categories of injurious neglect and futility.

Although this approach focuses on achieving conservation goals based on ROI, the generalized decision framework can be adapted to other conservation objectives (e.g., level of threat, endemism). For example, although these analyses are based on the implicit assumption that all threatened and endangered species are of equal value, there may be a reason to focus conservation efforts more on keystone species than on weak interactors that have little or no influence on the rest of biodiversity.

The ESA requires agencies to produce a recovery plan for each species and to include an estimated cost of and time to recovery in each plan. I compiled data on 1,125 species with recovery plans produced between 1980 and 2014. In hundreds of cases, agencies have not written a plan, or have failed to include a timeline or cost estimate in a plan. In other cases, the cost estimate is for a period, but gives no estimate of whether that expenditure will move the species toward recovery. For multispecies recovery plans, I considered single estimates for a recovery budget and divided it among species to get a cost estimate for each species covered by the plan. This analysis does not examine expenditures or recovery of ∼400 additional listed species for which there is insufficient recovery budget information.

To assess long-term patterns of population status, I transformed biennial status data from reports to Congress between 1989 and 2011 (5). These data include, for each species, whether its status is extinct, declining, stable, improving, or unknown. By coding these as numeric variables as −1 for declining, 0 for stable, and 1 for improving, the sum of data points indicates whether species are declining more often than improving. One issue with this dataset is that the summary statistic for successful recovery is an ordinal index with three values (1, 0, and −1) derived from the rank sum of annual status estimates. Indices near 0 can arise from consistently stable and consistently oscillating populations; only the former have a low probability of extinction. This uncertainty does not arise in populations with large-magnitude positive or negative rank sums. To address the potential bias of this uncertainty, I performed a rank correlation analysis on two alternate datasets. The first of these included the rank sum of annual status measures as a composite measure of recovery success (values ranging from −9 to 9), and the second had the same composite measure of recovery but excluded plans with a recovery status of 0.

Annual reports to Congress between 1989 and 2011 describe annual spending by government agencies on each species. I combined reported expenditures by the FWS with other federal and state spending to get a single annual spending estimate for each species. All spending and cost estimate data were converted into 2013 dollars using the Consumer Price Index.

To analyze how budget compression of the top 50 most expensive recovery efforts would translate into funding for species that are declining but underfunded (injurious neglect), I filtered the full dataset by setting the minimum funding deficit to 0 (all species in which funding exceeds the proposed budget) and the upper limit of status to −4 (plans with declining species). This set of filters produced 50 species in the costly failure category with a combined funding of $17.09 million. I then redistributed this triaged revenue to species with high risk (status declining in >5 of the 11 years of record) and a budget deficit. This redistribution was done to maximize the number of species with funding equal to the proposed budget (ratios of 1 in Fig. 2). To do this, I reallocated compressed funds to eliminate budget deficits from plans in increasing order of absolute spending deficit. Plans with low total deficits were rectified first, followed by plans with increasing total deficits until the compressed budget was exhausted. This budget compression equilibrated funding (to proposed budget levels) for 182 species.

The primary dataset used for the budget compression case study comprised recovery plans that are in progress—the full lifecycle budget (cost) and outcomes in terms of recovery or extinction are unknown. To corroborate the implicit assumption that prospects for recovery improve with realized funding, I analyzed a dataset of 15 species that have recovered and are no longer listed or proposed for delisting and for which we have full cost disclosure. These are the only species for which there is an estimate of recovery budget in a recovery plan, annual data on actual spending, and success in achieving the goals of the plan. For these species, the actual cost of recovery exceeded the budgeted estimate by 74%, suggesting that full recovery costs more than the projected budget. This result must be viewed with some caution owing to the small sample size (n = 15) relative to the primary dataset of in-progress recovery plans. With more data on actual delisting, this dataset could be explored as case study to examine additional scenarios. For example, one could quantify the number of species that could be recovered and identify which species would be triaged given full allocation of 174% of the projected recovery budget estimate.

To develop benchmarks for funding for endangered species recovery, I examined the relationship between funding (as a proportion of proposed budget) as a function of status (categorical from −11 to 9). Visual inspection of this plot suggests that the most money is spent on highly imperiled and recovering taxa. I estimated median funding rates for the most consistently recovering (status >5) and recovering (status >0), and used these as benchmarks for funding levels associated with recovery.

1. Donlan CJ, Gartner T, Male T, Li Y-W (2013) Species conservation incentives. *Environ Policy Law* 43:162–166.
2. Gibbs KECDJ, Currie DJ (2012) Protecting endangered species: Do the main legislative tools work? *PLoS One* 7(5):e35730.
3. Scott JM, et al. (2005) Recovery of imperiled species under the Endangered Species Act: The need for a new approach. *Front Ecol Environ* 3:383–389.
4. Ferraro PJ, McIntosh C, Ospina M (2007) The effectiveness of the US Endangered Species Act: An econometric analysis using matching methods. *J Environ Econ Manage* 54:245–261.
5. Male TD, Bean MJ (2005) Measuring progress in US endangered species conservation. *Ecol Lett* 8:986–992.
6. Kerkvliet J, Langpap C (2007) Learning from endangered and threatened species recovery programs: A case study using US Endangered Species Act recovery scores. *Ecol Econ* 63:499–510.
7. Miller JK, Scott JM, Miller CR, Waits LP (2002) The Endangered Species Act: Dollars and sense? *Bioscience* 52:163–168.
8. Joseph LN, Maloney RF, Possingham HP (2009) Optimal allocation of resources among threatened species: A project prioritization protocol. *Conserv Biol* 23(2):328–338.
9. McCarthy MA, Thompson CJ, Garnett ST (2008) Optimal investment in conservation of species. *J Appl Ecol* 45:1428–1435.
10. Wilson HB, Joseph LN, Moore AL, Possingham HP (2011) When should we save the most endangered species? *Ecol Lett* 14(9):886–890.
11. Murdoch W, et al. (2007) Maximizing return on investment in conservation. *Biol Conserv* 139:375–388.
12. Boersma PD, Kareiva P, Fagan WF, Clark JA, Hoekstra JM (2001) How good are endangered species recovery plans? *Bioscience* 51:643–649.
13. Clark JA, Hoekstra JM, Boersma PD, Kareiva P (2002) Improving US Endangered Species Act recovery plans: Key findings and recommendations of the SCB Recovery Plan Project. *Conserv Biol* 16:1510–1519.
14. Bottrill MC, et al. (2008) Is conservation triage just smart decision making? *Trends Ecol Evol* 23(12):649–654.
15. Gerber LR, Hatch LT (2002) Are we recovering? An evaluation of recovery criteria under the US Endangered Species Act. *Ecol Appl* 12:668–673.
16. Troyer CM, Gerber LR (2015) Assessing the impact of the US Endangered Species Act recovery planning guidelines on managing threats for listed species. *Conserv Biol* 29(5):1423–1433.
17. Gregory R, Arvai J, Gerber LR (2013) Structuring decisions for managing threatened and endangered species in a changing climate. *Conserv Biol* 27(6):1212–1221.