Correlates of Population Recovery Goals in Endangered Birds

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Abstract: *Endangered species recovery plans commonly set goals for population size that are used to define the success of recovery efforts. We examined variation in these population recovery goals for bird species listed under the U. S. Endangered Species Act to determine whether there were simple predictors of recovery population size. The median population sizes that must be met for a species to be removed from the list or downlisted to the threatened category are 4000 and 1500 respectively, but the thresholds varied considerably. Most variation in population recovery goals (≥75%) was explained by the population size when the recovery plan was written. Species listed when their population's size was relatively large have higher population recovery goals, whereas those listed when populations were small have lower population goals. Population sizes set for recovery also increased over time and were higher for species listed throughout the United States rather than for part of the country. In combination, these three variables explained 86% of the variance in population goals for delisting and 94% of the variance in goals for downlisting. Body mass, annual fecundity, maximum lifespan, whether the population was listed as threatened or endangered, and whether a formal population viability analysis was conducted were variables not significantly associated with population recovery goals. Thus, we found that variables relating to the circumstances under which the populations were listed could explain almost all of the variance in recovery population goals, and that biological traits of the endangered birds explained little of the variance.*

Correlaciones de Metas de Recuperación en Aves en Peligro

Resumen: *Los planes de recuperación de especies en peligro comúnmente establecen tamaños de poblaciones como metas que serán empleados para definir el éxito de los esfuerzos de recuperación. Examinamos la variación en estas metas para la recuperación de poblaciones para especies de aves enlistadas bajo el Acta de Especies en Peligro de los Estados Unidos para determinar si fueron estimadores simples del tamaño poblacional de recuperación. Las medianas de los tamaños poblacionales que deberían ser alcanzados para que una especie sea removida de las listas o para ser enviada a la categoría de especie amenazada fueron de 4000 y 1500 respectivamente, pero existió mucha variación. La mayoría de la variación en las metas de recuperación de poblaciones (≥75%) fue explicada por el tamaño poblacional presente cuando se escribió el plan de recuperación. Las especies enlistadas cuando sus tamaños poblacionales fueron relativamente grandes tienen metas de recuperación poblacional más altas, mientras que aquellas enlistadas cuando los tamaños poblacionales eran pequeños tienen metas poblacionales más bajas. Los tamaños poblacionales establecidos para la recuperación también incrementaron con el tiempo y fueron más altos para especies enlistadas a lo largo de los Estados Unidos que para aquellas enlistadas para una parte del país. En combinación, estas tres variables explicaron 86% de la varianza en las metas para remover especies de las listas y 94% de la varianza para las metas de cambio de categorías. La masa corporal, la fecundidad anual, la longitud máxima de vida, la condición de la especie de haber sido enlistada como en peligro o amenazada y el existir o no un análisis de viabilidad poblacional formal no fueron variables que estuvieran asociadas significativamente con las metas de recuperación poblacional. Por lo tanto, encontramos que podemos explicar casi toda la varianza de las metas de recuperación poblacional en base a variables relacionadas con las circunstancias bajo las cuales las poblaciones fueron enlistadas y que las características biológicas de las aves en peligro explicaron poco de la varianza.*

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Introduction

Since at least the 1930s, it has been thought that a population is increasingly likely to go extinct if its size drops below some threshold (Allee 1931; Leopold 1933), and maintaining population sizes above this threshold has become central to endangered species management. Modern attempts to estimate a minimum viable population size (MVP; Shaffer 1981) suggest that several thousand individuals are required for the long-term persistence of a typical population (e.g., Thomas 1990; Nunney & Campbell 1993; Franklin & Frankham 1998). Under the U. S. Endangered Species Act (ESA), explicit goals defining the recovery of endangered species must be set, and goals often include a target population size (Bonta 2000). In principle, the target for downlisting from the endangered to the threatened category should be the population size above which the species is no longer threatened with immediate extinction. The target for removing a species from the list entirely should be the population size above which the species is unlikely to become threatened with immediate extinction in the near future (ESA 1973). In other words, the recovery population size should be at least the MVP.

Rigorous scientific assessment of MVPs is extremely difficult because adequate data typically are lacking for rare taxa (e.g., Green & Hirons 1991). Endangered species in the United States are among the best studied in the world. Thus, correlates of recovery sizes for these species might facilitate the development of recovery plans for poorly known species worldwide, but only if recovery sizes are biologically based and adequately protect species against extinction. If simply measured biological traits such as body size were correlated with recovery goals, then they would be especially useful in setting initial recovery goals that could later be refined through a more comprehensive assessment.

