Indicator 7. The Status (Threatened, Rare,Vulnerable, Endangered, or Extinct) of Forest-Dependent Species at Risk of Not Maintaining Viable Breeding Populations, as Determined by Legislation or Scientific Assessment

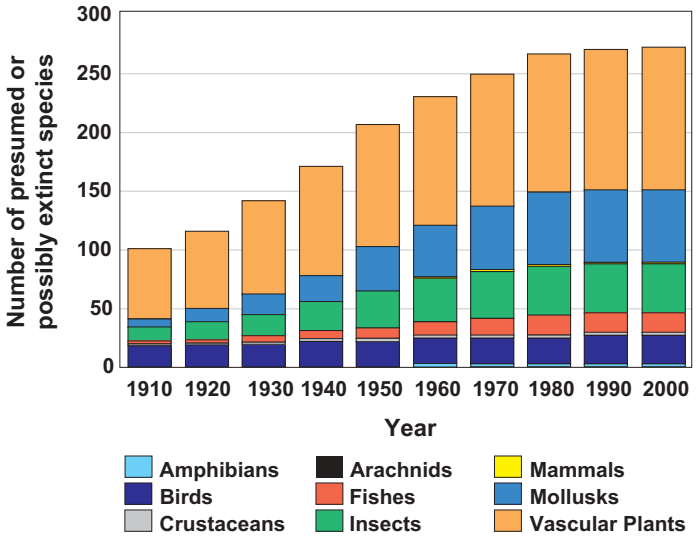

Figure 7-1. Cumulative number of species that are considered to have become extinct since 1900 by taxonomic group.[1]

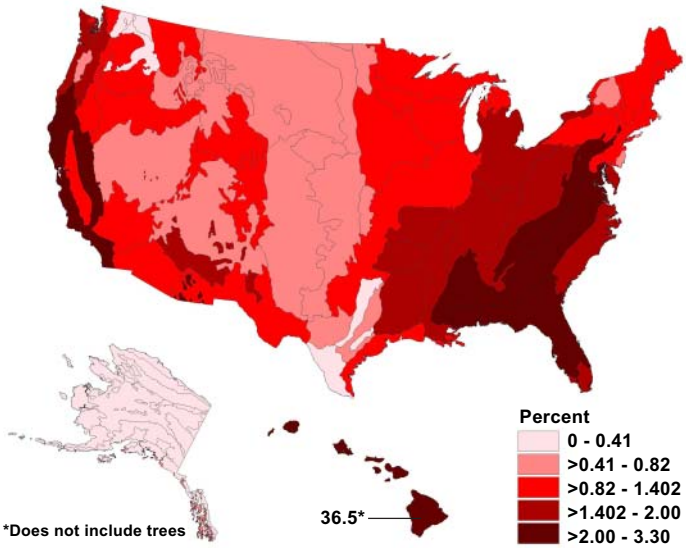

Figure 7-2. The percentage of tree and terrestrial animal species associated with forest habitats that are at risk of extinction. (Data from NatureServe and World Wildlife Fund.)

What Is the Indicator and Why Is It Important?

As the number of species considered rare increases, the likelihood of species extinction increases. This indicator focuses on species that have the greatest chance of being lost from the biotic community, and therefore presages potential declines in species richness. Because the goods and services that humans derive from ecological systems can be affected by the loss of species, tracking the number of species at risk of extinction can potentially indicate whether the use or management of forest resources is eroding or conserving biological diversity.

What Does the Indicator Show?

The trend in species extinction since the turn of the 20th century varies by taxonomic group (figure 7-1). Very few species of crustaceans, amphibians, or mammals, and no reptiles, have become extinct in the last 100 years. Although birds are prominent on the list of extinct species, their numbers have remained fairly constant since the early 1900s. In contrast, the number of insects, mollusks, fish, and vascular plants considered extinct has increased over time. When considering only trees and terrestrial animals associated with forests, 15 percent are currently at risk of extinction. Proportionately, most of those at-risk, forest-associated species are amphibians, butterflies, and grasshoppers. The at-risk species associated with forest habitats are concentrated geographically in Hawaii, in the Southeast, and on the west coast (figure 7-2).

Why Can't the Entire Indicator Be Reported at This Time?

Information on the conservation status of obscure species is lacking in many cases. Among all species (not just forest-associated ones), nearly 30 percent of insects, 11 percent of grasshoppers, and nearly 9 percent of fish species have not been assigned a conservation status category yet. In addition to dealing with this data limitation, we also are unable to examine trends in the number of at-risk species across all conservation status categories, in large part, because of the absence of periodic evaluations of species status from which trend information can be developed.

[1] The number of extinct species is for all species (not just forest-associated ones). The trend is based on only those species for which a "date of last observation" is reported.

CRITERION 1: CONSERVATION OF BIOLOGICAL DIVERSITY

Indicator 7: The Status (Threatened, Rare, Vulnerable, Endangered, or Extinct) of Forest-Dependent Species at Risk of Not Maintaining Viable Breeding Populations, as Determined by Legislation or Scientific Assessment

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ABSTRACT

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As the number of species classified as rare increases, the likelihood of species extinction also increases. This indicator focuses on species that have the greatest chance of being lost from the biotic community and therefore presages potential declines in species richness. The trend in species extinction since the turn of the 20th century varies by taxonomic group. Very few species of crustaceans, amphibians, or mammals, and no reptiles, are known to have become extinct in the last 100 years. Birds are prominent on the list of extinct species, but their numbers have remained fairly constant since the early 1900s. In contrast, the number of insects, mollusks, fish, and vascular plants considered to have become extinct has increased over time. When considering trees and species of terrestrial animals associated with forest habitats, 15 percent are currently at risk of extinction. Proportionately, most of those at-risk forest-associated species are amphibians, butterflies, and grasshoppers. The at-risk species associated with forest habitats are concentrated geographically in Hawaii, in the Southeast, and on the West Coast.

Keywords: at-risk species, rarity, sustainability indicators, threatened and endangered species, sustainable forest management.

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INTRODUCTION

Biological diversity has been defined as "... the variety of life and its processes" that encompasses "... the variety of living organisms, the genetic differences among them, and the communities and ecosystems in which they occur" (Keystone Center 1991:6). Over the last half-century, scientists and natural resource managers have learned much about how biodiversity contributes to human society, the economic significance of which can be considerable (Pimentel and others 1997). Most obviously, many of the goods that are harvested and traded in the human economy are a direct product of the biological diversity within ecosystems (Daily 1997). Biological diversity also provides indirect benefits to humans through its impact on important ecosystem functions (Risser 1995; Huston and others 1999; Naeem and others 1999), and less tangible, but equally important, benefits in the form of recreational opportunity, as well as spiritual and intellectual fulfillment (Postel and Carpenter 1997). Because intensive use of natural resources can stress ecosystems to a point where their ability to provide these benefits is compromised (Rapport and others 1985; Loreau and others 2001), it has been argued that the human enterprise may be jeopardizing the health and continued existence of some ecosystems (Vitousek and others 1997). This argument is the motivation behind a worldwide paradigm shift in natural resource management that is now focusing on long-term sustainability of ecosystems as the measure of responsible resource stewardship (Noble and Dirzo 1997). One of the fundamental goals emerging from the sustainable management paradigm is to use resources in ways that conserve biological diversity (that is, the variety of ecosystems, species, and genes) undiminished for future generations (Lubchenco and others 1991; Lélé and Norgaard 1996).

The nine indicators accepted by the Montréal Process countries for monitoring biological diversity trends consider ecosystem diversity (five indicators), species diversity (two indicators), and genetic diversity (two indicators). This report focuses on one of the species diversity indicators – namely, the conservation status (threatened, rare, vulnerable, endangered, or extinct) of forest-dependent species[1] at risk of not maintaining viable breeding populations, as determined by legislation or scientific assessment. Our purpose is to provide the rationale for the use of species conservation status as an indicator of biological diversity, to review the data available that relate to this indicator, and to present the findings from these data at national and regional scales. Finally, we will conclude with an evaluation of indicator adequacy and data limitations, which in turn form the basis for proposing a set of research topics directed at improving the use of species conservation status as an indicator of biological diversity.

