By the Numbers: How is Recovery Defined by the US Endangered Species Act?

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Nearly 40 years after passage of the US Endangered Species Act, the prospects for listed species remain dim because they are too severely imperiled by the time they receive the act's protection. Even if threats are abated, the low abundances required for recovery often preclude a high probability of persistence. The lack of sufficient data for setting recovery objectives also remains a barrier. Delisting is considered possible for only 74% of the 1173 species with recovery plans—92% of threatened and 69% of endangered species. The median number of populations required for delisting (8) was at or below the historical numbers for 64% and at or below the numbers at listing for 37% of the species. The median number of individuals required for recovery (2400) exceeded the abundances at listing for 93% of the species, but most were below the levels considered necessary for long-term persistence, especially in changing environments.

Keywords: extinction risk, Endangered Species Act, recovery, conservation reliant

Recent challenges to Department of the Interior decisions to remove species from the list of *endangered* species (by changing their status to *recovered*; US District Court 2009, 2010, 2011) have refocused attention on a fundamental question regarding the US Endangered Species Act (ESA): What is a *recovered* species? The drafters of the ESA provided only limited guidance on this question (Goble 2009). The purpose of the ESA is to "conserve" endangered and threatened species and the ecosystems on which they depend (ESA sec. 2(b)). *Conservation* is achieved when the measures that the statute provides are no longer necessary to prevent extinction (ESA sec. 3(3)). Therefore, a species is *recovered* when it is neither "in danger of extinction throughout all or a significant portion of its range" (ESA sec 3(6)) nor likely to become so "within the foreseeable future" (ESA sec. 3(20)). *Recovery* requires both that a species be sufficiently abundant and that the threats it faces are eliminated or managed such that removing the ESA's protection does not trigger a recurrence of the species' decline (Goble 2009).

The agencies charged with administering the ESA—the US Fish and Wildlife Service (USFWS) and the National Oceanic and Atmospheric Administration's Fisheries Service—operationally define *recovery* in two types of documents. *Recovery plans* synthesize the available information on biology, status, and threats for a species and specify measurable recovery objectives and threat-abatement measures that (when they are achieved) will allow the species to be delisted and categorized as *recovered* (ESA sec. 4(f)(1)). Delisting documents provide the agencies' rationale for delisting actions, including a discussion of abundance and distribution data and an analysis of continuing threats from five factors (ESA sec. 4(a)(1)(A–E)). From these documents, we collected data on what abundance the agencies require to consider a species to be *recovered*. In so doing, we provide the first comprehensive evaluation of the agencies' de facto quantification of the abundances required for recovery since 1991 (Tear et al. 1993, 1995). We asked six questions: (1) What percentage of listed species with recovery plans do the agencies consider to have potential to be delisted? (2) What quantitative abundance criteria are used to measure recovery? (3) What percentage of species with potential for delisting have quantitative objectives for delisting? (4) How do the abundances required for delisting compare with historical abundances, those at the time of the species' listing, those at the time of the recovery plan's writing; with objectives from previous reviews of listed species (Tear et al. 1993, 1995, Schemske et al. 1994); with the benchmarks suggested in the literature; and with quantitative criteria for the International Union for Conservation of Nature's (IUCN) Red List (2001)? (5) How do the abundances for

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delisted species compare with these same values? (6) Do the abundances required for the recovery of *threatened* species differ from those of *endangered* species?

We focused on abundance and distribution because they are the most commonly used quantitative objectives in recovery plans and delisting rules (see also Tear et al. 1993, 1995) and because they play disproportionate roles in determining extinction risk (Lande 1993, Mace et al. 2008). We recognize that relationships between abundance and recovery or extinction are strongly affected by extrinsic threats to species. Because the risks associated with any particular abundance depend on the threat context, abating threats is a key aspect of recovery. Therefore, abundance must be considered in the context of threat reduction and evaluated through the five-factor analysis in the delisting process. At the same time, abundance itself is a measure of the ultimate consequences of those threats. Unfortunately, threats are not described consistently across recovery plans, and their abatement is not specified as objective, measureable recovery criteria that would allow quantitative assessment. Our analysis therefore provides a detailed and important—but necessarily incomplete—assessment of recovery.

The ESA defines *species* to include not only biological species but also subspecies and—for vertebrates—distinct population segments (DPSs; ESA sec. 3(16)). On 31 December 2009, the USFWS tally of *endangered* and *threatened* species included 1320 domestic species (i.e., those found within the United States, its territories, or its possessions). Prior to this date, an additional 25 species had been delisted. Not all listed or delisted species had finalized recovery plans, and some had more than one plan. Given our focus on recovery, we excluded listed species without a recovery plan and separately counted plans for different regions for the same taxa. This process produced a database of 1173 entities. Although a small number did not meet the ESA definition of *species*, for brevity, we refer to them all as *species*.

We collected abundance data from the most recent approved recovery plan and from final listing and delisting documents published in the *Federal Register* for all 1173 species. We recorded the agency's determination of each species' potential for delisting as *possible*, *not possible*, *may not be possible*, or *not addressed*. If they were available, we recorded abundance data for both individuals (labeled in the plans as the total number or the number of adults, breeding pairs, breeding females, or nests and reported here as the number of individuals) and populations and distribution data for habitat and range. We recorded these data from five points in the endangerment-to-recovery process (historically, at listing, at plan writing, required for delisting, and at delisting). The *historical* time period represents the species' status before it declined to the level of endangerment but is necessarily vague, because dates were not typically given. We used population definitions employed by the USFWS in the plans; great effort was expended ensuring that the definitions were consistent for each species and, to the extent possible, among species. If the population definitions were unclear or could not be reconciled among different data points, the data were coded as missing and excluded from the analysis. *Range size* was defined as the total geographic extent of a species. *Amount of habitat* was quantified as the area of suitable environmental conditions available for a species within its overall geographic range. When a range of values was given, we chose the lowest number for recovery objectives (the minimum required for delisting) and the highest number for *historic* and *current abundance* values (the most optimistic view of abundance). When abundance values were presented as an upper or a lower limit (e.g., <100 or >100), we chose the next whole number (e.g., 99 and 101, respectively).