Many authors have hypothesized that extinction risk is related to biological traits of an organism such as body mass, fecundity, and generation time (Pimm et al. 1988; Tracy & George 1992; Gaston & Blackburn 1995, 1996, 1997; Bennett & Owens 1997; McKinney 1997; Beissinger 2000; Owens & Bennett 2000; Purvis et al. 2000). Because a species' risk of extinction increases as its population size declines, one might also expect these traits to be correlated with recovery goals. Species with traits that predict a high extinction risk should have higher population recovery goals than those with traits that predict a low extinction risk. Such a relationship could arise in two ways: (1) because the recovery goals reflect a real underlying relationship between the biological traits and extinction or (2) simply because the hypothesized relationship influences the setting of goals.

The predicted relationships between extinction risk and biological characteristics, however, are controversial and complex. Empirical studies have produced mixed evidence for proposed correlations, and theoretical relationships are often contradictory (Beissinger 2000). For example, species with large bodies and long generation times may be most vulnerable to extinction because they cannot recover quickly following a population decline. On the other hand, species with small bodies and short generation times could be most vulnerable because their populations are more likely to experience large fluctuations in size (Beissinger 2000). Recovery goals could reflect either of these hypotheses, or they could reflect the ambiguity of the proposed relationships.

For population recovery goals to be useful, they should accurately reflect the population size required for minimizing extinction risk. Tear et al. (1993) found that population targets were sometimes smaller than the population size when an organism was placed on the endangered species list and thus suggested that population goals are not always biologically defensible. Similarly, Schemske et al. (1994) found that recovery goals for endangered plant populations were rarely based on the biological status of the species and that collection of demographic information relating to the species' population dynamics was rarely proposed in recovery plans. They concluded their review by suggesting that plant recovery criteria were "little more than guesswork" (Schemske et al. 1994). Nonetheless, they found that population goals were somewhat predictable: the number of populations required for an endangered plant to be removed from the endangered species list was strongly correlated with the number of existing populations. This relationship suggests a systematic, albeit not necessarily biological, basis for setting recovery goals. Further analysis of this type could elucidate the factors that underlie the setting of recovery goals in practice, thus providing an informed basis for improving existing procedures.

We examined the relationships between population recovery goals and a variety of variables for bird species listed under the ESA. We tested whether three widely available biological characteristics that have been associated with extinction risk (body size, annual fecundity, and longevity) could be used to predict recovery goals. We hypothesized that recovery goals might change in a systematic manner over time. The size of populations in theoretical estimates of MVP have increased over the last two decades (Franklin & Frankham 1998), so recovery goals might also have increased to reflect this change. Recovery goals might also be influenced by the status of a species or the approach taken in developing its recovery plan. Thus, we also tested whether population goals were systematically related to a species' population size, its designated status under the ESA, the geographic scope of its endangerment, and whether or not a population viability analysis was conducted. Although many other factors might also influence recovery goals, we chose to restrict our analysis to variables that we felt could be objectively and unambiguously quantified and that were available for enough species to allow statistical analysis.

Table 1. Endangered bird species with recovery plans used in this study to obtain information on recovery population goals and characteristics of those species and their plans.