RATIONALE

Conservation scientists are concerned with anticipating how natural or human-induced disturbance to ecosystems affect the pattern of commonness and rarity of the biota inhabiting that system (Lubchenco and others 1991; Solbrig 1991). In a world with limited resources to direct toward biodiversity conservation, a common priority-setting strategy has been to focus on that subset of species that are thought to have the highest extinction risk (Sisk and others 1994;

[1] A forest-dependent species is any species that needs forest conditions for all or part of its requirements of food, shelter or reproduction (Report of the technical advisory committee to the working group on criteria and indicators for the conservation and sustainable management of temperate and boreal forests ["The Montréal Process"], Draft Version 3.0, September 25, 1996). We use the terms "forest-dependent" and "forest-associated" interchangeably throughout this report.

Flather and others 1998). Often these species represent those that have few remaining individuals or have small geographic ranges (Mace and Lande 1991; Gaston 1994), although other life history traits that affect a species' vulnerability to extinction have also been proposed to identify species of conservation concern (Millsap and others 1990; Gaston 1994).

Regardless of the extinction-risk criteria that are used, this indicator was proposed by the Montréal Process as a companion indicator to species richness (Indicator 6; see Flather and others 2003). Because Indicator 7 provides information on the status of species that are already of conservation concern (Montréal Process Working Group 2000), it focuses attention on those species that purportedly have the highest likelihood of being lost from the species pool – the ecological entity that is the focus of Indicator 6. Consequently, Indicator 7 essentially defines that set of species that are most likely to result in a reduction in species richness as measured by Indicator 6. Loss of species results in a loss of biotic integrity (Karr 1992), and maintenance of biotic integrity has been described as synonymous with ecologically sustainable management (Woodley et al. 1993: viii). Thus, a growing or diminishing list of those species that are at risk of becoming extinct indicates whether resource management practices are eroding or conserving biological diversity (Montréal Process Working Group 2000; Flather and Sieg 2000).

Targeting species that are vulnerable to extinction has become an important preoccupation of conservation science since recent estimates of global extinction rates appear to be unprecedented when compared to those that have occurred over geologic time (May 1990). Some 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). While much of the concern has focused on the species-rich tropics (Wilson 1988; Myers 1988; Myers and others 2000), 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), then increases in species rarity in any ecological system, including temperate and boreal forests, is of concern to assessing ecological sustainability.

DATA SOURCES AND ANALYSIS APPROACH

As the overall size of a given species' population is reduced, a point is reached where reproductive output is insufficient to offset mortality and the probability of persistence into the future is low enough such that the population is no longer considered viable (Montréal Process Working Group 2000). Population viability analysis (PVA) – where demographic models are used to evaluate the likelihood that a population will persist to some time in the future (Boyce 1992) – has become a common approach to setting habitat management and conservation policy (Ellner and others 2002). The concepts and principles underlying PVA also have been used as the basis for developing classifications of conservation status for species (Mace and Lande 1991). However, viability assessments often require detailed information on population vital rates (birth, death, and dispersal), the spatial arrangement of habitats on the landscape, and consideration of stochastic events (see Beissinger and Westphal 1998; Reed and others 2002) – information that exists for only a few well-studied species. Consequently, operational classifications of species conservation status have had to rely on criteria that are based on general principles of population biology and equally applicable to data-rich and data-poor species (Mace and Lande 1991).

A number of classification systems have been developed for assigning species to conservation status categories. 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). 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 those 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 NatureServe and its network of natural heritage programs (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). For this report we use two conservation status classifications: (1) the threatened and endangered categories developed by the U.S. Fish and Wildlife Service for the ESA, and (2) the global conservation status ranks developed by NatureServe.

Table 1. Conservation status ranks used by NatureServe and its network of natural heritage programs (Stein 2003).

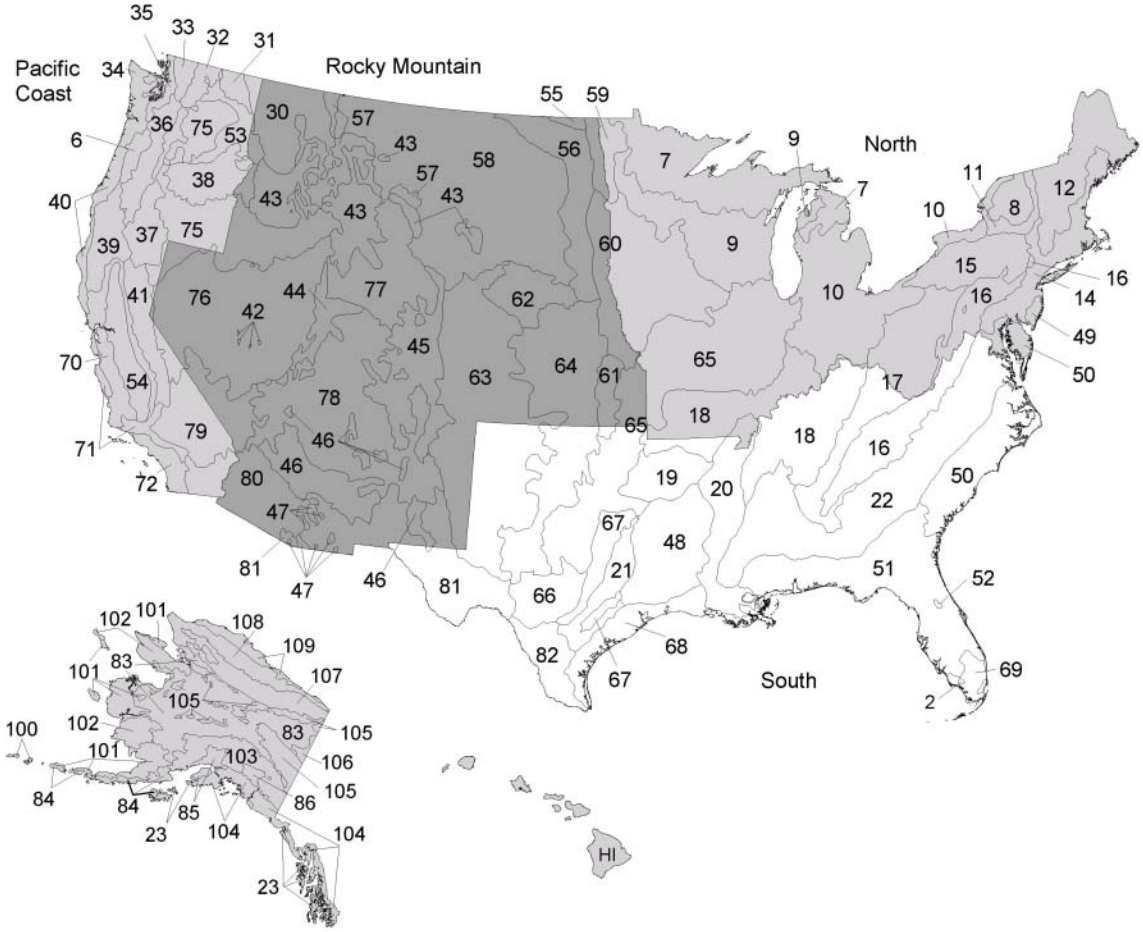
Rank	Definition
GX	Presumed extinct – Not located despite intensive searches and virtually no likelihood of rediscovery.
GH	Possibly extinct – Missing; known from only historical occurrences but still some hope of rediscovery.
G1	Critically imperiled – At very high risk of extinction due to extreme rarity (often 5 or fewer populations), very steep declines, or other factors.
G2	Imperiled – At high risk of extinction due to very restricted range, very few populations (often 20 or fewer), steep declines, or other factors.
G3	Vulnerable – At moderate risk of extinction due to a restricted range, relatively few populations (often 80 or fewer), recent and widespread declines, or other factors.
G4	Apparently secure – Uncommon but not rare; some cause for long-term concern due to declines or other factors.
G5	Secure – Common, widespread, and abundant (although it may be rare in parts of its range). Not vulnerable in most of its range.
GU	Unrankable – Currently unrankable due to the lack of information or due to conflicting information about status and trend.
G?	Unranked – Conservation status rank not yet assessed.