We used Wilcoxon signed-rank tests to compare the numbers of populations or individuals required for delisting with known historical numbers, those at listing, and those at plan writing for all species, combined by taxonomic group (plants, vertebrates, and invertebrates) and separately and by listing status (*threatened* versus *endangered*). Because different species have data at different points in the endangerment–recovery process, we also used Wilcoxon matched-pairs tests to compare the within-species differences in recovery objectives at different time points. We compared the major taxonomic groups with one another using Kruskal–Wallis tests; when the results were significant, we assessed which groups differed by using post hoc pairwise comparison tests with Bonferroni corrections for multiple comparisons. We used log-likelihood ratio tests to determine whether the *threatened* and *endangered* species differed in terms of having delisting objectives that were or were not greater than previous abundances. We then used Wilcoxon signed-rank tests to determine the significance of differences between the *threatened* and *endangered* species in terms of the absolute and relative differences between delisting objectives and prior abundances overall and separately for cases in which declines were permitted and in which more populations and individuals were required for delisting the species.

We determined the IUCN (2001) categories into which each species would fall, given the numbers of populations and individuals specified for recovery. We chose the IUCN standards because they have been peer reviewed (Mace et al. 2008) and because they are widely accepted, understood, and used. Our rankings are provisional, because they are based on only the numbers of populations or individuals because of a lack of sufficient data on the extent of occurrence, the area of occupancy, and the magnitude of decline required for full IUCN classification. We used the following definitions based on locations, which we interpret as roughly equivalent to populations in recovery plans: *critically endangered* (1 location), *endangered* (2–5 locations), *vulnerable* (6–10 locations), *secure* (more than 10 locations). The categories for individual abundance alone were *critically endangered* (fewer than 50 individuals), *endangered* (50–250 individuals), *vulnerable* (251–1000 individuals), and *secure* (more than 1000 individuals). Species with rapid declines or highly fragmented populations would have more-severe rankings. Species for which declines have been halted might have less-stringent rankings. We also determined how many recovery objectives for the number of individuals were above or below the following thresholds recommended for viable populations: 7360 individuals (Reed et al. 2003); 5244 individuals for vertebrates, 15,992 for plants (Traill et al. 2007); and an effective population size of 10,000 (Lynch and Lande 1998).

We determined whether the prognosis for listed species had changed since previous reviews (Tear et al. 1993, 1995, Schemske et al. 1994) by comparing species with plans completed through the end of 1992 ($n = 356$) with those completed between 1993 and 2009 ($n = 817$) in several ways. We used log-likelihood ratio tests to determine whether plans from before versus after the time cutoff differed in the number of species that could be delisted at all or in the number that could be delisted with no more populations or individuals than existed at the plan's writing. We used Wilcoxon signed-rank tests to ask whether the absolute recovery objectives or historical percentages of individuals and populations, those at listing, and those at plan writing that they represented differed between earlier and later plans. Finally, we used log-likelihood ratio tests to ask whether the IUCN rankings resulting from those recovery objectives would differ between the two groups of plans. All statistical tests were conducted using R (Version 2.11.1; R Development Core Team, *www.r-project.org*).

Recovery potential and criteria and the availability of quantitative objectives

Delisting was considered possible for 73% of the total of 1173 species (69% of the 942 species listed as *endangered* and 92% of 231 species listed as *threatened*). The USFWS noted uncertainty for 257 species, stating that although delisting was the goal, it may not be possible because of rarity and threats or lack of data. Of the 863 species for which delisting was deemed possible, more than 90% had at least one quantitative recovery objective related to abundance or distribution. The number of populations required for delisting was specified for 86%, and the number of individuals was specified for 55% of the species with quantitative objectives; 50% (391) of such species had both values. The amount of habitat was a quantitative recovery objective for 7% of the species with quantitative objectives, and the size of the range was an objective for 1%. Because of the paucity of quantitative information for other abundance-related recovery objectives, we analyzed only population and individual abundance.

The number of populations required for recovery. The median (Md) number of populations required for delisting ($Md = 8$, $n = 671$) exceeded the number at listing ($Md = 3$, $p < .001$; $n = 660$) and at recovery plan writing ($Md = 3$, $p < .001$; $n = 959$) (figure 1a) but did not differ from the number known historically ($Md = 6$, $p = .522$; $n = 575$). These values were strongly affected by the data on Hawaiian plants, most of which required eight populations for recovery (figure 2). Excluding Hawaiian plants decreased the median recovery objective to six populations ($n = 425$), which was still significantly greater (both ps $< .001$) than the number at listing and that at recovery plan writing. The range of the number of populations required for delisting (1–185; figure 2a), represented between 20% and 500% of the populations that existed historically, at listing, and at plan writing (figure 3b–3d). Plants (with and without Hawaiian species) had larger numbers of populations than vertebrates at all prior time points; invertebrates were intermediate, and each of these groups differed significantly from one another in terms of populations required for delisting ($p = .05$; figure 3a). The *endangered* ($Md = 8$, range = 1–185; $n = 527$) and

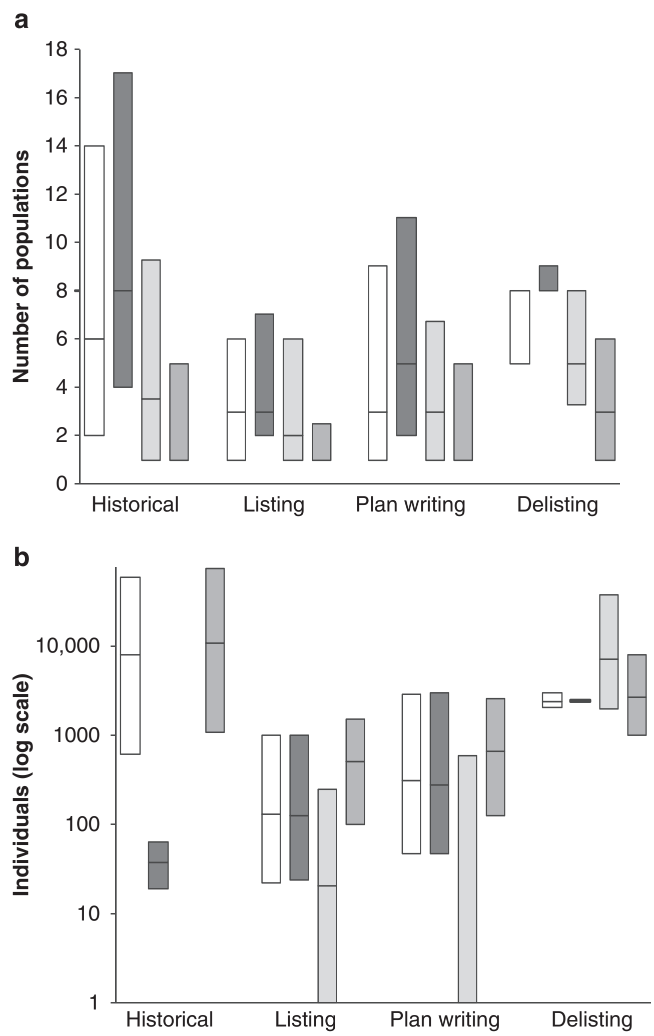

Figure 1. Median numbers of (a) populations and (b) individuals historically, at listing, at recovery plan writing, and required for delisting. The white bars represent all species, the dark gray represent threatened *species, and the light gray represent* endangered *species; the horizontal black bar on each vertical bar represents the median and the extremes represent the first and third quartiles.*