Listed population[a,b]	*Year listed*	*Year of recovery plan*	*Listing status*[c]	*Recovery plan objective*	*Population viability analysis*	*Population when plan written*	*Population goal*
California Brown Pelican (*Pelecanus occidentalis californicus*)	1970	1983	E	delist	no	7020	6000
Wood Stork (*Mycteria americana*)	1984	1997	E	delist	no	12000	20000
Wood Stork (*Mycteria americana*)	1984	1997	E	downlist	no	12000	12000
California Condor (*Gymnogyps californianus*)	1967	1996	E	downlist	yes	103	450
Aleutian Canada Goose (*Branta canadensis leucopareia*)	1967	1991	T	delist	no	7000	7500
Everglade Snail Kite (*Rostrhamus sociabilis plumbeus*)	1967	1999	E	downlist	yes	562	650
Bald Eagle (*Haliaeetus leucocephalus*), Chesapeake Bay population	1967	1990	E	delist	no	396	700
Bald Eagle (*Haliaeetus leucocephalus*), northern states population	1967	1983	E	delist	no	1140	2400
Bald Eagle (*Haliaeetus leucocephalus*), Pacific population	1967	1986	E	delist	no	1054	1600
Bald Eagle (*Haliaeetus leucocephalus*), Chesapeake Bay population	1967	1990	E	downlist	no	396	426
Bald Eagle (*Haliaeetus leucocephalus*), southeastern states population	1967	1989	E	downlist	no	1076	1200
Audubon's Crested Caracara (*Caracara cheriway audubonii*)	1987	1999	T	delist	no	400	600
Northern Aplomado Falcon (*Falco femoralis septentrionalis*)	1986	1990	E	downlist	no	unknown	120
Attwater's Prairie Chicken (*Tympanuchus cupido attwateri*)	1967	1993	E	delist	no	456	5000
Attwater's Prairie Chicken (*Tympanuchus cupido attwateri*)	1967	1993	E	downlist	no	456	3000
Light-footed Clapper Rail (*Rallus longirostris levipes*)	1970	1985	E	downlist	no	554	1600
Yuma Clapper Rail (*Rallus longirostris yumanensis*)	1967	1983	E	delist	no	850	850
Whooping Crane (*Grus americana*)[d]	1967	1994	E	downlist	yes	90	180
Piping Plover (*Charadrius melodus*), Atlantic Coast population	1985	1996	T	delist	yes	2700	4000
Piping Plover (*Charadrius melodus*), Great Plains population	1985	1994	T	delist	yes	2972	8600
Piping Plover (*Charadrius melodus*), Great Lakes population	1985	1994	E	downlist	no	34	300
California Least Tern (*Sterna antillarum browni*)	1970	1985	E	delist	no	2479	2400
Least Tern (*Sterna antillarum*), interior population	1985	1990	E	delist	no	5000	7000
Roseate Tern (*Sterna dougallii dougallii*), northeast population	1987	1998	E	delist	no	6764	17000
Roseate Tern (*Sterna dougallii dougallii*), northeast population	1987	1998	E	downlist	no	6764	10000
Least Bell's Vireo (*Vireo bellii pusillus*)	1986	1998	E	delist	yes	2692	8400
Least Bell's Vireo (*Vireo bellii pusillus*)	1986	1998	E	downlist	yes	2692	6600
Black-capped Vireo (*Vireo atricapillus*)	1987	1991	E	downlist	yes	unknown	9000
Kirtland's Warbler (*Dendroica kirtlandii*)	1967	1985	E	delist	no	434	2000
Inyo California Towhee (*Pipilo crissalis eremophilus*)	1987	1998	T	delist	no	200	400
Florida Grasshopper Sparrow (*Ammodramus savannarum floridanus*)	1986	1999	E	downlist	no	800	1500
Cape Sable Seaside Sparrow (*Ammodramus maritimus mirabilis*)	1967	1999	E	downlist	no	3056	6600

[a]*Recovery plans for the following species were excluded from this analysis either because no recovery population goal was given or because the recovery objectives did not include changing the listing status of the population: Eastern Brown Pelican (* Pelecanus occidentalis carolinensis*); Bald Eagle, southwestern population; Masked Bobwhite (*Colinus virginianus ridgwayi*); California Clapper Rail (* Rallus longirostris obsoletus*); Mississippi Sandhill Crane (*Grus canadensis pulla*); Roseate Tern, Caribbean population; Marbled Murrelet (* Brachyramphus marmoratus*); Mexican Spotted Owl (*Strix occidentalis lucida*); Northern Spotted Owl (*Strix occidentalis caurina*); Red-cockaded Woodpecker (* Picoides borealis*); San Clemente Loggerhead Shrike (* Lanius ludovicianus mearnsi*); Florida Scrub-Jay (*Aphelocoma coerulescens*); Golden-cheeked Warbler (*Dendroica chrysoparia*); and San Clemente Sage Sparrow (*Amphispiza belli clementeae*).*

[b]*Endangered species for which there were separate goals for downlisting to the threatened category and for removal from the endangered species list entirely were used in both analyses and are listed twice.*

[c]*Abbreviations: E, listed as endangered; T, listed as threatened.*

[d]*Population size expressed in terms of breeding birds only in concordance with recovery goals.*

Our analysis was based on data compiled during a review of bird recovery plans (Bonta 2000). In this review, the most recent recovery plans were read for each species, subspecies, or population of bird listed under the ESA in the 48 contiguous United States. For each plan, the criteria by which the species would be considered recovered and the factors used to determine these criteria were described and summarized. Biologically based recovery criteria were present in all plans, although the type of criteria varied. For example, all plans included recovery criteria based on habitat management, but only 68% included explicit population goals. Moreover, many plans were judged to be out of date and failed to reflect the latest scientific or policy information (Bonta 2000). Here, we extend one aspect of Bonta's study and determine which factors are related to explicit population recovery goals.