A simplistic interpretation of Indicator 7 suggests that a single estimate of the number of species in each conservation status category can be used to assess the status of biological diversity. However, a count pooled across all species masks the fundamental ecological differences that exist among the various kinds of species and can make it difficult to identify important trends and mechanisms that could be causing changes in conservation status. For example, some taxa may have a natural tendency to have a relatively high proportion of rare species (Yu and Dobson 2000). For this reason, we report species conservation status by a

number of taxonomic categories, which, at a minimum, will prevent taxa with many species from hiding important trends in other less diverse taxa (see Ricketts and others 1999a).

We summarize our results at a number of geographic scales. At the broadest scale, we report counts of species in various conservation risk categories by taxonomic group at the national level. We also display how those national counts vary geographically using the ecoregional classification of Ricketts and others (1999b). Finally, we also present summary statistics organized by U.S. Forest Service regional planning boundaries to support the Forest Service's national resource assessment mandate (USDA, Forest Service 2001). The ecoregional stratification and Forest Service regional planning boundaries are defined in figure 1.

Figure 1. Ecoregions (Ricketts and others 1999) and U.S. Forest Service planning regions (USDA, Forest Service 2001). Note that Alaska and Hawaii are part of the Pacific Coast planning region.



Code	Description	Code	Description
2	South Florida Rocklands	54	California Central Valley Grasslands
6	Willamette Valley Forests	55	Canadian Aspen Forest and Parklands
7	Western Great Lakes Forest	56	Northern Mixed Grasslands
8	Eastern Forest/Boreal Transition	57	Montana Valley and Foothill Grasslands
9	Upper Midwest Forest/Savanna Transition Zone	58	Northwestern Mixed Grasslands
10	Southern Great Lakes Forests	59	Northern Tall Grasslands
11	Eastern Great Lakes Lowland Forests	60	Central Tall Grasslands

Figure 1, cont'd

12	New England/Acadian Forests	61	Flint Hills Tall Grasslands
14	Northeastern Coastal Forests	62	Nebraska Sand Hills Mixed Grasslands
15	Allegheny Highlands Forests	63	Western Short Grasslands
16	Appalachian/Blue Ridge Forests	64	Central and Southern Mixed Grasslands
17	Appalachian Mixed Mesophytic Forests	65	Central Forest/Grassland Transition Zone
18	Central Hardwood Forests	66	Edwards Plateau Savannas
19	Ozark Mountain Forests	67	Texas Blackland Prairies
20	Mississippi Lowland Forests	68	Western Gulf Coastal Grasslands
21	East Central Texas Forests	69	Everglades
22	Southeastern Mixed Forests	70	California Interior Chaparral and Woodlands
23	Northern Pacific Coastal Forests	71	California Montane Chaparral and Woodlands
30	North Central Rockies Forests	72	California Coastal Sage and Chaparral
31	Okanagan Dry Forests	75	Snake/Columbia Shrub Steppe
32	Cascade Mountains Leeward Forests	76	Great Basin Scrub Steppe
33	British Columbia Mainland Coastal Forests	77	Wyoming Basin Shrub Steppe
34	Central Pacific Coastal Forests	78	Colorado Plateau Shrublands
35	Puget Lowland Forests	79	Mojave Desert
36	Central and Southern Cascades Forests	80	Sonoran Desert
37	Eastern Cascades Forests	81	Chichuahuan Desert
38	Blue Mountains Forests	82	Tamaulipan Mezquital
39	Klamath-Siskiyou Forests	83	Interior Alaska/Yukon Lowland Taiga
40	Northern California Coastal Forests	84	Alaska Peninsula Montane Taiga
41	Sierra Nevada Forests	85	Cook Inlet Taiga
42	Great Basin Montane Forests	86	Copper Plateau Taiga
43	South Central Rockies Forests	100	Aleutian Islands Tundra
44	Wasatch and Uinta Montane Forests	101	Beringia Lowland Tundra
45	Colorado Rockies Forests	102	Beringia Upland Tundra
46	Arizona Mountains Forests	103	Alaska/St. Elias Range Tundra
47	Madrean Sky Islands Montane Forests	104	Pacific Coastal Mountain Tundra & Ice Fields
48	Piney Woods Forests	105	Interior Yukon/Alaska Alpine Tundra
49	Atlantic Coastal Pine Barrens	106	Ogilvie/MacKenzie Alpine Tundra
50	Middle Atlantic Coastal Forests	107	Brooks/British Range Tundra
51	Southeastern Conifer Forests	108	Arctic Foothills Tundra
52	Florida Sand Pine Scrub	109	Arctic Coastal Tundra
53	Palouse Grasslands	HI	Hawaii

Analysis of the geographic pattern and temporal trends in the conservation status of species is based primarily on three extant data sources. First, trends in the number of species listed as threatened or endangered under the ESA, and their current geographic distribution, were provided by a database that is maintained by the U.S. Forest Service to support its national resource assessment mandate (see Flather and others 1999). These data were compiled from a number of sources including the U.S. Fish and Wildlife Service's *Endangered Species Bulletins*, the final listing decisions as published in the Federal Register, species recovery plans, environmental impact statements, and other federal and state agency reports on threatened and endangered species (see Flather and others 1998, 1999 for the details on the sources used to compile these data). 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. Furthermore, because information that would allow us to readily determine which listed species are forest

dependent was not available, these data represent the temporal and geographic patterns among all species regardless of their broad habitat affinity.

Second, NatureServe's Central Databases (NatureServe 2002) were accessed to derive nationwide estimates of the number of all native species (and their identity) in each of the conservation status ranks defined in table 1. We focus in particular on those species thought to be extinct (categories GX and GH), and those that are thought to be at least vulnerable to extinction (categories G1, G2, and G3). We refer to the latter set of species as "at-risk." These data were also used to identify that subset of species that are thought to be dependent on forest habitats[2] and included trees, forest-associated terrestrial vertebrates (mammals, birds, amphibians, and reptiles), and some forest-associated terrestrial invertebrates (butterflies and grasshoppers). Stein and others (2000: Appendix A), also using NatureServe's data, provided information on the date when presumed or possibly extinct species were last observed. Assuming these dates provide an estimate of when each became extinct in the United States, we used this previously published data to estimate the cumulative trend in species extinctions by taxonomic group. We note that the date when last observed can only be regarded as a coarse approximation of the possible extinction event since there may have been little inventory activity targeting any given species for long periods of time. Because the data from Stein and others (2000) did not identify those species associated with forest habitats, the cumulative extinction trend we report here is reflective of all species.

Third, a database compiled by the World Wildlife Fund on native species occurrence (Ricketts and others 1999b) was used to provide information on the number and identity of forest-associated species (as determined by NatureServe) that occurs within each ecoregion. By comparing the list of forest-associated species within each ecoregion from the World Wildlife Fund data against the global conservation ranks from the NatureServe data, we estimated the percentage of forest-associated species within each ecoregion that were in each conservation status category. These data provide a baseline against which future analyses can be compared to determine if the number of at-risk species is increasing or decreasing in different ecoregions.

