Geographic Patterns of At-Risk Species

Curtis H. Flather, Michael S. Knowles, and Jason McNees

A Technical Document Supporting
the USDA Forest Service Interim Update of the 2000 RPA Assessment

U.S. Department of Agriculture   Forest Service

Abstract

This technical document supports the Forest Service's requirement to assess the status of renewable natural resources as mandated by the Forest and Rangeland Renewable Resources Planning Act of 1974. It updates past reports on the trends and geographic patterns of species formally listed as threatened or endangered under the Endangered Species Act of 1973. We compare the geographic occupancy of threatened and endangered species at the county-level against the geographic occupancy of a broader set of species thought to be at risk of extinction. This is done to determine if new areas where species rarity may be concentrated emerge. Here we document whether past trends and geographic occupancy patterns have changed over time, thereby providing resource planners and conservation practioners with updated information on where they should focus biodiversity conservation efforts.

Keywords: at-risk species, conservation hotspots, coterminous United States, listing trends, threatened and endangered species, wildlife assessment

Authors

Curtis H. Flather, Research Wildlife Biologist, U.S. Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Michael S. Knowles, Information Systems Analyst, Anadarko Industries, LLC, Fort Collins, CO.

Jason McNees, Conservation Data Specialist, NatureServe, Arlington, VA.

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Introduction

Given a collection of organisms sampled from a specific region, one will find that most **individuals** are clustered among very few species, while most **species** are characterized by very few individuals. Why this distribution of species abundances is so regularly observed among different taxonomic groups in geographically diverse systems has received considerable theoretical and empirical investigation (Harte and others 1999, Hubbell 2001). Understanding the mechanisms leading to the pattern of few common and many rare species will not only provide insight into community assembly, but will also be of great practical importance to species conservation.

Conservation science is concerned with anticipating how natural or human-caused disturbances to ecosystems affect the pattern of commonness and rarity (particularly rarity) in the biota inhabiting that system (Lubchenco and others 1991). Because budgets for biodiversity conservation are limited, a common strategy for allocating resources has been to focus on the subset of species thought to have the highest extinction risk (Sisk and others 1994, Flather and others 1998). All other things being equal, rare species will have a greater extinction risk than common species (Pimm and others 1988, Johnson 1998). Small populations are more likely to be impacted by chance demographic and environmental events such as failure to find a mate, diseases, flooding, and fires (Boyce 1992, Mangel and Tier 1994). Genetic simplification also has the potential to reduce population viability in a number of ways. In addition to reducing a species' ability to adapt to changing environmental conditions, a loss of genetic diversity can lead to higher rates of inbreeding or outbreeding and to the chance expression of deleterious genes (Wright 1977, Rieseberg 1991, Ellstrand and Elam 1993, Lande 1995). For these reasons, conservation science has become preoccupied with developing schemes for identifying at-risk species in order to focus conservation efforts on the subset most likely to be lost from the species pool.

Apart from moralistic or intrinsic arguments for conserving biological diversity (see Callicott 1986, Crozier 1997), why should natural resource planners and policy-makers be concerned with species loss? One argument is that species may play a critical role in maintaining overall ecosystem functionality. However, our understanding of the relationship between diversity and ecosystem function is incomplete and is the subject of an ongoing debate (Huston 1997, Kaiser 2000, Mittelbach and others 2001, Naeem 2002). One contention is that species loss could alter ecosystem functions (for example, productivity, nutrient cycling, or resilience) or stability (for example, cascading extinctions, ecosystem invasibility) in ways that ultimately affect the goods and services that human society derives from ecosystems (Chapin and others 1998, Borrvall and others 2000, Lundberg and others 2000, Tilman 2000, Cottingham and others 2001, Loreau and others 2001, Cardinale and others 2002, van Ruijven and others 2003). The opposing view is that redundancy in species functions exist and therefore judicious targeting of species that provide key functions may be an adequate conservation goal (see reviews by Schwartz and others [2000] and Hector and others [2001]). Regardless of which perspective ultimately prevails, it is important to realize that ecosystem function is but one argument for biodiversity conservation. Other equally legitimate arguments draw from legal, aesthetic, scientific, and utilitarian values that are independent of the functional importance of species (Chapin and others 1998, Hector and others 2001).

Given these uncertainties and the diverse values for biodiversity, a precautionary approach would suggest that conserving the full complement of species would be wise until the relationships between biotic structure and ecosystem function are more clearly understood. Because species abundances are distributed inequitably and those that are less abundant are more likely to be lost from regional or local assemblages than common species, a

conservation focus on at-risk species in order to maintain biodiversity appears justified.

This report updates the trends and geographic distributional patterns among species thought to be at risk of extinction as part of the Forest Service's requirements to assess natural resources as mandated by the Forest and Rangeland Renewable Resources Planning Act of 1974 (RPA; P.L 93-378, 88 Stat. 476, as amended: 16 U.S.C. 1600[note], 1600-1614). It extends past reports on: (1) the trends and geographic occurrence of species formally listed as threatened and endangered under the Endangered Species Act of 1973 (Flather and others 1998) and (2) the geographic occurrence pattern of at-risk forest-associated species (Flather and others 2004). It provides recent information on at-risk species and extends the species of interest to include all plant and animal species, not just those associated with forest habitats. The objective of this update is to document whether past trends and geographic patterns have changed over time, perhaps indicating the emergence of new areas in need of conservation focus.

Methods

Identification of At-Risk Species

A number of qualitative classification systems have been developed for assigning species to conservation status categories (see Flather and Sieg 2007). Perhaps the most familiar legislated system is defined by the Endangered Species Act of 1973 (ESA; P.L. 93-205, 87 Stat. 884, as amended; 16 U.S.C. 1531-1536, 1538-1540). The ESA defines two categories of extinction risk: (1) **endangered** refers to a species that is in danger of extinction throughout all or a significant portion of its range (Sec. 3. [6]) and (2) **threatened** refers to a species that is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range (Sec. 3. [20]). Internationally, the World Conservation Union (IUCN) has developed a set of criteria for classifying threatened species that is used in the publication of the Red Lists or Red Data Books (Gärdenfors 2001). For species with adequate data, a total of seven categories are defined by the IUCN, including extinct, extinct in the wild, critically endangered, endangered, vulnerable, near threatened, and least concern (IUCN 2001). Within the United States, one of the more comprehensively applied classification systems was developed by the Natural Heritage Network and The Nature Conservancy (Master 1991, Stein and others 1995). This system is based on a number of criteria related to species occurrence, range size, population size, population trend, threats, fragility, and number of protected occurrences (Master and others 2000) that are used to assign species to nine conservation status ranks (table 1). We use two conservation status classifications in this report: (1) the threatened and endangered categories developed by the U.S. Fish and Wildlife Service for the ESA and (2) the national conservation status ranks developed by The Nature Conservancy now maintained by NatureServe (2004; see Appendix for metadata).

Table 1—National (N) conservation status ranks used by NatureServe and its network of natural heritage programs (http://www.natureserve.org/explorer/ranking.htm).