Methods

We based our analysis on data compiled during a review of all 41 recovery plans for bird populations in the contiguous United States (Table 1) that were completed by 1999 (Bonta 2000). Twenty-seven of these plans (66%) included numeric population goals for removal or downlisting from the endangered species list; these plans provided the basis for this analysis. Seventeen plans provided goals for population size that need to be met for the population to be removed from the endangered species list, and 15 provided population goals for downlisting an endangered species to the threatened category. Five plans had goals for both actions.

We used univariate tests and multiple regression to evaluate sources of variation in population recovery goals. We conducted separate analyses for delisting and downlisting goals. In each case, we determined whether there were significant relationships between recovery goals and (1) body mass, (2) annual fecundity, (3) maximum lifespan, (4) year the recovery plan was written, (5) listing status—whether the population was listed as threatened or endangered, (6) whether or not a population viability analysis had been conducted, (7) whether or not the listed population was part of a species considered endangered throughout the United States, and (8) population size at the time the recovery plan was written.

Body-mass data were taken from Dunning (1993) and Poole and Gill (1992–2000). For sexually size-dimorphic species, we used the mass for the larger sex. For species with geographic variation in body size, we used the mass for the population to which the recovery plan referred. Data on annual fecundity and maximum lifespan were compiled from Poole and Gill (1992–2000) and del Hoyo et al. (1992–1999). Annual fecundity was defined as the average number of eggs laid or the midpoint if only the range of values was known. Maximum lifespan was used as a surrogate for average annual survival rate, which is unknown for most species. The year the recovery criteria were set, the listing status of each species, whether or not a population viability analysis had been conducted, the geographic scope of endangerment, and the existing population size were determined from the recovery plans (summarized by Bonta 2000). Whenever population sizes were given as a range of values, we used the midpoint of the range.

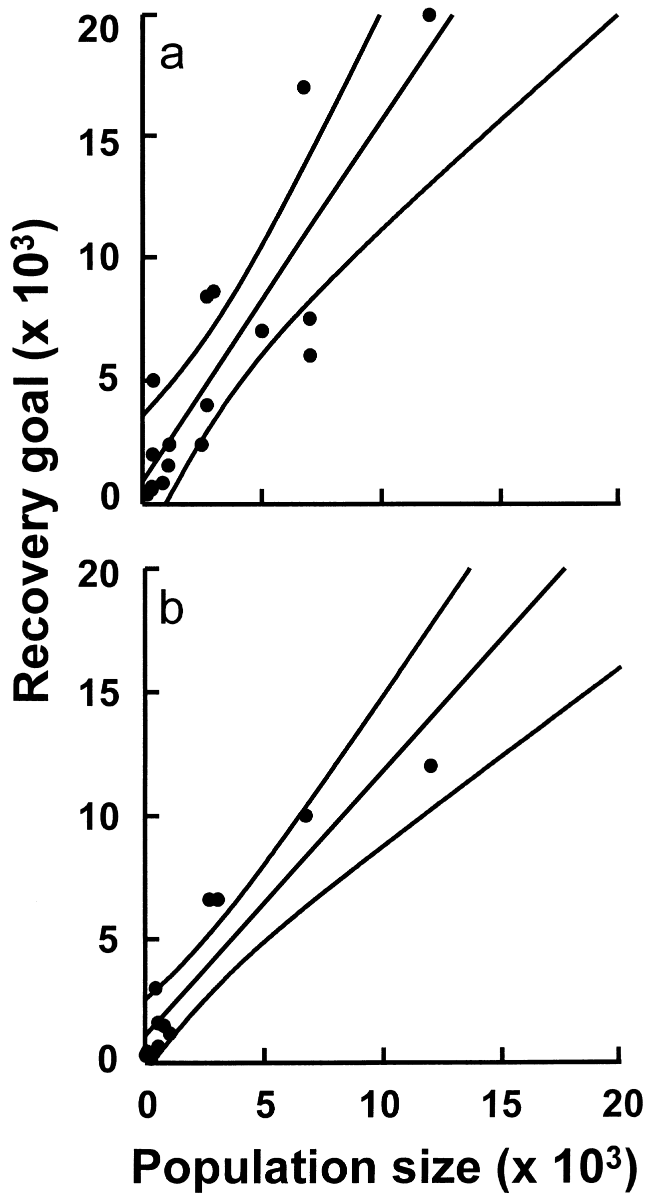

Figure 1. Relationship between an endangered bird's population size when a recovery plan is written and the target population sizes used to define recovery: (a) population goals for removal from the endangered species list and (b) population goals for downlisting from endangered to threatened status. Regression lines and 95% confidence intervals are shown.