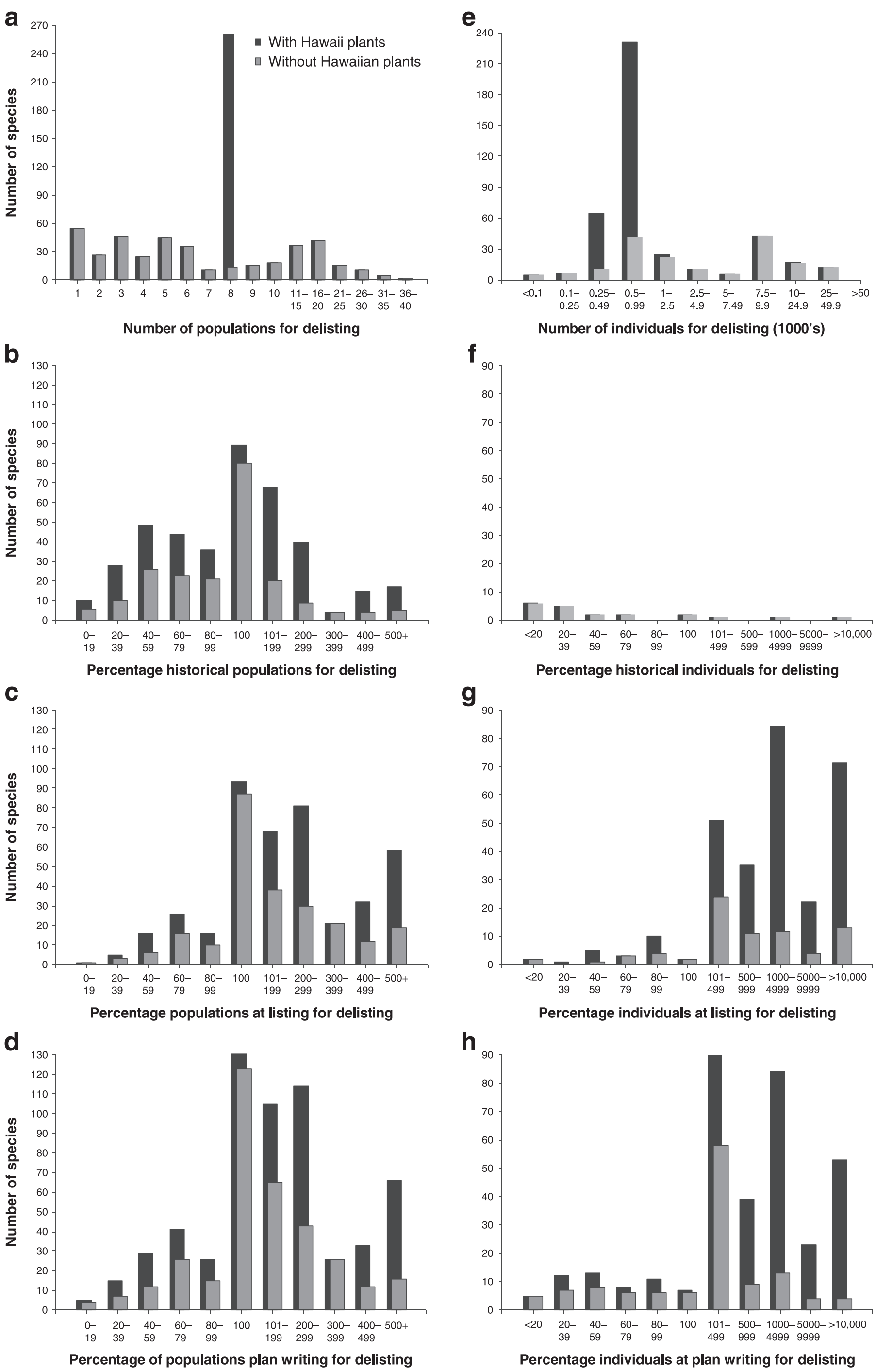

Figure 2. Frequency distribution of the number of (a) populations and (e) individuals required for delisting and the percentage of (b–d) populations and (f–h) individuals (b,f) historically, (c,g) at listing, and (d,h) at recovery plan writing represented by those objectives. The delisting population objectives for 246 plant species from Hawaii are identical and the individual abundance objectives take on a small number of values. These species are noted separately on the figures.

yielded median recovery objectives of six populations for both the *threatened* and *endangered* species.

The large differences in data availability at different points in the endangerment–recovery process limited our interpretation of the recovery objectives. When paired comparisons were used to control for these differences, the levels of population-based delisting objectives were still higher than the numbers of populations at listing and at plan writing, and the differences from historical population numbers became significant (all *p*s < .001). Although the overall median values were higher, 63.9% of the 396 species with data required no more populations for delisting than were known to exist historically, 37.1% of 423 species required no more than existed at listing, and 40.2% of 614 species required no more than existed at recovery plan writing (figure 2b–2d). When the species required fewer populations than existed previously, the median magnitude of decrease for the three time periods ranged between 5 and 7 populations, depending on the specific time comparison (figure 4a). These decreases would result in recovered species' having a median of 57.1% of the populations known to exist historically and around 66% of the populations known at listing and at plan writing (figure 4b). The minimum percentages of the remaining populations were 4.2% of the historical number, 17.6% of the number of populations at listing, and 8.7% of the number at plan writing. When the species required more populations, the median magnitude of increase was 3–5 populations (representing 200%–267% of the previous values; figure 4a). The maximum increases would represent 1000%, 2000%, and 1950% of the numbers of populations from the three prior time points, respectively.

threatened (*Md* = 7, range = 1–131; *n* = 143) species did not differ from one another (*p* = .86) in number of populations required for delisting (figure 1). Excluding Hawaiian plants