RESULTS: INDICATOR INTERPRETATION

National Scale

Trends in Species Extinctions

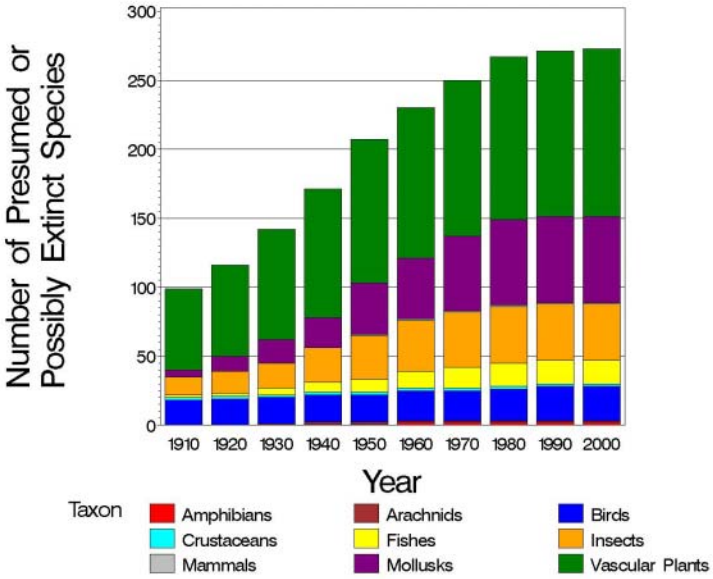
Extinction is a natural process that operates on any collection of organisms. The heightened concern for species extinctions is thus not focused on the fact that species are being lost per se, but rather is focused on the rate of loss. By some estimates the current extinction rate is several orders of magnitude higher than the natural background level (Myers 1988; Lawton and May 1995; Pimm and Lawton 1998). Furthermore, the causes for recent species extinctions are not associated with the natural calamities of the past, but are attributable to human exploitation or habitat loss stemming from land use and resource extraction activities (Pimm and others 1995). Many of the recent species extinctions that have occurred chronicle our past failures in managing our natural resources in an ecologically sustainable fashion.

[2] Data on forest-associated species available upon request from Jason McNees, NatureServe, 1101 Wilson Blvd., Arlington, VA 22209 (jason_mcnees@natureserve.org).

The number of U.S. species that are presumed or possibly extinct (hereafter, extinct) varies greatly among taxonomic groups (Appendix A). As a percentage of the number of species in each taxonomic group, freshwater mussels and snails have undergone the greatest loss of species (12.2 percent), followed by grasshoppers (4.3 percent), birds (4.0 percent), and insects (3.0 percent). The only taxonomic groups that have no recently recorded U.S. extinctions are reptiles and butterflies/skippers. Among those species associated with forest habitats, few species have recently gone extinct (Appendix A), the exceptions being birds (5.2 percent) and grasshoppers (4.0 percent). We note, however, that all grasshoppers that are potentially extinct have a GH rank (see table 1) indicating that there is still some possibility for rediscovery. More focused inventories on this and other taxonomic groups may actually reduce the proportion of species that are thought to be extinct.

The trend in species extinctions during the 20th century also varies by taxonomic group. Figure 2 shows the cumulative number of species that are thought to have gone extinct since 1900 based on a reported "date of last observation" from Stein and others (2000: Appendix A). Because very few species of crustaceans, reptiles, amphibians, or mammals have gone extinct in the last 100 years, these taxa contribute little to the overall pattern of accumulated extinctions. A moderate number of bird species have gone extinct, but most had been extirpated prior to 1900. The species that have contributed most to the growing list of extinct species are insects, mollusks, fish, and vascular plants. Aquatic ecosystem health is an issue that is apparent in the pattern of extinctions shown in figure 2. Although the overall rate of species extinctions appears to have slowed in recent decades, this pattern is likely an artifact of how species extinctions are assessed. Species can be added to the list of presumed or possibly extinct species when a

Figure 2. Cumulative number of species that are presumed extinct or possibly extinct since the early 1900s. Note that these cumulative plots only account for those species with a reported "last observed" date. For many species (248), a "last observed" date was not reported; most of these species were mollusks (104) and insects (132). These plots reflect the pattern among all species, not just forest-associated species. Data are from Stein and others (2000: Appendix A).



geographically well-documented species suffers some catastrophic loss, or when a species has been absent from inventories for some period of time (Stein 2003). Therefore, any cumulative plot of extinct species is expected to show fewer additions in recent years since insufficient time has passed to qualify under the second condition.

Trends in the Number of Species Listed as Threatened or Endangered Under the ESA

Over the last 25 years, the number of species added to the threatened or endangered categories under the ESA has varied greatly over time (figure 3a, next page). As described in Flather and others (1999:54-55), the ESA listing history is 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 (USDI, Fish and Wildlife Service 1979). This phase was followed by a period of relative inactivity (see phase 2 in figure 3a). The final phase of species listing was characterized by a high rate of new species being classified as threatened and endangered. Although phase 3 is bounded by the listing moratorium that occurred in April 1995, once the moratorium was lifted, the rate of listings appears to have 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 (figure 3a). Animal taxa that have contributed the greatest number of new species to the list include fish, mollusks, and insects (figure 3b, c).

Relying on lists of species determined to be at risk based on legislative assessment can underestimate the number of species that are actually at risk of extinction (Master and others 2000:108). The rate with which species appear on legislated lists of endangerment is often more sensitive to changes in law, budget, bureaucratic process, and listing policy than the biological status of the particular species itself (Langner and Flather 1994). For this reason, it is informative to examine the number of species whose conservation status is based more completely on biological criteria.