Rank	Definition
NX	*Presumed extirpated*—Species is believed to be extirpated from the nation. Not located despite intensive searches of historical sites and other appropriate habitat, and virtually no likelihood of rediscovery.
NH	*Possibly extirpated*—Species occurred historically in the nation, and there is some possibility of rediscovery. Some effort has been made to relocate occurrences, but its presence has not been verified in the past 20 to 40 years.
N1	*Critically imperiled*—At a very high risk of extirpation due to extreme rarity (often five or fewer occurrences), very steep declines, or other factors.
N2	*Imperiled*—At high risk of extirpation due to very restricted range, very few populations (often 20 or fewer), steep declines, or other factors.
N3	*Vulnerable*—At moderate risk of extirpation due to a restricted range, relatively few populations (often 80 or fewer), recent and widespread declines, or other factors.
N4	*Apparently secure*—Uncommon but not rare; some cause for long-term concern due to declines or other factors.
N5	*Secure*—Common, widespread, and abundant.
NU	*Unrankable*—Currently unrankable due to the lack of information or conflicting information about status and trend.
NNR	*Unranked*—Conservation status rank not yet assessed.

Data Sources and Analysis

Analysis of the conservation status of species was based primarily on two extant data sources. First, trends in the number of species listed as threatened or endangered under the ESA were provided by a database maintained by the U.S. Forest Service to support its national resource assessment mandate (see Flather and others 1999). These data were compiled from the U.S. Fish and Wildlife Service's *Endangered Species Bulletins* and report the cumulative number of species listed (accounting for delistings) by major taxonomic categories from 1 July 1976 through 1 November 2004. Because the ESA offers protection to species, subspecies, and distinct population segments (Committee on Scientific Issues in the Endangered Species Act 1995), these data necessarily include information on taxonomic units below the species level. Second, NatureServe's Central Databases (NatureServe 2004) were accessed to document the county-level occurrence of all native species in each of the conservation status ranks defined in table 1.

Because species counts are known to be affected by area, we report both the species count within a county and an adjusted species density that accounts for the nonlinear species-area relationship (National Research Council 2000:77). The adjusted species density (D_i) is given by:

$$D_i = S_i / A_i^z \qquad (1)$$

where S is the species count, and A is the area for county i. The exponent z indicates the rate at which species are added with increasing area and is estimated by fitting the following nonlinear regression (SAS Institute 2003):

$$S_i = cA_i^z. \qquad (2)$$

We focused in particular on those species considered to be at risk of extinction at the national scale, where at-risk species are defined as those with a conservation rank of N1, N2, or N3. The geographic distribution of at-risk species is thought to be a less biased depiction of those geographic areas of greatest conservation concern (that is, have high concentrations of species that are vulnerable to extinction) than those based on the occurrence of

formally listed species under the ESA (as in Flather and others 1998, 1999). This bias is thought to stem from the political process underlying ESA species listings that is affected by budget constraints, bureaucratic process, and listing policy (Langner and Flather 1994, Master and others 2000).

To test for this bias, we used the NatureServe data to depict the county-level occurrence of formally listed threatened and endangered species and compared it to the geographic occurrence of at-risk species. Again, we report both the species count and the adjusted species density estimated from Eqs. 1 and 2. We categorized species count and adjusted species density into the following percentile classes: class 1 (0 to 40 percentile, lowest count [density], class 2 (>40 to 60 percentile), class 3 (>60 to 80 percentile), class 4 (>80 to 90 percentile), and class 5 (>90 percentile, highest count [density]). Our assessment of bias is based on a 5 x 5 contingency table (Agresti 2002) constructed from county assignment to these classes under threatened and endangered species occurrence and at-risk species occurrence. We first look for evidence of bias using the kappa statistic (Cohen 1960), which quantifies the degree to which class assignments agree. Because disagreements in county class assignment are not equally important (for example, there is far more disagreement when a class 5 county under threatened and endangered species occurrence is assigned to a class 1 under at-risk species occurrence than if it were assigned to a class 4), we use weighted kappa (K_w) as our measure of agreement (Cohen 1968). Weighted kappa can range from -1 to 1, with values near 0 indicating levels of agreement that are expected due to chance; values <0 indicating disagreement; and values >0 indicating agreement.

One criticism of kappa (and weighted kappa) is that summarizing a contingency table into a single overall statistic of agreement ignores the detail pattern of agreement and disagreement in the contingency table (Agresti 2002:435). The detail agreement-disagreement structure may also indicate bias that could be masked if we relied solely on an overall measure of agreement as quantified by kappa. To look for notable outliers and interactions within our 5 x 5 contingency table, we use the method of Mosteller

and Parunak (1985:189) to identify extreme deviations between observed cell counts and the counts expected under a null hypothesis of independence (that is, counts of counties in each percentile class under threatened and endangered species occurrence and at-risk species occurrence are unrelated).

Evidence for disagreement (that is, values of K_w near or less than 0) between the geographic occurrence of formally listed species as threatened or endangered and the geographic occurrences of at-risk species would imply a potential bias in the ESA listing process. Conversely, positive values of K_w, large positive standardized residuals along the diagonal elements of the contingency table, and large negative standardized residuals among the off-diagonal elements of the contingency table would indicate a strong pattern of geographic coincidence between the two criteria (ESA listing and NatureServe's conservation status ranking). These latter patterns in the contingency table would provide evidence for the lack of bias, at least as manifested in the geographic occurrence of species.

Finally, NatureServe's data were used to count the number of species that are thought to have been extirpated from each state (that is, have a state conservation rank of SX [presumed extirpated] or SH [possibly extirpated]). We interpret the number of extirpated species as an indicator of where past conservation efforts have failed to maintain the historical species composition.

Although NatureServe's data represent a comprehensive source of the occurrence and conservation status of the nation's biota, there are some important data gaps in the current version of the database that warrant remark (see Appendix): (1) Location information was generally lacking for New Hampshire and Massachusetts; (2) With the exception of some selected species, animal location data was unavailable for Washington; (3) Idaho fish location data was unavailable; (4) Indiana location data for non-vascular plants was unavailable; (5) Minnesota did not provide location information for Gray Wolf (*Canis lupus*); (6) Location information was unavailable for Native American Tribal lands in most western states (with the exception of Navajo Nation); and (7) Data on the state-level location of extirpated species was incomplete and often exists only for species that were known to exist in a state in the recent past.

Results

Trends in ESA Listed Species

As of 1 November 2004, there were a total of 1,264 species formally listed as threatened or endangered within the United States (USDI, Fish and Wildlife Service 2004a). Of that, 746 were plants (59 percent) and 518 were animals (41 percent). A total of 182 species have been added to the list since the last Wildlife Assessment (see Flather and others 1999). Since the mid-1970s, the number of species added to the list has varied greatly over time (fig. 1a). As described in Flather and others (1999:54-55), the ESA listing history has been characterized by three phases, defined primarily by the rate at which species were listed. Early in the listing history, species were added at a relatively moderate rate and culminated in the mass listing of cactus species that were threatened by the plant trade in the late 1970s (USDI, Fish and