Results

Population goals for removing a species from the federal endangered species list ranged widely, from 400 (Inyo California Towhee) to 20,000 (Wood Stork), with a mean of 5556 (SE = 1370; 95% confidence interval: 2651–8461) and a median of 4000 (Table 1, scientific names provided therein). Similarly, population goals for downlisting a species from endangered to threatened status ranged from 120 individuals (Northern Aplomado Falcon) to 12,000 (Wood Stork and Black-capped Vireo), with a mean of 3575 (SE = 1061, 95% confidence interval: 1299–5852) and a median of 1500 (Table 1). In both cases, the distribution of population goals was skewed, and most goals were smaller than the mean value.

The single best predictor of the population recovery goal was the listed population's size at the time the recovery plan was written (Fig. 1). In univariate analyses, this variable accounted for three-quarters of the variance in population goals for delisting (recovery population goal = 931 + [1.47 × extant population size], $r^2 = 0.75$, $n = 17$, $p < 0.001$; Table 2) and even more of the variance in population goals for downlisting (recovery population goal = 1045 + [1.08 × extant population size], $r^2 = 0.86$, $n = 13$, $p < 0.001$; Table 2). When considered alone, none of the other variables examined was significantly associated with population goals for downlisting ($p > 0.20$ in all cases; Table 2). Two other variables, however, were significantly associated with the population goal for delisting. On average, recovery population sizes increased over time and were higher for species listed throughout the United States (Table 2). For both delisting and downlisting population goals, the multivariate model that best explained the data included both of these variables in combination with the population size at the time of the plan. In both cases all three variables were significant at $p < 0.10$; these models explained 86.4% and 94.4% of the variance in recovery population goals, respectively (Table 3).

Discussion

Two conclusions can be drawn from these results. First, the analysis demonstrates that, on average, bird populations must number at least in the several thousands before they are thought to be sufficiently large for removal from the endangered species list. Thus, minimum population sizes considered acceptable for North American bird populations are broadly in line with theoretical estimates of MVP (e.g., Thomas 1990; Nunney & Campbell 1993; Franklin & Frankham 1998). Variation in population recovery goals, however, spans two orders of magnitude.

The second conclusion concerns the reasons for variation among the recovery goals proposed for different populations. Ideally, such variation should reflect differences among species or populations, which result in differences in vulnerability to extinction. If this were the case, then the predictor variables could be used to extrapolate population recovery goals to those species to which considerable attention has not yet been paid. Biological characteristics can be important determinants of extinction risk (Beissinger & Westphal 1998; Reed et al., unpublished data) and might explain variation in MVP and thus recovery goals. In our analysis, however, we found that none of the biological traits examined (mass, fecundity, and longevity) explained variation in population recovery goals. This lack of relationship between variables and recovery goals could mean that they do not influence extinction risk, perhaps because the idiosyncratic details of each species' situation have primacy or because some other variable needs to be accounted for first (e.g., cause of endangerment; Owens & Bennett 2000). Alternatively, the nonsignificant results might indicate that recovery goals do not accurately reflect variation in the vulnerability of different species. In either case, this analysis provides no basis for setting recovery goals based on a simple assessment of a species' biological characteristics in cases where a major recovery assessment has not been completed.

Table 2. Results of univariate tests used to evaluate variation in population recovery goals for endangered North American birds.

	Downlisting population goals			*Delisting population goals*		
	test statistic[a]	df	p	*test statistic*[a]	df	p
Body mass	1.722	1,13	0.212	0.301	1,15	0.591
Annual fecundity	0.081	1,13	0.780	0.131	1,15	0.722
Maximum life span	1.320	1,12	0.273	0.019	1,15	0.892
Year of plan	1.779	1,13	0.205	3.431	1,15	0.084
Listing status[b]	N/A	N/A	N/A	0.617	15	0.547
Population viability analysis	0.128	13	0.900	−0.476	15	0.641
Broad-scale endangerment[c]	0.283	13	0.782	−2.625	15	0.019
Current population size[d]	69.378	1,11	<0.001	44.911	1,15	<0.001

[a]*The* F *ratio is given for continuous variables,* t *statistic for categorical variables.*
[b]*Listing status could not be related to downlisting population goals because, by definition, all species that could be downlisted are endangered and none are threatened.*
[c]*Defined as whether or not the species was listed throughout the United States or for just a limited portion of its range.*
[d]*Defined as the estimated population size at the time the recovery plan was written.*

Table 3. Results of significance tests from multiple-regression models that best accounted for variation in population recovery goals for endangered North American birds.