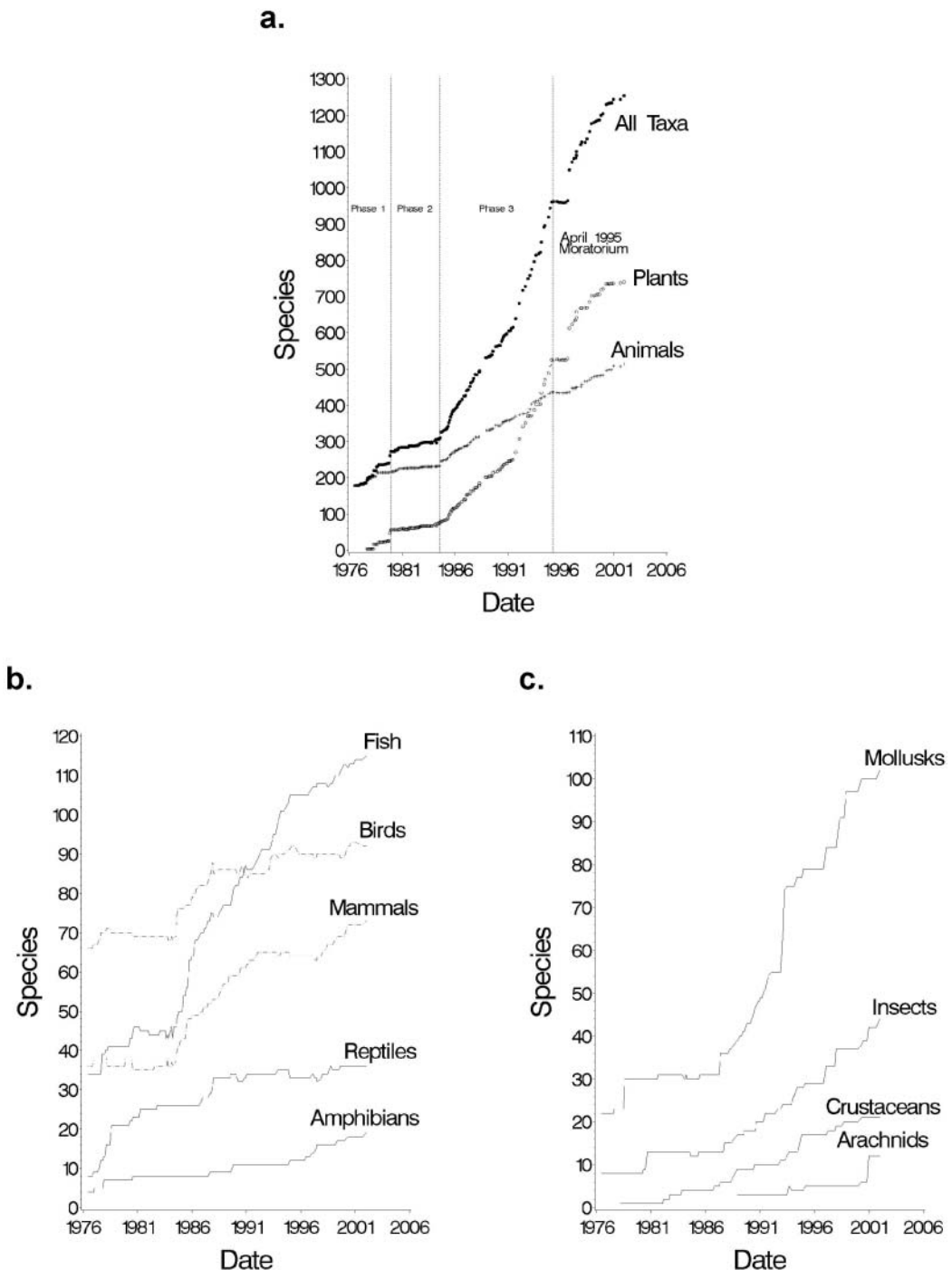
Number of At-Risk Species

More than 8,600 U.S. species among the taxonomic groups we considered are classified as critically imperiled (G1), imperiled (G2), or vulnerable (G3) to extinction (Appendix B) using NatureServe criteria (table 1). For comparison, a total of 1,242 species (for the same taxonomic groups listed in Appendix B) are currently listed as threatened or endangered (USDI, Fish and Wildlife Service 2002). The discrepancy in species counts between the two classifications is primarily due to vascular plants – a total of 595 plants are listed under ESA, while a total of 5,088 plants are considered at-risk under NatureServe criteria. More than half of the at-risk species are vascular plants (Appendix B). Other taxonomic groups with a high number of at-risk species include insects, freshwater mussels and snails, crustaceans, and fish. Because taxonomic groups with a high number of species would be expected to have a higher number of at-risk species, it is helpful to look at imperilment as a percentage of the total number of species in each group. Viewed this way, crustaceans have the greatest percentage of at-risk species at nearly 60 percent (Appendix B), followed by freshwater mussels and snails (58.0 percent), grasshoppers (54.8 percent), and amphibians (42.6 percent). Other taxa where the percentage of at-risk species exceeds 20 percent includes insects in general, vascular plants, fish, and reptiles.

Among trees and forest-associated animals (terrestrial vertebrates and some insects), the percentage of species under some degree of extinction threat is generally less than that observed across all species (Appendix B). Only forest-associated grasshoppers and amphibians had more

than 30 percent of their species in the at-risk conservation categories. Other taxonomic groups with relatively high percentages of at-risk forest-associated species include butterflies/skippers (nearly 18 percent) and mammals (nearly 11 percent).

Figure 3. Cumulative number of species listed as threatened or endangered under the Threatened and Endangered Species Act of 1973 from July 1976 through December 2001 for (a) plants and animals, (b) vertebrates, and (c) invertebrates. These plots reflect the pattern among all species, not just forest-associated species. Data from the U.S. Fish and Wildlife Service.



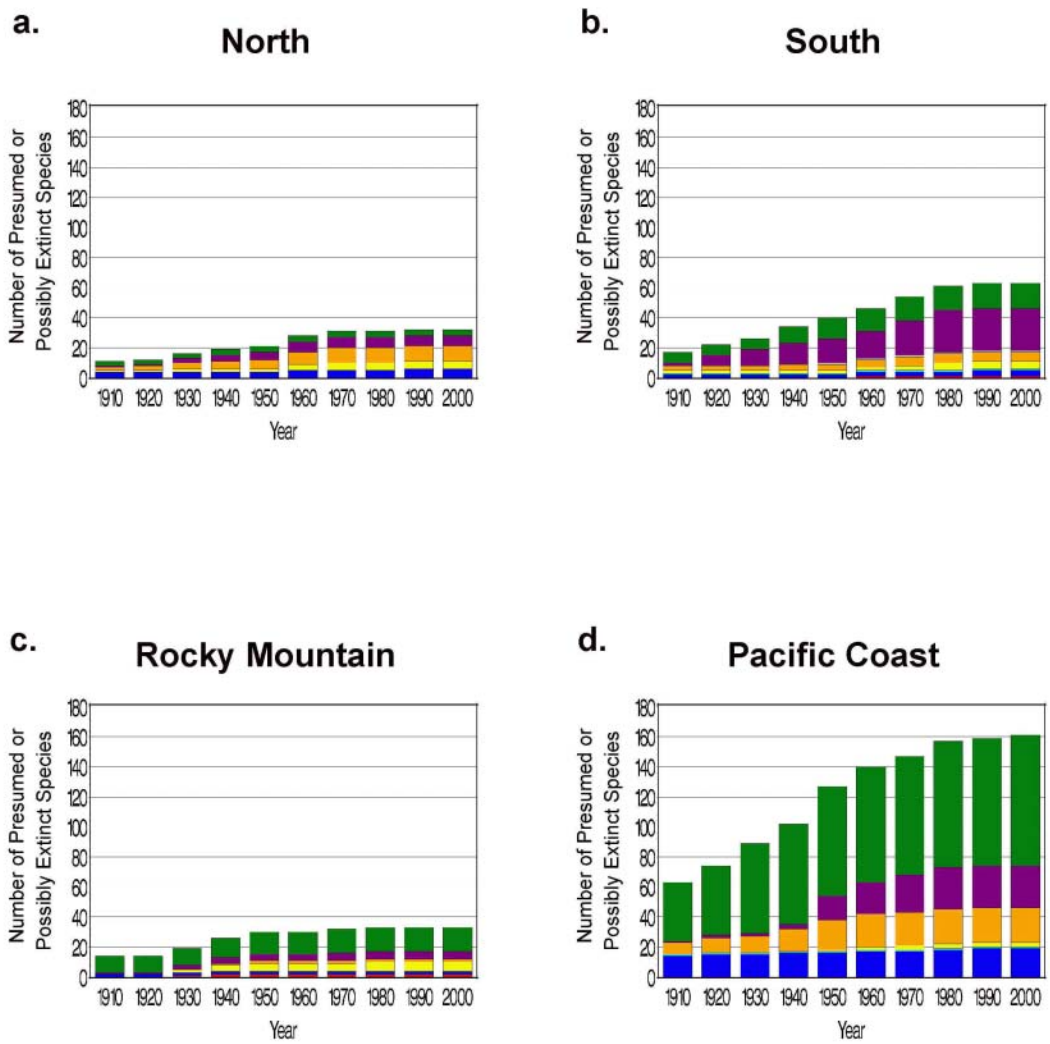
Regional Scale

Because species richness for these taxonomic groups varies geographically (Flather and others 2003), and because resource extraction, land use intensification, and human population density are not uniformly distributed across the country (Hof and others 1999), we expect the number of species that are of conservation concern to also vary geographically.

Geographic Patterns in Species Extinction

Based on the data provided in Stein and others (2000: Appendix A), we were able to plot the historical trends in species extinctions for Forest Service planning regions (figure 4).

Figure 4. Cumulative number of species that are presumed and possibly extinct since the early 1900s by Forest Service planning regions (as defined in figure 1). Note that these cumulative plots only account for those species with a reported "last observed" date. For many species (248) a "last observed" date was not reported; most of these species were mollusks (104) and insects (132). These plots reflect the pattern among all species, not just forest-associated species. Data are from Stein and others (2000: Appendix A). Refer to the color key in figure 2 for taxonomic group codes.