Wildlife Service 1979). This phase was followed by a period of relative inactivity from 1980 through 1986. The third phase of species listing was characterized by a high rate of new species being classified as threatened and endangered. Although a listing moratorium (April 1995) occurred during this phase, once the moratorium was lifted, the rate of listings resumed at pre-moratorium levels. The listing rate in phase 3 was caused primarily by new plant listings as animal listings have increased more slowly than plants (fig. 1a). Among animals that have been added to the list, fish, mollusks, and insects contributed the greatest number of new species (fig. 1b, c). Since the last Wildlife Assessment (Flather and others 1999), there appears to be a fourth phase characterized by a listing rate of about 12 species/year (fig. 1a). Whether this reduced listing rate emerges as a long-term pattern will depend in large part on how the more
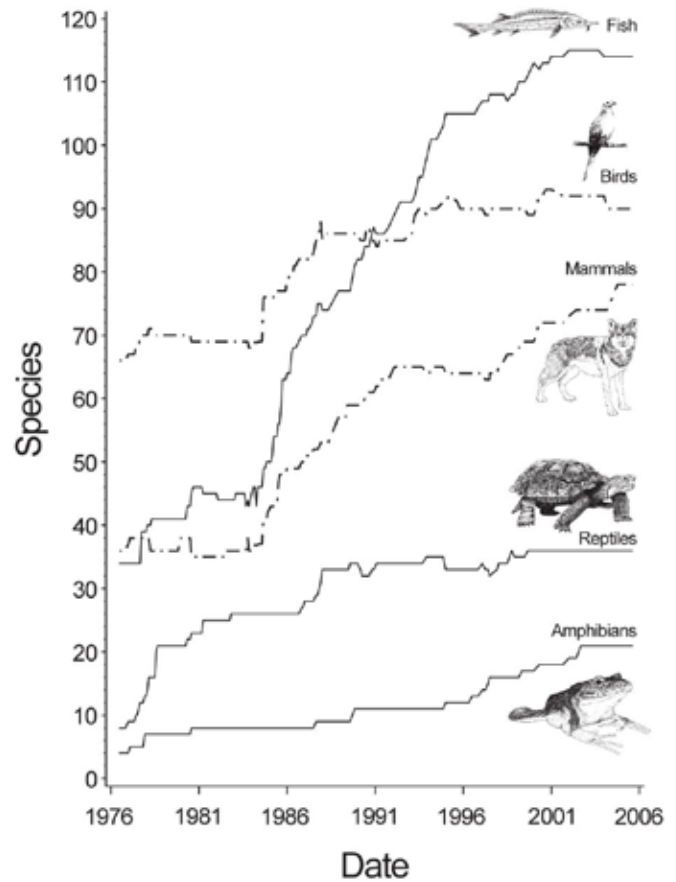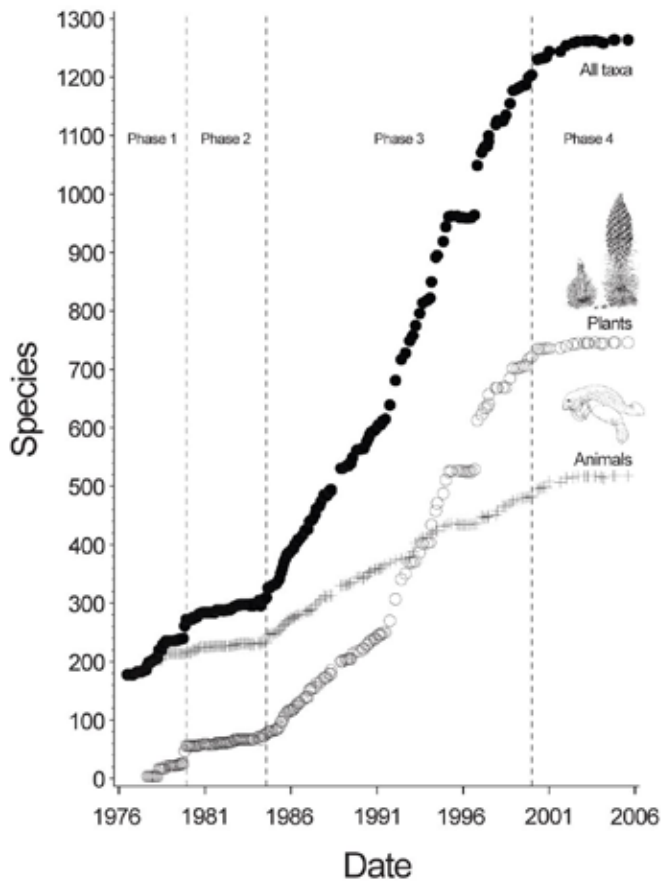
than 300 species considered candidates[1] for listing, or have published proposed rules to list, are treated.

## *Geographic Patterns in the Occurrence of ESA Listed Species*

The number of species that are formally listed as threatened or endangered under the ESA and occur in any given geographic area is known to vary greatly from place to place. Past RPA Assessment efforts have documented endangerment hotspots across the United States (Flather and others 1994, Flather and others 1998). This general geographic pattern of listed species occurrence has not changed. Based on recent NatureServe location records, threatened and endangered species remained concentrated in the southern Appalachians, peninsular Florida, coastal areas, and the arid Southwest (fig. 2a).

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[1]A candidate species is one for which the USDI, Fish and Wildlife Service has sufficient information on file to support a proposal to list that species as either threatened or endangered, but for which preparation and publication of a proposal is precluded by higher-priority listing actions (USDI, Fish and Wildlife Service 2004b).
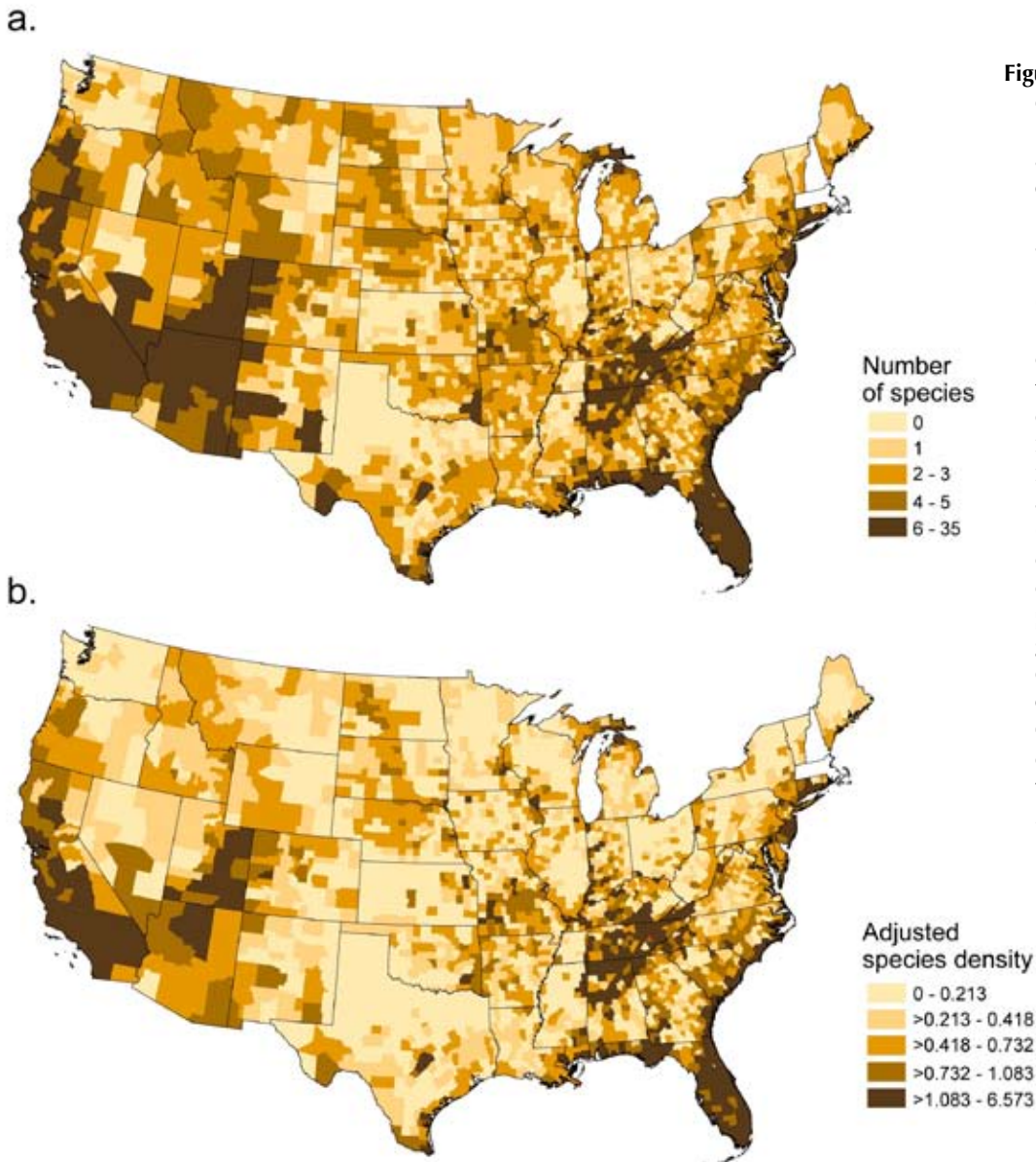
The geographic pattern of adjusted species density ($\hat{z} = 0.22$; $F=1101$; $p < 0.0001$) was qualitatively similar to the raw species counts (fig. 2b). However, larger western counties ranked lower in terms of the adjusted density relative to some of the smaller eastern counties. Many of the arid Southwest counties dropped out of the >90 percentile.