The *endangered* species had significantly fewer populations (*p* < .001) than did the *threatened* species at listing and at plan writing but not in the historical time period

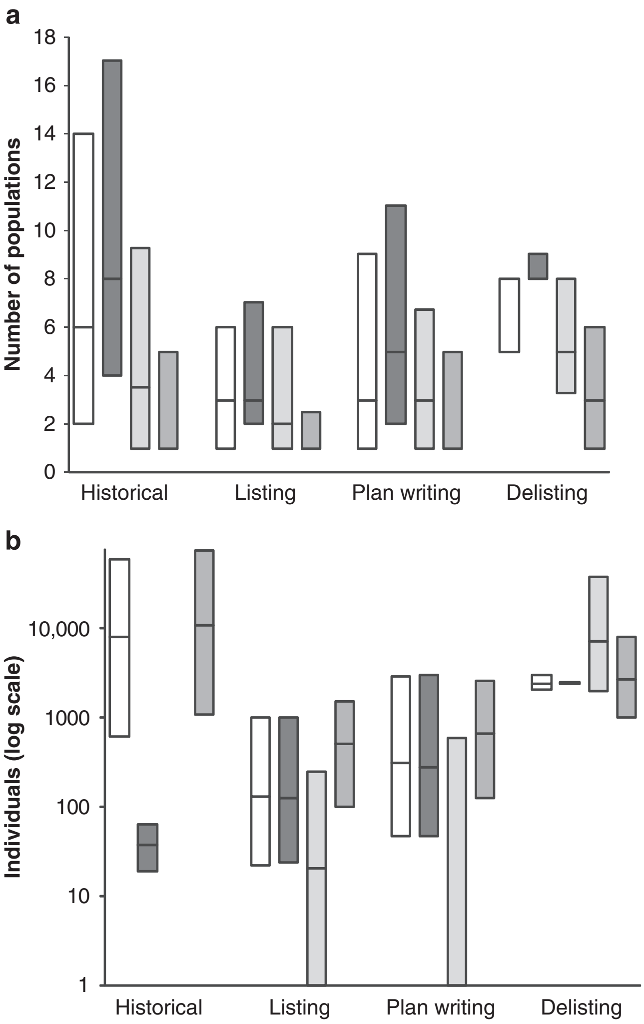

Figure 3. Median numbers of (a) populations and (b) individuals historically, at listing, at recovery plan writing, and required for delisting. The white bars represent all species, the dark gray represent plant species, the light gray represent invertebrate species, and the medium gray represent vertebrate species. The bars' extremes represent the first and third quartiles.

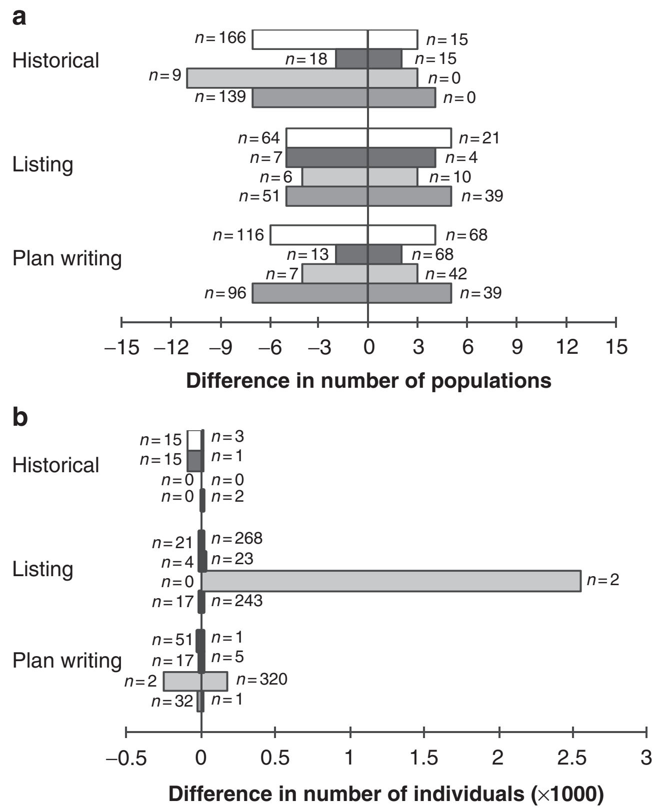

Figure 4. Median differences in (a) the number of populations and (b) the number of individuals between delisting objectives and abundances historically, at listing, and at plan writing for all species (white bars), plant species (dark gray), invertebrate species (light gray), and vertebrate species (medium gray).

(p = .23; figure 1a). The number of populations required for delisting also did not differ significantly (p = .86) between the two groups. However, the recovery objectives represented significantly smaller percentages of populations of *threatened* species (all *p*s < .001) known historically (*Md* = 90%), and at listing and recovery plan writing (both *Md*s = 100%) than did the recovery objectives for *endangered* species (*Md* = 100%, *Md* = 200%, and *Md* = 160%, respectively). We also found through application of log-likelihood ratio tests that a larger percentage of *threatened* species could be delisted with no increase in the number of populations over the number that existed historically, at listing, or at plan writing than was the case for *endangered* species (all *p*s < .001; table 1a). Furthermore, when species could be delisted with fewer populations than occurred at prior time points, *threatened* species would lose more populations relative to the numbers at listing (p < .01) and plan writing (p < .001) than would *endangered* species (table 1a), but the differences relative to the historical data were not significant (p = .11). The differences in the percentages of populations that would remain after such losses (60.0%–67.9% of the populations of *threatened* species versus 57.1%–66.7% of *endangered* species) at each time point were not significant (p = .23, p = .38, and p = .32 for historical, listing, and plan writing, respectively; table 1a).