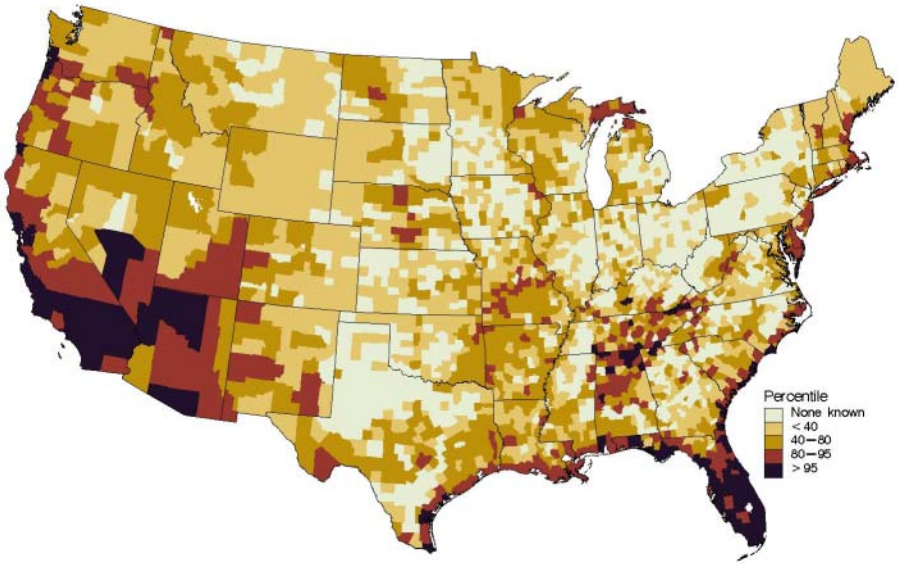


Assignment of each extinct species to a planning region was based on the list of states where the species originally occurred. The Pacific Coast region has had the greatest number of species extinctions over time. This was largely caused by the extinction of many species that are endemic to the Hawaiian Islands (primarily vascular plants and invertebrates). The South also has lost a large number of species, with the increase over the last 50 years being caused by extinction of many freshwater mollusks that inhabit the southern Appalachian Mountains. The most prominent taxon among extinct species in the North is birds; however, since the mid-1900s the number of extinct insects and fish has been growing. The Rocky Mountain region is characterized by a relatively low number and rate of species extinctions. Taxonomic groups responsible for the growing list of extinct species in this region include vascular plants, fish, and mollusks.

Geographic Patterns in the Number of Threatened and Endangered Species

In a study of the 631 species that were formally listed as threatened or endangered under the ESA (as of November 1994) that also occurred in the conterminous U.S., Flather and others (1998) found that listed species were concentrated in a number of "hotspots" that included the southern Appalachians, peninsular Florida, coastal areas, and the arid Southwest (figure 5). This same pattern 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). Species occurring in hotspots across the eastern United States were mostly associated with forest habitats; an average of 69 percent of these species used forest habitats. Species occurring in hotspots across the West were primarily associated with grassland, shrubland, and desert habitats. Only 26 percent of the species across western hotspots were associated with forest ecosystems (see Flather and others 1998).

Figure 5. The geographic distribution of county-level counts of species formally listed as threatened and endangered by the Endangered Species Act (ESA) in the conterminous United States. Counties are shown in percentile classes according to the number of listed species they contain. These data reflect the pattern among all species, not just forest-associated species. Because the ESA offers protection to species, subspecies, and distinct population segments, these data necessarily include information on taxonomic units below the species level (from Flather and others 1998).



Data on the occurrence of threatened and endangered species coupled with environmental information (for example, climate, physiography, human population density, resource extraction, and land use activities) have been used to develop a set of statistical models that relate environmental variables with the density of listed species. Separate models were developed for listed plants and animals. These models, when used with projections of future human population growth, land use activities, and resource extraction, can highlight those geographic areas where species endangerment may be concentrated in the future (see Hof and others 1998; 1999). Projected future hotspots of plant species endangerment were concentrated in the South, and were often in areas that already supported high numbers of endangered plants. New areas of endangered plant species concentrations were projected to emerge in the southern piedmont, the desertic mountains and basins of west Texas, and the Edwards Plateau region of west-central Texas (see Flather and others 1999: figure 34a). Areas where animal endangerment is projected to increase differed from plants. New listings for animals were predicted to be concentrated in the Pacific Coast region, with the greatest increase in listed species to occur in the California Central Valley, coastal Washington and Oregon, and the Palouse Prairie and upper Columbia Plateau regions of eastern Washington and Oregon (see Flather and others 1999: figure 34b).

Geographic Patterns in 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 not maintaining viable populations (Master and others 2000), the geographic pattern of species that are at risk of extinction based on biological criteria show somewhat similar geographic patterns. Those ecoregions with the greatest percentage of their tree and forest-associated fauna at-risk include the southeastern United States, peninsular Florida, and coastal and interior California (figure 6a). This pattern of imperilment does vary among taxonomic groups with trees, forest amphibians, and forest reptiles showing a high percentage of at-risk species in both the southeast and scattered ecoregions in the West (figure 6b, e, f). At-risk forest birds were primarily concentrated in southeast and southcentral forests (figure 6d). Areas with a relatively high percentage of at-risk forest mammals are found in the upper mid-west, the Mississippi lowland and central upland forests, the central grassland ecoregions, and the small scattered ecoregions of the arid southwest (figure 6c). The geographic pattern of at-risk forest butterflies was unique in that ecoregions with the highest percentage of at-risk species were well dispersed across the United States (figure 6g).

When the map of at-risk species (figure 6) is compared to the map of species richness (see Flather and others 2003: figure 2), ecoregions with relatively high numbers of at-risk species often are not coincident with ecoregions that are particularly rich in species. Determining whether this pattern has an ecological basis (for example, species that occur on the periphery of the taxon's high richness core are more prone to extinction) or is simply an artifact of estimating percentages with small counts will require additional investigation.

Figure 6. The percent of forest-associated species that are at-risk (conservation status ranks G1, G2, and G3 as defined in table 1) by ecoregion (as defined in figure 1) for all taxa (a), trees (b), mammals (c), birds (d), amphibians (e), reptiles (f), and butterflies (g). Data are from Ricketts and others (1999b) and NatureServe (2002). Plotted at-risk classes were based on percentiles defined to approximately reflect the upper 90th percentile (dark red), the 80th - <90th percentile, 60th - <80th percentile, 20th - <60th percentile, and < 20th percentile (lightest red). Cases where the legend has fewer than five classes are due to insufficient variation to distinguish among the lower percentile categories. The highest at-risk class represents the 10 percent of ecoregions with the greatest proportion of at-risk species. Gray boundary lines delineate Forest Service planning regions as defined in figure 1.