Geographic Patterns in the Occurrence of At-Risk Species

Although the species that are formally listed as threatened or endangered may be a biased reflection of the number of species that are truly at-risk of extinction (Master and others 2000), the geographic pattern of at-risk species counts and adjusted species density ($\hat{z} = 0.49$; $F=1561$; $p < 0.0001$) based on NatureServe's biological criteria showed similar geographic patterns to that for species formally listed under the ESA (compare figs. 3 and 2). Specifically, that 10 percent of counties with the highest counts of at-risk species (fig. 3a, b) again highlighted such
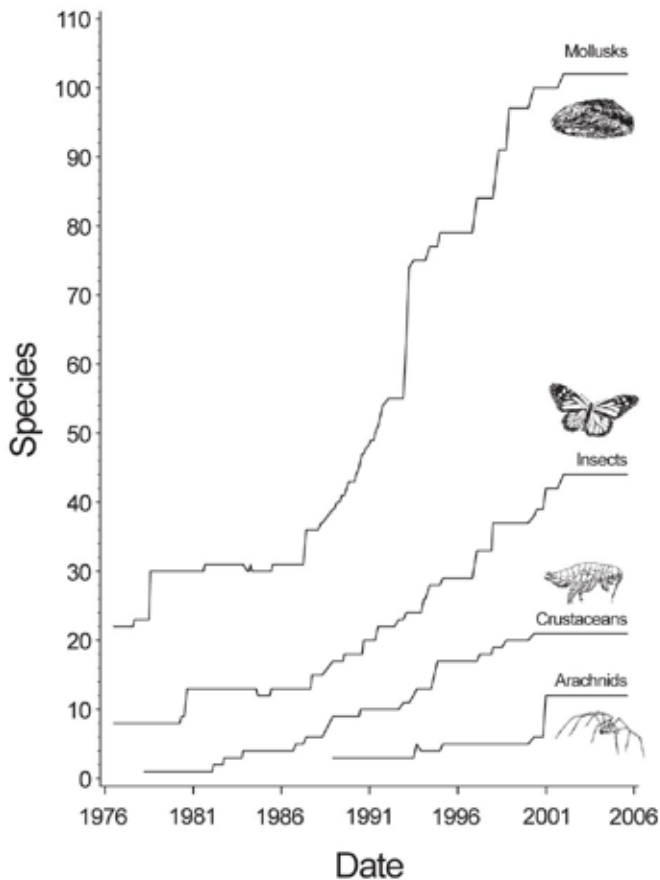
Figure 1. Cumulative number of species listed as threatened or endangered under the Endangered Species Act of 1973 from 1 July 1976 through 1 November 2004 for (a) plants and animals, (b) vertebrates, and (c) invertebrates. Three plant subcategories are tracked in the data and include "flowering plants," "conifers," and "ferns and others." Because >95 percent of plants occur in the flowering plants subcategory, only total plants are displayed here. Data from U.S. Fish and Wildlife Service.

a.

b.

Number
of species

- 0
- 1
- 2 - 3
- 4 - 5
- 6 - 35

Adjusted
species density

- 0 - 0.213
- >0.213 - 0.418
- >0.418 - 0.732
- >0.732 - 1.083
- >1.083 - 6.573

Figure 2. The geographic distribution of (a) county-level counts and (b) adjusted species density of species formally listed as threatened and endangered by the Endangered Species Act (ESA) in the conterminous United States. Legend categories reflect the 0 to 40 percentile (lowest class), >40 to 60 percentile, >60 to 80 percentile, >80 to 90 percentile, and >90 percentile (highest class). Under this categorization, the highest class includes the 10 percent of counties with the greatest count or adjusted density of threatened or endangered species. County-level occurrence data were not available for New Hampshire and Massachusetts. Data from NatureServe (2004).

regions as the Southern Appalachians, peninsular Florida, Atlantic and Gulf coasts, and the arid Southwest.

The qualitative consistency between figures 2 and 3 was confirmed by large positive K_w, with stronger agreement observed for adjusted species density ($K_w = 0.520$; asymptotic SE = 0.011) than for the species counts ($K_w = 0.485$; asymptotic SE = 0.011). Evidence for agreement was further supported by the pattern of large positive standardized residuals among the shared percentile classes (that is, the diagonal terms in table 2). The degree of agreement was particularly noteworthy among those counties classified in the highest percentile (class 5)—a class that had the

highest positive standardized residual for both the species counts and adjusted species density (table 2).

Despite the strong support for geographic coincidence, there was some evidence for differences between the two criteria sets for identifying species of conservation concern. Table 2 indicates that off-diagonal elements immediately adjacent to the diagonal terms tended to be positive—an indication that disagreement was primarily restricted to neighboring class levels. Moreover, in the case of species counts, those off-diagonal terms tended to fall below the diagonal elements. This pattern was suggestive of a weak bias with the counts of counties in the percentile classes for ESA listed species being higher than those based on