When the *threatened* species required more populations for delisting than existed at earlier time points, the median increase was 3–3.5 populations, which yielded numbers of populations that were 181%–230% of the prior values. The *endangered* species would increase by 4–5 populations, which yielded 200%–267% of the prior numbers of populations (table 1a). The only significant difference was that recovery of *endangered* species required a greater percentage of populations relative to what existed at plan writing than did *threatened* species (p = .009). The net result is that the *threatened* species had more populations at listing and at plan writing than did the *endangered* species, but the numbers would be brought into parity at delisting more through proportionally lower recovery

Table 1a. Differences between the numbers of populations required for recovery and the numbers that existed historically, at listing, and at plan writing for threatened *and* endangered *species.*

	Historically		At listing		At plan writing	
	Threatened	*Endangered*	*Threatened*	*Endangered*	*Threatened*	*Endangered*
Number of species with data	85	314	80	343	127	487
Percentage of species requiring fewer populations	51.8	38.9	27.5	12.2	27.5	16.6
Percentage of species requiring the same number of populations	36.4	18.5	47.5	16.0	44.1	15.4
Percentage of species requiring more populations	11.8	42.7	25.0	71.7	28.3	68.0
Median increase in the number of populations	3.0	4.0	3.0	5.0	3.5	4.0
Median percentage of populations represented by delisting objective for species with increases	200.0	200.0	230.8	266.7	181.8	266.7
Median decrease in the number of populations	10.5	6.0	7.0	4.0	11.0	5.0
Median percentage of populations represented by delisting objective for species with decreases	60.6	57.1	67.9	66.7	60.0	66.7
Overall median percentage of populations represented by recovery objectives	100	90	100	200	100	160

Table 1b. Differences between the numbers of individuals required for recovery and the numbers that existed historically, at listing, and at plan writing for threatened *and* endangered *species.*

	Historically		At listing		At plan writing	
	Threatened	*Endangered*	*Threatened*	*Endangered*	*Threatened*	*Endangered*
Number of species with data	4	16	30	261	44	329
Percentage of species requiring fewer individuals	75.0	75.0	30.0	4.6	45.4	9.4
Percentage of species requiring the same number of individuals	25.0	6.2	6.7	0.0	9.1	0.3
Percentage of species requiring more individuals	0.0	18.7	63.3	95.4	45.5	90.2
Median increase in the number of individuals	—	637	351.2	2301	2850	2200
Median percentage of individuals represented by delisting objective for species with increases	—	1200.0	315.4	856.3	175.5	1230.7
Median decrease in the number of individuals	92,651	3933	700	1000	2692	2200
Median percentage of individuals represented by delisting objective for species with decreases	19.3	23.0	78.8	73.3	51.7	48.9
Overall median percentage of individuals represented by recovery objectives	22.0	45.3	154.5	800.0	100.0	1000.0

objectives and greater declines for a larger percentage of the *threatened* species than through increases for the *endangered* species.

The number of individuals required for recovery. The median number of individuals required for delisting (Md = 2400, n = 423) exceeded the median number existing at listing (Md = 130, $p < .001$; n = 511) and at plan writing (Md = 304.5, $p < .001$; n = 676) but was not significantly different from the few values available for historical numbers (Md = 8002, $p < .14$; n = 36; figure 1b). The recovery objectives represented from 20% to 10,000% of the individuals known to exist at earlier time points (figure 2f–2h). The median values were strongly affected by Hawaiian plants, most of which required 2400 individuals for delisting (figure 2e). The median number of individuals required for delisting when Hawaiian plants were excluded (Md = 5000) was still significantly larger than the abundances at listing and plan writing ($p < .001$) and was still indistinguishable from the historical abundance (p = .55).

The extent of comparison for different taxonomic groups was limited by a lack of historical data for many species (especially invertebrates) and broad ranges of values for groups at other times (figure 3b). Generally, however, all groups required more individuals for delisting than existed at listing or plan writing (figure 3b).

Significantly ($p < .001$) fewer individuals were required in order to delist the *endangered* (Md = 2400, n = 359) than to delist the *threatened* (Md = 5000, n = 63) species. Although, on average, the *endangered* species could be recovered at 48% of the individual abundances of the *threatened* species, there was substantial variation in the number of individuals required for both the *endangered* (56–1,300,000 individuals) and the *threatened* (96–174,000 individuals) species. Excluding Hawaiian plants yielded increased median numbers of individuals necessary for delisting both the *endangered* (Md = 4000, n = 120) and the *threatened* species (Md = 8750, n = 56), still leaving the *endangered* species requiring around 45% of the number of individuals required for the *threatened* species. Despite the magnitude of this difference, it was not statistically significant (p = .145).

When we compared within the species using matched-pairs tests, the delisting objectives remained significantly higher than the abundances at listing and plan writing (p < .001) and were significantly lower than the historical abundance (p = .003). Of the 291 species with data, 7.9% required no more individuals for delisting than existed at listing, and 13.7% of 373 species required no more individuals than were known to exist when the recovery plan was written (figure 4b). Comparisons with historical abundances could be made for only 20 species, 17 of which required no more than the number of individuals known to exist historically. The median magnitude of decrease from the historical abundances would be 8900 individuals (leaving 22% of the original abundance), that from the time of listing would be 861 individuals (leaving 78% of the individuals), and that from the recovery plan writing would be 2600 individuals (leaving 48% of the individuals) (figure 4b, table 1b).

When the recovery objectives required more individuals than were known at earlier time periods, the median increase relative to historical (n = 3) was 637 individuals, relative to listing (n = 268) was 2301 individuals, and relative to plan writing (n = 317) was 2200 individuals, which yields increases of between 1200% and 2400% of the individuals at earlier time periods (figure 4b). More important, depending on the time frames being compared, a lack of data or quantitative objectives precluded the assessment of the relationships between the recovery objectives and the earlier abundances for 67%–98% of the 863 species with potential to be delisted.

As with the number of populations, a higher percentage of *threatened* than *endangered* species could be delisted with no more individuals than were known at listing and at recovery plan writing (both ps < .001; table 1b). The historical data were too sparse for statistical comparison: Recovery of 3 of the 4 *threatened* species and 12 of the 16 *endangered* species with data required fewer individuals than existed historically; the abundances would be 19%–23% of the historical abundances. When the recovery objectives allowed for decreased numbers of individuals relative to those at listing or plan writing, neither absolute declines (p = .775 and p = .678, respectively) nor the resulting percentages (p = .88 and p = .775, respectively) differed significantly between the *threatened* and the *endangered* species.

A significantly larger percentage of *endangered* than *threatened* species required more individuals for recovery than existed at listing (p < .001) and recovery plan writing (p < .001; table 1b). The absolute magnitude of increases required did not differ significantly by listing status (p = .24 from listing, p = .95 from plan writing), but the ultimate magnitude of the recovery objectives that would result from these increases was greater for the *threatened* species (ps < .001 for listing and plan writing), although the percentages of individuals required were greater for the *endangered* species (p = .001 for listing, p < .001 for plan writing; table 1b, figure 1b).