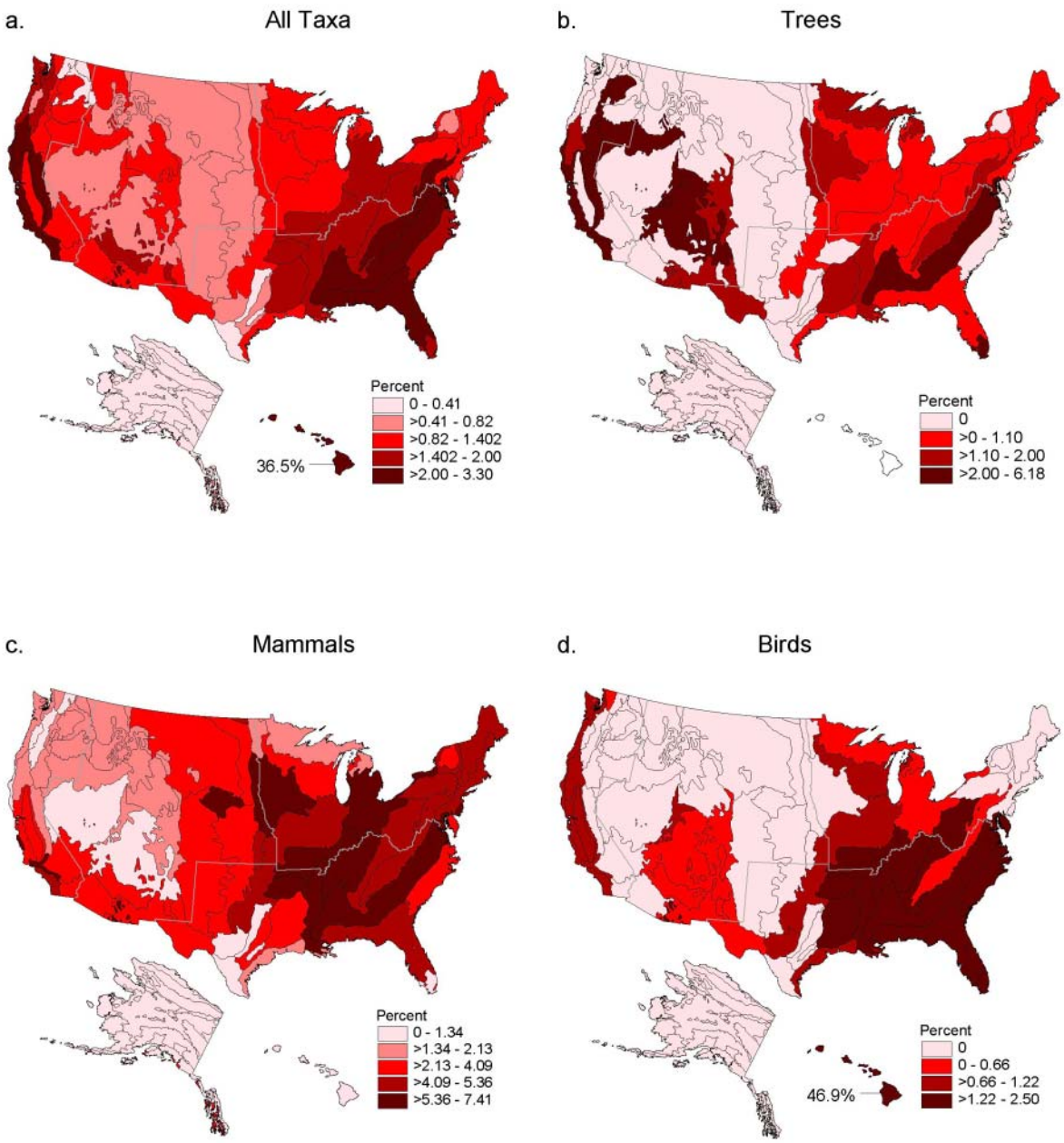
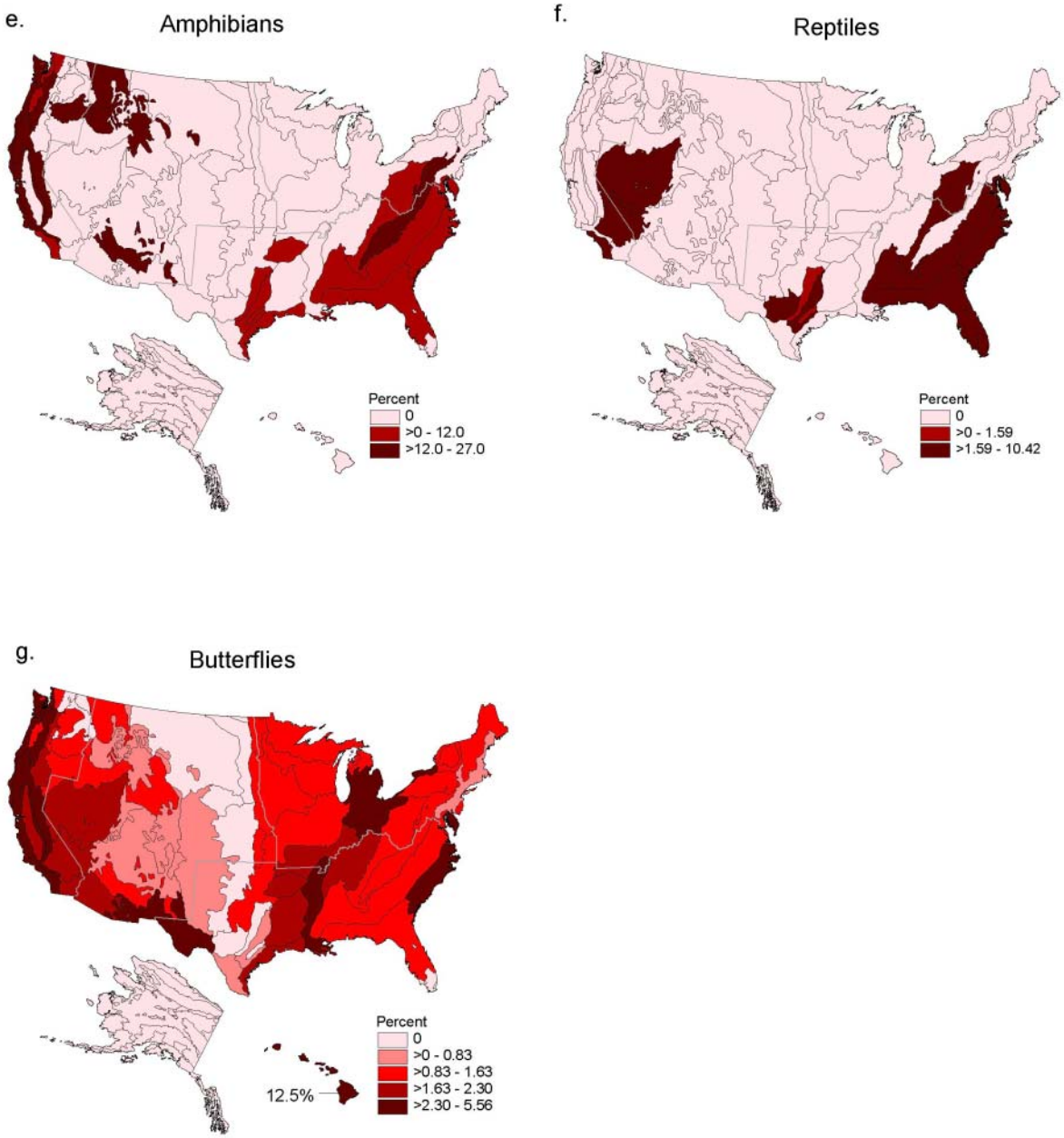


Figure 6, cont'd



The estimated area of the highest percent at-risk class that occurs in each Forest Service Planning region further illustrates the east-west differences among taxa (table 2). About 75 percent of the high at-risk areas for all taxa combined occur in the east (North and South planning regions). Moreover, the majority (>50 percent) of the high at-risk areas for mammals, birds, reptiles, and butterflies occur in the east. Trees and amphibians were the only taxa where the majority of the high at-risk areas occurred in the west (Rocky Mountain and Pacific Coast planning regions).

Table 2. Area and percent (shown parenthetically) of high at-risk areas (the 90th percentile, see figure 6) occurring in Forest Service planning regions. Planning region boundaries are defined in figure 1.

	Forest Service planning region			
Taxon	North	South	Rocky Mountain	Pacific Coast
	---------- 1000 km^2 (percent) ----------			
All taxa[a]	59.9 (6.0)	685.3 (69.0)	9.0 (0.9)	239.2 (24.1)
Trees	8.2 (0.7)	359.0 (30.4)	471.2 (39.8)	344.0 (29.1)
Mammals	552.8 (39.9)	677.7 (48.9)	132.7 (9.6)	20.9 (1.5)
Birds	262.0 (16.8)	1,272.1 (81.6)	8.0 (0.5)	16.6 (1.1)
Amphibians	51.7 (5.9)	107.8 (12.2)	373.2 (42.3)	348.9 (39.6)
Reptiles	130.6 (8.5)	908.0 (59.2)	381.3 (24.9)	113.1 (7.4)
Butterflies	243.0 (24.1)	315.6 (31.3)	109.5 (10.9)	339.2 (33.7)

[a] Includes trees and forest-associated mammals, birds, amphibians, reptiles, and butterflies.