a.
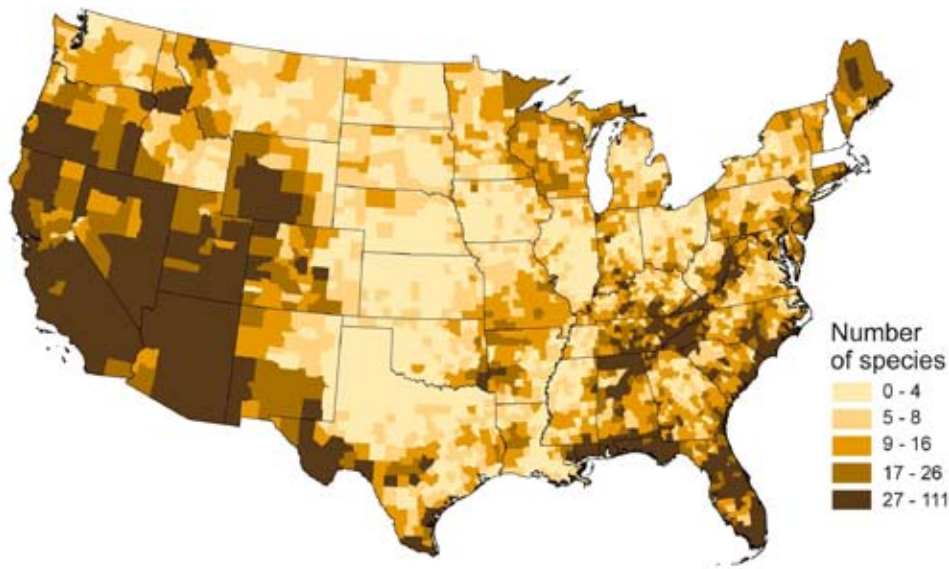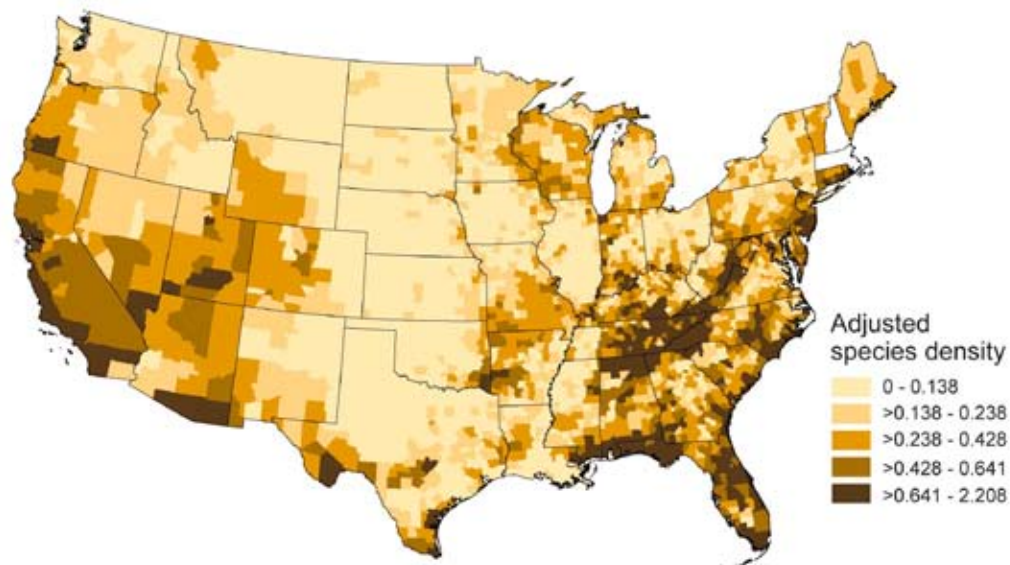
Figure 3. The geographic distribution of (a) county-level counts and (b) adjusted species density of species considered to be at-risk of extirpation (conservation rank N1, N2, and N3 as defined in table 1) from the conterminous United States. Legend categories reflect the 0 to 40 percentile (lowest class), >40 to 60 percentile, >60 to 80 percentile, >80 to 90 percentile, and >90 percentile (highest class). Under this categorization, the highest class includes the 10 percent of counties with the greatest count or adjusted density of at-risk species. County-level occurrence data were not available for New Hampshire and Massachusetts. Data from NatureServe (2004).

b.

NatureServe's at-risk species. However, this pattern disappears in the adjusted species density contingency table. Therefore, this noted bias is likely an artifact of using counts unadjusted for variation in county area.

Notwithstanding the strong statistical evidence for coincidence, a visual inspection of the maps in figures 2 and 3 did suggest some differences that were not discernable from the contingency tables. First, at-risk species hotspots appeared to have a broader geographic footprint when compared to threatened and endangered species hotspots. For example, the southern Appalachians and the arid Southwest at-risk species hotspots spanned a greater area than that observed for threatened and endangered species. This

effect was particularly apparent in the species count maps (figs. 2a and 3a). Second, there was evidence from the at-risk species maps for the emergence of new areas of conservation concern in the upper and lower Mid-western regions of the country. In particular, the driftless area (a region that escaped glaciation during the most recent ice age) of southwestern Wisconsin, southeastern Minnesota, and northeastern Iowa; and the Ouachita Mountains region of west central Arkansas and southeastern Oklahoma had more prominent concentrations of at-risk species when compared to the geographic occurrence of species formally listed as threatened or endangered (figs. 2b and 3b).

Table 2—Summary statistics for tests of independence (5 x 5 contingency table) between the frequency of counties in percentile classes of species counts and adjusted species density for species listed as threatened or endangered (ESA listing criteria) and species listed as at-risk (NatureServe's conservation rankings). Classes are defined as: class 1 (0 to 40 percentile), class 2 (>40 to 60 percentile), class 3 (>60 to 80 percentile), class 4 (>80 to 90 percentile), and class 5 (>90 percentile) as displayed in figures 2 and 3. Notable ($p \leq 0.05$) positive standardized residuals are underlined and bold. Gray highlighted cells identify the diagonal elements that measure the coincidence of counties in each class.

T&E species class	Species counts					Adjusted species density				
	At-risk species class					At-risk species class				
	1	2	3	4	5	1	2	3	4	5
1	465[a]	111	52	7	2	816	266	129	16	7
	214.12[b]	150.32	143.71	63.18	65.66	493.6	246.8	246.8	123.2	123.6
	23.62[c]	-4.12	-9.76	-8.36	-9.31	**24.18**	1.76	-10.82	-13.14	-14.27
	5.00E-06[d]	6.45E-05	8.57E-06	9.33E-06	9.00E-06	5.00E-06	0.0815	8.75E-06	8.00E-06	7.50E-06
2	342	227	129	30	6	246	170	151	37	13
	246.73	173.21	165.6	72.81	75.66	246.8	123.4	123.4	61.6	61.8
	8.53	**5.36**	-3.7	-6.05	-9.69	-0.07	**5.24**	**3.11**	-3.69	-7.32
	9.29E-06	1.00E-05	0.0003	9.44E-06	8.75E-06	0.9337	1.20E-05	0.0023	0.0003	9.23E-06
3	212	326	323	107	36	153	142	196	91	35
	337.49	236.92	226.51	99.59	103.49	246.8	123.4	123.4	61.6	61.8
	-10.21	**8.06**	**8.87**	0.95	-8.53	-8.62	**2.09**	**8.17**	**4.41**	-4.02
	8.33E-06	9.38E-06	9.09E-06	0.3426	9.23E-06	9.09E-06	0.04	9.17E-06	3.89E-05	0.0001
4	16	60	148	79	63	18	35	110	89	56
	123.03	86.37	82.57	36.3	37.73	123.2	61.6	61.6	30.75	30.85
	-12.61	-3.46	**8.71**	**7.95**	**4.63**	-12.89	-3.99	**7.27**	**11.67**	**5.03**
	7.50E-06	0.0006	9.17E-06	9.41E-06	1.80E-05	8.33E-06	0.0001	9.29E-06	8.57E-06	1.38E-05
5	2	4	44	83	211	1	4	31	75	198
	115.63	81.18	77.61	34.12	35.46	123.6	61.8	61.8	30.85	30.95
	-13.76	-10.39	-4.6	**9.35**	**33.02**	-15.01	-8.66	-4.62	**8.83**	**33.36**
	6.67E-06	8.00E-06	1.86E-05	8.89E-06	0.00E+00	6.67E-06	9.00E-06	2.18E-05	8.89E-06	0.00E+00

[a] Observed county count.
[b] Expected county count under the null hypothesis of independence.
[c] Standardized residual.
[d] Probability of observing a larger standardized residual (absolute value) in 100,000 simulated tables under the null hypothesis (code available upon request).