Delisted species: The recovery record

As of December 2009, 25 species had been delisted and categorized as *recovered*; 20 had recovery plans prior to their delisting. The number of populations required for delisting was stated in the recovery plans for 9 of the 20 species; the number of populations at delisting was clearly provided in the delisting documents for only 4 species, 3 of which also had population-based delisting objectives. Therefore, we could not compare the numbers of populations at delisting for 13 of the delisted species with plans, either because the population definitions in the listing and recovery documents did not match those in the delisting document or because the numbers were unclear or not provided.

The Douglas County DPS of the Columbian white-tailed deer (*Odocoileus virginianus leucurus*) met the delisting requirement of one population. The plant species *Helianthus eggertii* (Eggert's sunflower) required 20 secure populations for delisting and had 27, which was a subset of 287 known populations (USFWS 2005). The third species, the plant *Potentilla robbinsiana* (Robbins' cinquefoil), was delisted with four populations, although the recovery objective was five populations. Two of these populations were natural, and two were established through transplantation. After several failures, the USFWS concluded that locating habitat suitable for additional transplants was unlikely. Recovery efforts increased the size and extent of the two natural populations and, in combination with threat abatement through trail relocation and securing management agreements, was considered to have reduced extinction risk sufficiently to warrant the species' delisting (USFWS 2002).

The number of individuals at delisting (Md = 2360) was clearly provided for 17 of the 20 delisted species and ranged from 144 for the Arctic peregrine falcon to 52,596 for the US Atlantic Coast DPS of the brown pelican and to more than 12 million for the plant *Eriastrum hooveri*. Six species were delisted with less than 600 individuals; because all but one of these were DPSs, there was at least one additional population elsewhere and the total number of individuals at the species level would be higher. The numbers of individuals required for delisting and those at delisting were provided for 12 of the delisted species. In all cases, the number of individuals at delisting exceeded the recovery plan objective by 36 to 29,607 individuals, representing relatively small percentage excesses (0.1%–11.1%, Md = 1.1%).

Comparing recovery objectives with other benchmarks

On the basis of IUCN (2001) rankings for numbers of populations, only 131 of the 671 species with population-based objectives would have a high likelihood of ranking better than *vulnerable*; 55 species would be *critically endangered*, 144 would be *endangered*, and 341 would be *vulnerable*. Incorporating continued declines into the rankings for the 244 species for which recovery can be accomplished with further reductions in populations could yield higher risk categories. Rankings based on individual abundance (not considering decline) are much more encouraging: Only 1.4% of the 423 species with individual abundance as a recovery objective would be categorized as *endangered*; 18.0% would be *vulnerable*, and the rest would rank as *secure*. Lower rankings could result for the 51 species that could continue to decline in the number of individuals beyond what existed at plan writing and still meet recovery plan delisting objectives.

Seventy-three percent of the 89 vertebrates with recovery objectives stated as a number of individuals were below sizes that Reed and colleagues (2003) considered minimally viable (7360 individuals), and 68% were below the 5244 individuals suggested by Traill and colleagues (2007). Plant species fared even worse, with 90% of 324 species having objectives below the suggested minimum of 15,992 individuals (Traill et al. 2007). Three hundred sixty-three species of all taxa could be delisted with 10,000 or fewer individuals, the effective population size considered necessary to ensure long-term evolutionary capacity (Lynch and Lande 1998), and effective sizes are typically only a small fraction of census size (Frankham 2007).

Are things improving?

Comparisons between plans completed before and after December 1992 (the approximate cutoff date for prior reviews) indicate that the potential for delisting improved somewhat. The percentage of species that could not be delisted decreased from 38.8% prior to 1993 to 19.2% in later plans. However, there was increasing uncertainty because the number of species for which the USFWS claimed that the delisting might not be possible increased from 7% of the species prior to 1993 to 28.7% in the later plans. The number of species for which delisting was considered possible without qualification were equivalent before and after the prior reviews (54.1% and 52.1%, respectively).

Post-1992 plans required significantly more populations (eight versus five; $p < .001$), but the percentages of populations at listing and plan writing represented by these numbers did not differ because of commensurate increases in the median numbers of populations at listing (from one to three populations) and at plan writing (from two to four populations). The percentages of species that could be delisted with no more populations than existed historically, at listing, or at plan writing were also not significantly different. We found no significant difference in the number of individuals required for delisting ($p = .42$) in plans approved before and after our cutoff time. The percentages of historical abundance ($p = .56$) and at listing ($p = .22$) represented by these objectives also did not differ. The median percentage of individuals at plan writing required for recovery increased from 133% in earlier plans to 926% in the post-1992 plans ($p < .001$). This difference led to significantly ($p < .001$) more species with post-1992 plans that required more individuals than existed at plan writing (88.3%) than did species with earlier plans (61%).

A significantly higher percentage of species were ranked by the IUCN as *critically endangered* (14.5%) or *endangered* (39.1%) on the basis of recovery objectives for populations in pre-1993 plans than in later plans (6.6% and 16.9%, respectively; $p < .001$). Although the reduction in the higest-risk categories is heartening, the percentage of species that would rank as *secure* in later plans declined from 25.4% to 18.0%, and the percentage of species ranked as *vulnerable* rose from 21.0% to 58.5%. IUCN rankings based on the number of individuals also improved over time: 87% of the *endangered* rankings were from recovery objectives approved prior to 1993, and they represented 9% of the objectives from that time. Only one species after the 1992 cutoff would rank *endangered*, representing less than 1% of all species with plans from that time.

Conclusions

We found a number of key improvements in recovery potential that make us hopeful for the future for species listed under the ESA. In comparison with plans completed prior to previous comprehensive reviews (Tear et al. 1993, 1995, Wilcove et al. 1993, Schemske et al. 1994), a larger proportion of species in later plans have the potential to be delisted, more have at least one quantitative recovery criterion, the overall numbers of populations and individuals required for recovery would increase, and these numbers would exceed the numbers when the recovery plan was written for more species. The objectives for populations and individuals for species with plans completed after 1992 would translate to a reduction in the number of rankings in the highest IUCN risk category.

In other ways, however, little has changed since the prior reviews. Apparent improvements in the potential for delisting are accompanied by such great uncertainty that the USFWS states that delisting may not be possible for many species, despite a recovery plan's implementation. Delisting objectives for abundance remain on the lower end of the continuum of viability, with 68%–91% falling below published thresholds for the minimum numbers of individuals. In addition, 144 species could be considered *recovered* with even fewer populations than existed when the recovery plan was written; 51 species could decline in their numbers of individuals. IUCN (2001) rankings of *secure* for 81% of the species based on the number of individuals indicate that the objectives might be sufficient to prevent immediate extinction, but a comparison with other thresholds indicates that longer-term viability and evolutionary capacity are likely to be compromised, even when ongoing deterministic threats are not included in the analysis. The numbers of populations yield even less-optimistic IUCN rankings, with 81% of the species having recovery objectives that leave them *vulnerable*, *endangered*, or *critically endangered*.