	Downlisting population goals			*Delisting population goals*		
Explanatory variables	F	*df*	p	F	*df*	p
Year of plan	4.497	1,9	0.063	4.220	1,13	0.061
Broad-scale endangerment[a]	10.865	1,9	0.009	3.652	1,13	0.078
Current population size[b]	111.612	1,9	<0.001	45.547	1,13	<0.001

[a]*Defined as whether or not the species was listed throughout the United States or for just a limited portion of its range.*
[b]*Defined as the estimated population size at the time the recovery plan was written.*

Although biological characteristics of the species could not be used to predict population recovery goals, it was possible to explain almost all the variance in these goals with other variables. The single overriding variable influencing recovery goals was the size of the population at the time the recovery plan was prepared. The relationship between these two variables was highly significant and explained the majority of the variation in population goals. This result mirrors that found during a similar analysis of plant recovery plans (Schemske et al. 1994). In this earlier analysis, there was a highly significant relationship between the target number of populations required for delisting of a species and the existing number of populations. As in our study, much of the variance in delisting goals was explained by this single variable ($r = 0.73$, $p < 0.0001$, $n = 70$; Schemske et al. 1994). Such similar results for independent analyses of birds and plants strongly suggest parallels in the process of setting recovery goals for endangered species in these disparate taxonomic groups.

Three hypotheses could account for the relationship between population size at the time a plan is written and population recovery goals. First, it is possible that the relationship has a biological basis and that differences in population size when populations are listed and the recovery goals set for those populations reflect vulnerability to extinction. In other words, species that are listed while they still have relatively large populations might genuinely require larger populations to stave off extinction than do species that are not listed until they have relatively small populations. A second possibility is that, in the absence of adequate data to estimate MVP, teams developing recovery plans might simply decide on population targets that increase populations by some “reasonable” amount, and there might be consistency in the proportionate increase that seems reasonable. Finally, when setting population goals, teams might be influenced by their assessment of what management actions are feasible. For example, teams developing a recovery plan for a small population restricted to a tiny range might view a recovery goal of several thousand individuals to be hopelessly implausible. Thus, they might (consciously or unconsciously) set lower recovery goals even if the best available science suggests that such a small population would continue to be vulnerable to extinction.

We know of no evidence for or against any of these hypotheses. The first explanation would be supported if formal population viability analyses accounted for the relationship, but such analyses have been conducted for few of the species we considered (Table 1; Bonta 2000). Less formal assessments of the ecological factors influencing the vulnerability of each species could also account for the observed relationships, but testing this hypothesis would be difficult. The remaining hypotheses suggest that population goals for endangered species recovery are subject to human impressions of the level of protection that is necessary or plausible, rather than a purely biological assessment of MVP. Distinguishing among these three explanations would provide valuable insight into the process by which recovery goals are set, which in turn might help make the process more rigorous and repeatable.

We also found that two other variables were significantly associated with recovery population goals. The increase in population goals over time is concordant with increases in theoretical estimates of MVP size (e.g., Franklin & Frankham 1998), but it could also result from a more subjective shift in opinion as concerns about increasing extinction rates mount. Higher recovery goals for species endangered throughout the United States suggest that species viewed as likely to become extirpated from the entire country are viewed with more concern than species that are less widely endangered.

In summary, we found no evidence that recovery population goals for endangered birds under the ESA are associated with biological traits. In contrast, however, we found that three variables relating to the circumstances under which the populations were listed and the recovery plans written explain almost all variation in recovery goals. Improving the goal-setting process depends on distinguishing among alternative hypotheses that could explain these results. For example, if the population size at the time a plan is written were truly a good indicator of MVP, then we could conclude that the current system is working well. Alternatively, if recovery goals are determined by the recovery team’s perception of how much the population can be increased given available resources, then goals will lack an appropriate biological basis. A solution to this problem is to require recovery teams to explain the biological basis for recovery goals and to describe explicitly the extent to which they have considered the logistical opportunities for recovery when setting goals. Only by studying the way conservation practitioners make decisions about recovery goals can we address these issues.

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