Species Extirpation Among States

Recent extirpation of species was most prominent in the southern third of the coterminous United States (fig. 4). More than 30 species of plants and animals have been lost from five states that, for the most part, lay south of the 37th parallel (a latitude that approximately defines the northern boundary of Arizona, New Mexico, and Oklahoma). Four of the five states that lost the greatest number of species occurred entirely south of that latitude—only California extends northward. The species extirpated within those five states varied taxonomically. Vertebrates never made up more than one-fourth of the state-level species extirpations—reaching 22 percent in Florida and 24 percent in Texas. Invertebrates represented the majority of the extirpated species in Alabama (88 percent) and Tennessee (65 percent). Plants were notable components of the extirpated biota in Florida (46 percent) and California (49 percent). California's recently lost biota was also characterized by a high percentage of invertebrates (47 percent)—a pattern that may be related to observed relationships between plant and insect diversity in California Mediterranean ecosystems (Keeley and Swift 1995).
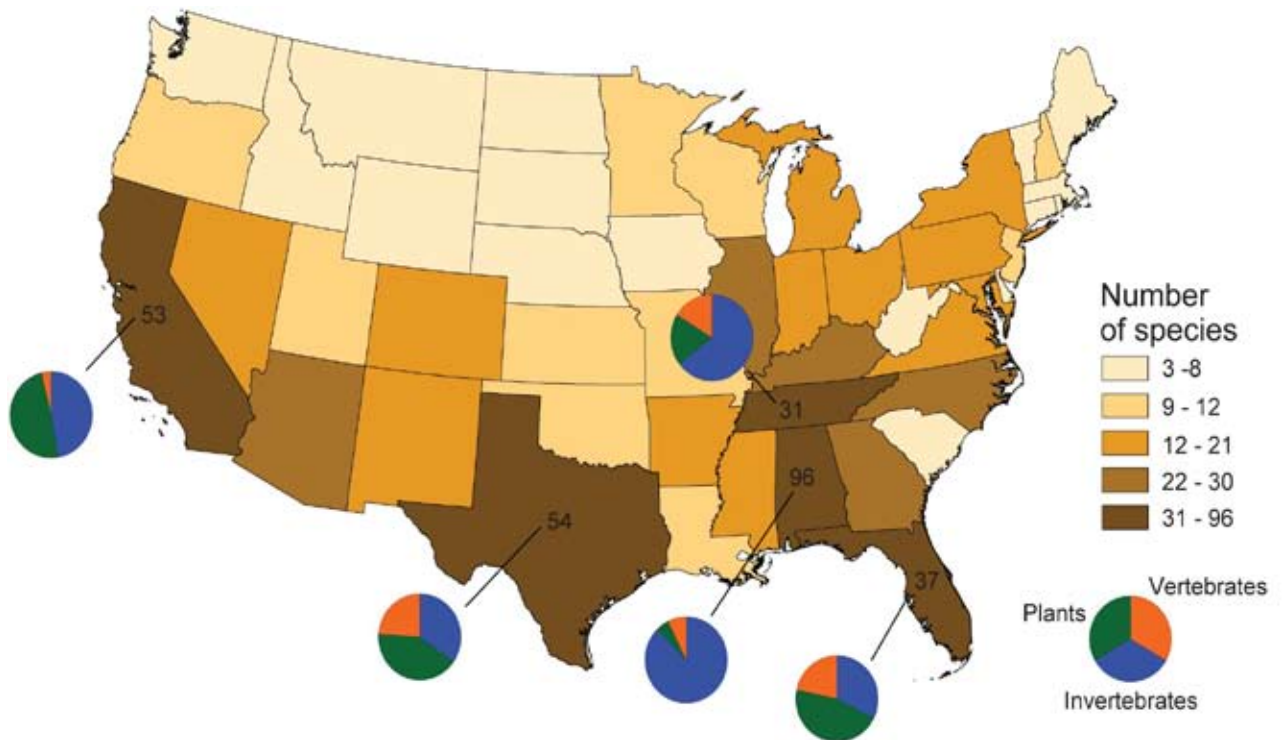
Figure 4. The geographic distribution of state-level counts of species considered to be extirpated from a state (conservation rank SX and SH) for the conterminous United States. Legend categories reflect the 0 to 40 percentile (lowest class), >40 to 60 percentile, >60 to 80 percentile, >80 to 90 percentile, and >90 percentile (highest class). Under this categorization, the highest class includes the 10 percent of states with the greatest count of extirpated species. Pie charts represent the proportional composition of extirpated species from each state that are vertebrate, invertebrate, and plant species. Data from NatureServe (2004).

Discussion

Recent estimates of global extinction rates appear to be unprecedented when compared to those that have occurred over geologic time (May 1990). Estimates of the current extinction rate place it at 100 times the so-called natural background level (Lawton and May 1995, Pimm and Lawton 1998). Even if the precision of recent extinction rate estimates is low, they do project a sense of urgency among conservation organizations to identify those species that are most susceptible to extinction. This urgency is greater if ecosystem function is sensitive to species richness and composition (see Chapin and others 2000, Loreau and others 2001, Hector and others 2001, Cardinale and others 2002) since increases in species rarity in any ecological system, whether it be temperate forest, steppe, or desert, is of concern to the maintenance of ecological sustainability.

Since the last Wildlife Assessment (Flather and others 1999), there has been a notable decline in the rate at which species are formally listed as threatened or endangered species. The annual listing rate of 12 species/year represents nearly a 5-fold drop in the species listing rate observed at the time of the last Assessment. This decline should not be interpreted as reflecting an asymptotic approach to a ceiling number of species that are thought to be threatened with extinction in this country. There are more than 300 species that biologically warrant listing (that is, they are proposed or candidate species). This backlog of species would take more than five years to clear under a listing rate characteristic of Phase 3 (57 species/year).

Although the number of species added to the list of threatened or endangered species has increased by nearly 175 since the last Wildlife Assessment, the geographic pattern of where these species are concentrated has remained relatively stable. Moreover, this same geographic pattern of concentration has been observed by other investigators using different data sources and hotspot criteria (Dobson and others 1997, Chaplin and others

2000, Rutledge and others 2001). This constancy suggests that the geographic extent of identified endangerment concentrations is not an artifact of any particular data set and the addition of species appears to emphasize, rather than change, the boundaries that were identified nearly a decade ago.