We do not see this lack of change as a failure of the ESA itself. There are such severe barriers to recovery that the agencies consider delisting to be possible for only 73% of listed species, and improvements in this percentage since earlier reviews are the result of species for which there is great uncertainty about the true delisting potential. The two primary obstacles found in the previous studies remain: The first is that the data deficiencies noted by Tear and colleagues (1993) still preclude rigorously assessing extinction risk and establishing recovery objectives. Although around 90% of the species with potential for delisting have quantitative recovery objectives, the quantification of species decline is limited, because 46%–71% of these species lack population data, and 67%–98% lack individual abundance data either historically, at listing, or when the recovery plan was written. Despite the fact that curtailment in habitat and range are key threats evaluated for delisting (ESA sec. 4(a)(1)(A)), quantitative data on their amounts and extent are virtually nonexistent in recovery plans. We know from qualitative data that ranges have declined for 656 species (Leidner and Neel 2011), but without quantifying the extent and magnitude of those declines, it is difficult to understand whether extinction risks have been sufficiently alleviated in significant portions of these species' ranges to eliminate their need for protection under the ESA.

The second obstacle that remains unchanged since earlier reviews (Wilcove et al. 1993) is that species are not listed until their abundances are too low for a high likelihood of eventual recovery (figure 1). Extremely low abundances at the time of listing make measuring the success of the ESA solely in terms of delisting problematic. When ongoing declines that are allowed after listing are also considered, simply slowing extinction rates and improving the status of listed species are significant accomplishments and provide evidence that the ESA is working, albeit imperfectly (Schwartz 2008). Our findings that *threatened* species had more populations and individuals than did *endangered* species at listing and recovery plan writing (figure 1) and that the USFWS considers delisting possible for approximately 33% more *threatened* species indicates that *endangered* species (79% of all listed species) are far too close to extinction by the time they are listed to have a high potential for recovery even if threats are controlled.

Low abundances and continued declines are of concern, because extensive theory and empirical evidence confirm that the extinction risk is higher in small than in large populations (Frankel and Soulé 1981, Gabriel and Burger 1992, Ellstrand and Elam 1993, Blackburn and Gaston 2002), and the risk is higher to species with small than with large ranges (Gaston 1994, Channell and Lomolino 2000a, 2000b, He and Gaston 2003, Hemerik et al. 2006) and when there are small or declining numbers of populations (Hanski et al. 1995, Fox and Gurevitch 2000). Listed species are often at risk from both their initial natural rarity and their reduction from anthropogenic activities (figure 1), which makes aspects of both the small population and the declining population paradigms (Caughley 1994) relevant for recovery planning.

Despite clear theoretical predictions for the general risks of small and declining populations, there is little scientific guidance for exactly how many individuals and populations are sufficient for recovery (Neel and Cummings 2003, Svancara et al. 2005, Tear et al. 2005, Sanderson 2006, Neel 2008), and no specific abundance is appropriate across all taxa (Flather et al. 2011). Uncertainty arises in part because of the ESA's vague terminology. Given the ESA's definitions of *endangered* and *threatened species*, a species could be delisted when it is no longer likely to be "in danger of extinction." What remains unspecified is what "not in danger of extinction" means and what threshold is used to justify delisting (Goble 2009). Is this threshold met when abundances are the equivalent of zoo populations that will require ongoing husbandry (Shaffer 1981), when wild populations are minimally viable (Reed et al. 2003, Traill et al. 2007), when populations are ecologically viable (Peery et al. 2003, Sanderson 2006), or are abundances sufficient to conserve the evolutionary potential of the species necessary (Soulé 1980, Lynch and Lande 1998)? These scenarios represent decreasing degrees of the danger of extinction over time into the foreseeable future. Although there are examples of listed species with recovery objectives that fit each of these scenarios, more than 85% of the listed species are below all but the lowest threshold. We consider these suggested values to be general guidelines rather than prescriptions for absolute numbers of individuals (Flather et al. 2011), yet they provide strong evidence of great risk from abundances alone that could remain after "recovery." At these abundances, the prospects for establishing self-sustaining populations are poor, and ongoing management for the foreseeable future is likely, regardless of threat abatement (Scott et al. 2010).

Additional uncertainty arises because extinction risk involves interactions between intrinsic and extrinsic factors (Lee and Jetz 2011). Recovery is a question of more than just the numbers, because the threat context in which a species is embedded can result in different extinction risks from those of another species with the same abundance (Isaac and Cowlishaw 2004). The USFWS heavily weighs five threat factors (ESA 4(a)(b)) when determining endangerment and recovery status and treats abundance as a surrogate for the reduction of threats (Goble 2010); recovery is not achieved until the threats to the species are mitigated or managed (Goble 2009). Abundances are the objective, measurable criteria that document an improved status resulting from threat abatement.

We know that starting from extremely low abundances (figure 2) will limit the potential for persistence and growth, but how a particular change in the number of individuals or populations translates into a change in extinction risk given a species' biology and the threat context in which it is situated is still not understood. The IUCN (2001) evaluation process has contributed greatly to qualitatively linking abundance and threats to risk, but quantitative links are lacking. Determining the magnitude of changes in risk that would result from threat abatement is even more difficult and, to date, has not been attempted in recovery plans. Even quantifying the magnitude of threat abatement achieved by any particular recovery action is problematic. Short of having quantitative links among recovery objectives, threats, and extinction risk, recovery plans would be greatly improved if they better articulated the logic for requiring particular abundance values and for linking abundances and reduction of particular threats.

Despite the uncertainty described above, the intrinsic extinction risk is lower when individual and population abundances are higher, and reducing threats should yield increased abundances by stopping or reversing declines. Therefore, it is logical to expect most species to be no less abundant at recovery than they were at listing or plan writing (i.e., when they were considered to be at risk of extinction). Previous reviews of recovery plans documented a widespread failure to meet this expectation, and we found a mixed record since those assessments. Tear and colleagues (1993) reported that recovery could be achieved for 37% of 163 species with no more populations than existed at plan writing; we found this to be the case for 40% of 614 species, and we found no significant difference in the plans approved after their review. We did find significantly more species requiring more individuals than during previous time periods, but this recovery objective was not evaluated in previous reviews.