We do have evidence that geographic concentrations of rare species were not affected by the criteria used to identify species of conservation concern (that is, formally listed species using ESA criteria versus at-risk species using NatureServe's criteria). Counts and adjusted density estimates of threatened and endangered species and at-risk species within counties resulted in very similar, or coincident, patterns of concentration (table 2). Although there was strong evidence for coincident geographic patterns among these two species ranking schemes, there was visual evidence that geographic differences may exist. Based on NatureServe's conservation status rankings, some hotspots were broader in their spatial extents (southern Appalachians and the arid Southwest) and new areas of at-risk species concentration appeared to be emerging in the upper and lower Mid-west (*cf.* figs. 2 and 3). Given the backlog of candidate species qualifying for formal listing under the ESA (~300 species) but not yet on the list, these differences will either erode or become more distinct—distinguishing these outcomes will require the inspection of the occurrence pattern among candidate species.

Species with evidence suggesting they have already been lost from the biotic community are essentially indicators of where conservation efforts have failed to maintain the biological diversity of that area. The states where the most extirpations have occurred (fig. 4) differ entirely from those identified in the National Report on Sustainable Forests (see Flather and others 2004). These differences reflect the fact that this report examined all species, while Flather and others (2004) focused only on those species associated with forest habitats. This illustrates an important point when it

comes to identifying areas that warrant conservation focus—namely, the areas identified are sensitive to the suite of species that are of interest.

Interestingly, those states where species extirpations were most prominent (fig. 4) coincided qualitatively with those currently supporting high concentrations of at-risk species (figs. 2 and 3). One argument for focusing conservation efforts in areas supporting high numbers of species thought to be at risk of extinction is that these areas represent places where species are likely to be lost (that is, extirpated) from the species pool in the future. If there is any merit to this expectation, then one would predict recent extirpations to be associated with those areas currently supporting concentrations of rare, or at-risk, species. Our results provide evidence that this is in fact the case and represent a retrospective confirmation of a key assumption underlying basic conservation prioritization schemes. Therefore, land and resource management policies targeting those factors causing increased rarity in hotspots have the potential to avert future species losses.

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APPENDIX: NatureServe Metadata for At-Risk Species

NatureServe Central Databases – 9/9/04

Questions contact: Jason McNees - Database Project Specialist
1101 Wilson Blvd.; 15th Floor
Arlington, VA 22209
(703) 908-1849; jason_mcnees@natureserve.org

SPECIES CRITERIA:

The species included in this analysis consisted of all species with a Global Conservation Status Rank of GX/ TX – G5/T5 and/or Federal status under the U.S. Endangered Species Act (USESA) for which NatureServe has associated Element Occurrence (EO) data.

FILE DESCRIPTIONS:

The following tables are included in Excel format:

- Final_county_extirpated_Crosstab.xls –a summary of the number of extirpated species by county for which NatureServe has location data for.
- Final_state_extirpated_Crosstab.xls - a summary of the number of extirpated species by state.
- Final_county_grank_Crosstab.xls – a summary of the number of species in each county by Grank category.
- Final_county_nrank_Crosstab.xls – a summary of the number of species in each county by Nrank category.
- Final_county_usesa_Crosstab.xls – a summary of the number of species in each county by U.S. Endangered Species Act Status (USESA) category.
- nrank_srank_discrepencies.xls – a list of species that are NX or NH, but do not have Sranks that are consistent with state extirpated or historic status. These are being reviewed but will take some time to resolve so this table is being provided instead to note the issue. It needs to be determined if the Nrank is incorrect or the Srank needs to be changed (though this could also be due to a lag in data exchange) for these species.

IMPORTANT NOTES:

Data Completeness: NatureServe performs a data exchange with each Heritage Program in the United States on an annual basis, but NatureServe cannot guarantee the currentness or completeness of any data provided. Because data is constantly being revised and new data is constantly being developed, for ongoing analyses, NatureServe reccommends this dataset be refreshed on an annual basis.

NatureServe's species location database, including the data used in this analysis, is generally considered **"complete"** for all species **with a global rank of G1/T1 – G2/T2 or those that have USESA status**. By "complete" this means that all Heritage Programs actively track locations of these species within their states. For species that are more common - that is, **have a Global Rank of G3-G5 with no Federal status** – or species that are **extirpated**, the location data is **"spotty"** and whether it exists often depends on how rare a species is within a particular state. This is extremely important to remember when doing analyses that will compare biodiversity of one county or other geographic area of the country to another based on the county level data. In those cases, it is often more appropriate to do a comparison using only the core dataset of G1/T1 – G2/T2 or Federal status species, which allows for a consistent dataset across states.

For example, if there is a fish that is a G5 with no Federal status, and it is an S5 in Pennsylvania, then the PA Natural Heritage Program is not likely to be tracking any location data for that species beyond having it on their state species list and tracking state-level data for it (that is, S_RANK, SNAME, and so forth), because it is so common. However, if that same species is an S1 in North Carolina because it is at the edge of its range, then the NC Natural Heritage Program may have complete location data for that species within their state because it is so rare within their state.

Furthermore, regardless of whether a species falls into the category of having "complete" location data, the absence of data for a particular species in a particular area does not necessarily mean the species does not occur there – it could also mean the area has not yet been inventoried, or a particular state may not yet have developed data for a particular species group (especially invertebrates and non-vascular plants). Any question as to the presence or absence of a particular species in a particular location should be addressed to the appropriate Natural Heritage Program. A directory of contact information for all of the Heritage Programs and Conservation Data Centres in the United States and Canada can be found at the following location on NatureServe's homepage:

http://www.natureserve.org/visitLocal/index.jsp.

Data Gaps: The following data is missing in the NatureServe Central Databases and the dataset used for this analysis.

- Most Washington animal data - with the exception of some select species, animal data in Washington is tracked by an agency outside the Washington Natural Heritage Program and the methodology of that animal location data is not currently compatible with Heritage EO Methodology.
- Massachusetts data - NatureServe does not currently have location data available for Massachusetts. County level species data can be obtained from MA by contacting the Massachusetts Natural Heritage and Endangered Species Program (http://www.state.ma.us/dfwele/dfw/nhesp/)
- New Hampshire data – NatureServe does not currently have location data available for New Hampshire. County level species data can be obtained from NH by contacting the New Hampshire Natural Heritage Bureau (http://www.nhdfl.org/formgt/nhiweb/).
- Idaho fish data – location data for fish species is tracked by Idaho Fish and Game, which is separate from the Idaho Conservation Data Center, as Streamnet data.
- Indiana – Indiana does not track location data for non-vascular plants.
- Minnesota – Minnesota does not maintain location data for Gray Wolf (Canis lupus).
- Tribal Lands – data is not available for Native American Tribal lands in most western states (with the exception of Navajo Nation, which has its own Natural Heritage Program and has a subnation code of "NN" in this dataset).
- Extirpated and historical species – location data for species that are extirpated or historical to a particular state or across their range is very spotty and often exists only for species that were known to exist in a state in the somewhat recent past.

USESA Status: U.S. Endangered Species Act listing status is tracked at three levels in the NatureServe Central Databases – at the Global (range-wide) level, State level, and Element Occurrence (population) level. Often, a Federal status applies to a species across its range, and in those cases the USESA status is recorded at the Global level (USESA_CD or INTERPRETED_USESA). If the status is officially assigned by the U.S. Fish and Wildlife Service it is recorded in USESA_CD. If the status is assigned as interpreted by NatureServe, it is recorded in INTERPRETED_USESA. An example of this would be if the USFWS assigns an entire genus (such as *Achatinella*) with Federal status. In that case, every species record that NatureServe has for that genus would get the USESA status recorded in INTERPRETED_USESA because NatureServe is "interpreteting" that status to apply to each species.

Often a Federal status will only apply to a species in portions of its range. An example of that would be the Bald Eagle, which has federal status in the lower 48 states, but not Alaska. In those cases, the global USESA field will contain a "PS" followed by the status, which indicates "Partial Status." Records with "PS" followed by a status will also have a value in either STATE_INTERPRETED_USESA or EO_INTERPRETED_USESA to indicate at what level the true Federal Status applies. In the Bald Eagle example, all states in the lower 48 would have the applicable Federal status recorded in the STATE_INTERPRETED_USESA, while Alaska would have no status value. In the event that a Federal status only applies to a species in a portion of its range within a state, the status will be recorded in the EO_INTERPRETED_USESA status. An example of this is the Least Tern (*Sterna antillarum*), which is listed everywhere except within 50 miles of the coast. In this case, USESA status is recorded in STATE_INTERPRETED_USESA for states that entirely further than 50 miles from the coast. For states along the coast, the USESA status is recorded in the EO_INTERPRETED_USESA field to indicate which populations on the ground within those states the Federal status applies.

For the purposes of this analysis, location records were only included for which USESA status applies to them on the ground (EO_INTERPRETED_USESA). In other words, if a species has a Federal status that applies in one state and not another, then only the location records for that species in the state where it applies would have been included.

Lastly, some records have the value "PS" stored in the Global INTERPRETED_USESA field that is not followed by a status. This indicates that there is some record associated with this species that has federal status, but this species as a whole does not. An example of this would be if the USFWS assigns Federal status to a subspecies or population but not the species as a whole. In that case, the full species record would get the status "PS" in the NatureServe Central Databases, and the subspecies record would be given the actual status value assigned by USFWS. In this analysis, no species with an INTERPRETED_USESA status of "PS" are included in the USESA crosstab table as none of the location records for these full species have USESA status on the ground. The location records for the associated subspecies or populations that do carry the actual USESA status were included.

DATA FIELD DEFINITIONS:

COUNTY_NAME - The name of the county or other sub-provincial/sub-state jurisdiction where the species is located.

ELCODE_BCD - Unique record identifier for the species that is assigned by the NatureServe central database staff. It consists of a 10-character code that can be used to create relationships between all data provided. *NOTE:* the ELCODE was primarily used in the old Natural Heritage BCD database system. This database has recently been upgraded to a modern Oracle based system called Biotics 4.0. In this new system, ELCODE is currently being maintained but will eventually be phased out. "ELEMENT_GLOBAL_ID" is the unique identifier for each species in the new system.

ELEMENT_GLOBAL_ID - Unique global record identifier for the species that is assigned by the NatureServe central database staff.

G_PRIMARY_COMMON_NAME - The global (that is, range-wide) common name of an element adopted for use in the NatureServe Central Databases (for example, the common name for *Haliaeetus leucocephalus* is bald eagle). Use of this field is subject to several caveats: common names are not available for all plants; names for other groups may be incomplete; many elements have several common names (often in different languages); and spellings of common names follow no standard conventions and are not systematically edited.

G_RANK - The conservation status of a species from a global (that is, range-wide) perspective, characterizing the relative rarity or imperilment of the species or community. The basic global rank values are:

- *GX* - Presumed Extinct;
- *GH* - Possibly Extinct;
- *G1* - Critically Imperiled;
- *G2* – Imperiled;
- *G3* – Vulnerable;
- *G4* - Apparently Secure;
- *G5* – Secure;
- *G#G#* - Numeric range rank (with range no greater than 2) indicating uncertainty in the status;
- *GNR* - Not yet ranked; status has not yet been assessed; GNA - Rank not applicable; and
- *GU* – Unrankable, status cannot be determined at this time.

Qualifiers:

- *?* - Inexact numeric rank; and
- *Q* - Questionable taxonomic classification.

For more detailed definitions and additional information, please see: http://www.natureserve.org/explorer/granks.htm

GNAME - The standard global (that is, range-wide) scientific name (genus and species) adopted for use in the Natural Heritage Central Databases based on standard taxonomic references.

INTERPRETED_USESA - The current status of the taxon designated under the U.S. Endangered Species Act (USESA), which is also recorded in the associated USESA Status field, OR the current status as interpreted by NatureServe Central Sciences. Interpreted status is derived from the taxonomic relationship of the Element to a taxon having USESA status, or its relationship to geopolitical or administratively defined members of a taxon having USESA status. The taxonomic relationships between species and their infraspecific taxa may determine whether a taxon has federal protection. Section 17.11(g) of the Endangered Species Act states, "the listing of a particular taxon includes all lower taxonomic units." Also, if an infraspecific taxon or population has federal status, then by default, some part of the species has federal protection. Thus, an Element may have an interpreted USESA status value even though it may not be specifically named in the Federal Register.

Domain values for INTERPRETED_USESA in this analysis are:

- *C*: Candidate;
- *LE*: Listed endangered;
- *LT*: Listed threatened;
- *LT, PDL*: Listed threatened, proposed for delisting;
- *PE*: Proposed endangered;
- *PT*: Proposed threatened; and
- *SAT*: Listed threatened because of similar appearance;

N_RANK - The conservation status of a species from a national perspective, characterizing the relative rarity or imperilment of the species or community. The basic national rank values are:

- *NX* - Presumed Extinct;
- *NH* - Possibly Extinct;
- *N1* - Critically Imperiled;
- *N2* – Imperiled;
- *N3* – Vulnerable;
- *N4* - Apparently Secure;
- *N5* – Secure;
- *N#N#* - Numeric range rank (with range no greater than 2) indicating uncertainty in the status;
- *NNR* - Not yet ranked; status has not yet been assessed; GNA - Rank not applicable; and
- *NU* – Unrankable, status cannot be determined at this time.

Qualifiers:

- *B* - Breeding—Conservation status refers to the breeding population of the species in the nation or state/province.
- *N* - Nonbreeding—Conservation status refers to the non-breeding population of the species in the nation or state/province.
- *M* - Migrant—Migrant species occurring regularly on migration at particular staging areas or concentration spots where the species might warrant conservation attention. Conservation status refers to the aggregating transient population of the species in the nation or state/province.

For more detailed definitions and additional information, please see: http://www.natureserve.org/explorer/granks.htm

ROUNDED_G_RANK - The Global conservation status rank (G_RANK) rounded to a single character. This value is calculated from the G_RANK field using a rounding algorithm to systematically produce conservation status values that are easier to interpret and summarize.

ROUNDED_N_RANK - The National conservation status rank (N_RANK) rounded to a single character. This value is calculated from the N_RANK field using a rounding algorithm to systematically produce conservation status values that are easier to interpret and summarize.

STATE_COUNTY_FIPS_CD - A numerical code assigned by the U.S. government as part of the U.S. Federal Information Processing Standard (FIPS) to uniquely identify each county and equivalent subdivisions in the United States. The first two digits indicate the state code, and the last three digits indicate the county code. Source: National Institute of Standards and Technology; http://www.itl.nist.gov/fipspubs/fip6-4.htm

SUBNATION_CODE - Abbreviation for the subnational jurisdiction (state or province) where the species is located.

Total of ELEMENT_GLOBAL_ID - The total number of species across categories for a particular county or subnation.