The differences between *threatened* and *endangered* species highlight the complexities of the intersection among prior rarity, continued declines, and recovery. The *threatened* species had more populations and individuals at listing and plan writing, and their recovery required twice the number of individuals that the *endangered* species' recovery required, but the number of populations required for recovery did not differ (figure 1). The higher-number-of-individuals recovery objectives may be driven largely by the abundances at listing and plan writing (Elphick et al. 2001); they may also result from greater habitat availability if habitat destruction has not proceeded as far as it has for the *endangered* species. The relatively positive outlook for *threatened* species is tempered, however, because a disproportionate number of *threatened* species would be allowed to decline on their way to meeting recovery objectives, and their numeric recovery objectives overall reflected smaller percentages of prior abundances. In fact, around six times more of the *threatened* species than of the *endangered* species would be considered *recovered* with fewer individuals than occurred at earlier time points (ranging from 19% to 79% of the numbers of individuals previously known; table 1b). Two to three times more of the *threatened* than of the *endangered* species required no more populations than existed at listing and plan writing, and the magnitudes of decline for the *threatened* species in these cases were around 1.8–2 times those of the *endangered* species (table 1b). At the same time, more *endangered* species would require increases that would yield larger population sizes relative to those at plan writing. The summary effect of two opposing trends is that the *threatened* species' abundances would approach those of the *endangered* species at delisting primarily through declines that negate the benefits of having greater abundances at listing.

We are intrigued by the finding of greater improvement in the requirements for the numbers of individuals than for populations. This differential improvement may reflect the fact that much less attention has been paid to quantifying the effects of different numbers of populations on extinction risk. It could also be due to the rationale that losing small, nonviable populations while reducing threats facing the remaining larger, more viable populations could sufficiently reduce extinction risk in some situations to result in *recovery*. We question, however, whether sufficient risk reduction would result for all 247 species that would be considered *recovered* after the extirpation of populations that existed at plan writing (table 1a). Even if continuing threats are abated, population numbers, individual abundance, and the extents of range and habitat may be so curtailed after continued losses (factor A in the five-factor analysis) that species remain at high risk of extinction throughout all or a significant portion of their range because of natural factors (factor E). Such species would not have a high likelihood of persisting without the provisions of the ESA and, therefore, would not meet the requirements for delisting.

We also found the magnitude of declines relative to the historical numbers of populations that can represent recovery to be sobering. Although restoration to preendangerment levels is not required to prevent extinction, it is hard to understand how a species with only a small percentage of its original number of populations would not remain at high risk of extinction throughout all or a significant portion of its range or how the provisions of the ESA would not be required even if extrinsic threats were reduced in the remaining locations. Historical numbers also provide benchmarks for the degree and magnitude of declines. Without such data, we are at risk of accepting a shifting baseline of abundance (Pauly 1995) without fully acknowledging or understanding the consequences of the diminished expectations.

Of as much concern as the generally low abundance values that define *recovery* is the order-of-magnitude variation in absolute and relative abundances considered sufficient for recovery (figure 2, table 1a and 1b). For example, although the USFWS did not delist the bald eagle (*Haliaeetus leucocephalus*) until its range was larger than it was at the time of the arrival of the first European settlers (Buehler 2000), the agency has repeatedly sought to delist the gray wolf (*Canis lupus*) and categorize it as *recovered*, despite the facts that it occupies less than 5% of its historical range in the lower 48 states and that its population is similarly diminished

(USFWS 2003, 2007, 2009a, 2009b). Although the acceptability of the smaller percentage of the range occupied by wolves may be due to a lack of suitable habitat in much of their historical ranges, reports suggest that it more likely results from societal intolerance of their recovery over a large area due to conflicts between wolves and livestock (Bangs and Shivik 2001, Gunther et al. 2004) and due to competition between wolves and hunters for big-game species. Recovery teams consider such factors in specifying the conditions for delisting. Even beyond incorporating social values, the teams necessarily make normative decisions in setting recovery objectives, because those objectives are based on the degree of risk that is acceptable in delisting a species (Vucetich et al. 2006). Until the agencies develop a policy on acceptable risk that is quantified in an objective and measurable framework, the wide variation of recovery goals that we observed is inevitable.

As was found in prior reviews, abundance-related recovery objectives are far more frequently specified as the number of populations and individuals than as the amount of habitat or range; probabilistic assessments of persistence over time are nearly nonexistent (they exist for around 3% of the species). This focus on populations and individuals could be interpreted as a bias toward demographics and away from conserving "the ecosystems upon which [listed] species depend" (ESA sec. 2(b)) or from assessing the significance of the portion of the range in which a species is threatened or endangered (ESA secs. 3(6), 3(20)). However, demographic measures are the most basic quantities necessary for understanding population trajectories and the probabilities of persistence, and even they are lacking for many species. Recovery plans qualitatively incorporate habitat conservation by specifying that the populations selected for conservation represent the ecological and geographic range of the species or are distributed in different management units or geographic areas. In addition, recovery strategies commonly specify habitat protection and management actions that are required to meet the demographic objectives. Although it was not possible to quantify such statements and strategies as a specific amount of habitat or range, qualitative statements may facilitate the conservation of the ecosystems on which species depend, thus meeting the intent of the ESA (ESA sec. 2(b)). Establishing objective and measurable criteria for habitat and range would improve the likelihood of such conservation and would reduce the risk of endangerment such that species are no longer in danger of extinction throughout all or a significant portion of the range (ESA sec. 3(6)) or to become so in the foreseeable future (ESA sec. 3(20)).

In summary, our findings suggest that the recovery objectives for many of the 1173 species with recovery plans are too low to ensure those species' long-term persistence. The numbers of individuals and populations of most of the species were lower than the levels suggested for maintaining ecological viability or evolutionary potential. Recovery abundances may prevent extinction in the short-term but are unlikely to remove the need for continuing conservation management. We are particularly concerned with the number of species that would continue to decline in abundance on the way to "recovery." For a few species, removing threats alone might reduce their extinction risk to levels sufficient for delisting, with no increase in abundance or distribution. For most species, however, continuing declines are likely to increase the need for ongoing management interventions to maintain their abundances and distributions above those required to prevent relisting. Substantial advances in the practical understanding of the links among demography, a species' biology, and anthropogenic threats are necessary to improve the recovery process. Even without this understanding, recovery plans would be improved through a clearer articulation of the logic for choosing particular abundances and of the relationships between those abundances and threats.

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