INDICATOR EVALUATION

Indicator Adequacy

The underlying theoretical relationship that forms the ecological basis for this indicator is the species-abundance distribution. The distribution of species-abundances is a simple frequency plot of the number of species in discrete abundance classes. Typically, empirical data collected to quantify this frequency distribution show that any given collection of species tends to be comprised of many species that are relatively rare and few species that are relatively common (Fisher and others 1943; Hairston 1959; MacArthur 1960; Brown 1984; Hughes 1986). However, the actual shape of the distribution appears to be affected by the intensity and spatial extent of the sample. Local studies, and those with small samples, commonly find that the modal abundance class (that is, that class with the most species) is usually the least abundant (Taylor 1978; Gaston and Blackburn 2000). Studies completed over broader geographic areas and with larger samples find the modal class is characterized by moderate abundance (Williamson 1981; Gaston and Blackburn 2000). Regardless of what form the species-abundance distribution takes,

the count of species within each abundance class forms one of the key ecological attributes that is used to assign species to various conservation status categories.

A literal interpretation of Indicator 7 implies that an inventory of species conservation status would be based on counts over all species. However, we know from the data presented for Indicator 6 (Flather and others 2003), that different taxonomic groups can vary greatly in their species counts. All other things equal, a taxonomic group with more species will likely have more species that are rare. Consequently, it is important that Indicator 7 account for variation in species numbers by taxonomic group. Ignoring the fact that species richness varies among taxa runs the risk of masking important changes to the conservation status of species within some taxonomic groups by the sheer number of species in speciose groups. Furthermore, by pooling across taxa, opportunities to identify those taxonomic groups that may have a natural tendency toward having a large proportion of species that are relatively rare (Yu and Dobson 2000), or that are particularly sensitive to human-induced changes to the environment, will be missed. As was concluded by Flather and Sieg (2000:89), the interpretability of this indicator, and the opportunity for gaining a better understanding of the factors causing increased rarity, will be enhanced if species conservation status is summarized as the proportion of species in each taxonomic group for each status category, relative to the total number of species in that taxonomic group.

Interpretability of this indictor with respect to sustainability would be further enhanced if a “standard” or “benchmark” condition could be defined (Karr 1992). Since most species in any given collection are relatively rare, the absence of rarity is an unrealistic goal. What is an acceptable species-abundance distribution? At what point do we regard the proportion of at-risk species as indicative of an ecologically unsustainable condition? Answers to these questions, which are ultimately related to the adequacy of this indicator, will not be possible in the absence of a clearly defined standard.

Data Limitations

There is a growing list of databases that monitor the conservation status of species. The World Conservation Monitoring Center (http://www.wcmc.org.uk/species/data/index.html), the IUCN red list (http://www.redlist.org/), NatureServe (http://www.natureserve.org/explorer/), and the U.S. Fish and Wildlife Service (http://endangered.fws.gov/index.html) all maintain lists of species of conservation concern using varying criteria to classify species. It is important to realize that the data upon which the decision to assign a species to a particular conservation status category vary from detailed demographic analysis of population viability to expert judgment. For example, in an evaluation of the biological data supporting the decision to list a species as threatened or endangered under the ESA, Easter-Pilcher (1996) found that basic biological data required to make such decisions were often lacking. Similarly, Boyce (1992) noted that there are no guidelines on what constitutes a valid assessment of population viability and therefore such analyses can be burdened with severe assumptions. Consequently the existence of data sets that provide species conservation status information does not necessarily do away with data limitation concerns. Users of these data must be aware that the underlying empirical data (and in some cases ecological theory) supporting species conservation assessments are, for many taxonomic groups, lacking or scientifically weak. Evidence for this data limitation can be found in the count of species for which there is insufficient information to rank their conservation status. In the NatureServe database, nearly 30 percent of insects, 11

percent of grasshoppers, and nearly 9 percent of fish species have not, as yet, been classified into a category of conservation status (that is, GU or G? in table 1).

The uncertainty associated with species conservation status determinations introduces a second kind of data limitation – namely, varying criteria over time. As conservation science develops, there is an inevitable modification in the criteria used to judge whether a species is at risk of extinction. For example, in 1994, after three decades of using one set of criteria for judging the world-wide conservation status of taxa, the IUCN adopted a new set of criteria (Gärdenfors 2001). The motivation for such changes is well intentioned – to institute more quantitative criteria that better reflect the state-of-the-art in species conservation assessment. However, with the implementation of such changes, it often becomes necessary to reinitialize the state of the system because historical counts are no longer comparable. Therefore, it becomes difficult, if not impossible, to interpret long-term trends. Because shifts in species counts among conservation status categories caused by new criteria can distort real change in the conservation status of a particular taxonomic group, any evaluation of the historical trajectory must acknowledge and account for criteria shifts over time.

A third data limitation characterizing this indicator is associated with inadequate information on where species of conservation concern occur geographically. Location information is often used to identify biodiversity hotspots that rank high in the number of rare species that occur over a particular geographic area (Prendergast and others 1993; Reid 1998). Such an approach has also been used to identify those areas that may not be using natural resources in ways that are considered ecologically sustainable (Hof and others 1999). These approaches, however, assume that species location data is of sufficient quality to support spatially explicit inferences that serve to delineate areas that warrant more comprehensive conservation planning efforts. As was noted in Indicator 6 (Flather and others 2003), basic distributional data for most taxa are lacking, and attempts to predict species occurrence based on habitat associations have a component of error that is often unquantified (Flather and others 1997). Even if location data exist, much of it has been compiled opportunistically from independent sources that are not based on any probabilistically designed inventory. In the absence of statistically rigorous taxonomic inventories, spatially explicit assessments of species conservation status will be characterized by an unknown level of uncertainty.

Recommendations for Improvement and Research Needs

Any attempt to monitor the conservation status of a group of species is made easier by systematic, well-designed inventories of species distribution and abundance. The need for additional research into the design and implementation of taxonomically broad surveys was outlined in detail for Indicator 6 (Flather and others 2003). An aspect of such inventories that is unique to this indicator concerns that component of the species assemblage that is rare and threatened with extinction. Species that are at risk of not maintaining viable populations introduce a set of statistical issues that emerge because of the inherent difficulty in detecting rare species (Burgman and others 2000). Statistical techniques that are powerful enough to detect shifts in conservation status among rare species need to be developed.

A research need that is as important as designing tenable inventory and statistical estimation techniques is the development of an agreed-upon set of criteria that identify at-risk species (Gaston 1994:19). Currently, there are a number of classification schemes with varying criteria and thresholds for assigning membership to various conservation status categories. The

criteria are omnibus in the sense that the same criteria are used regardless of the taxonomic identity of species. In the absence of a generally agreed-upon classification, criteria will continue to vary from scheme to scheme and will likely change over time rendering trend interpretations difficult. A research need that is related to the classification of at-risk species is the development of a tenable standard against which to judge whether a system, and its mix of species in various at-risk categories, is sustainable. There is also the potential that by being able to differentiate species with increased rarity due to human factors from those which are naturally rare will enable us to better gauge how sustainably resources are being managed. That is, if the number of species considered to be at-risk due to human activities is decreasing, this might be an indication of sustainable management of resources.

Even if an agreed upon system for determining the conservation status of species is developed, and even if rigorous inventory data on species occurrence are available, a count of species by conservation status categories does little to explain why conservation status counts change. Gaining this understanding will be facilitated by monitoring the abundance of at-risk species over time. Furthermore, population trend data for at-risk species has the advantage of being more sensitive to early changes in biodiversity than a shift in species counts among conservation status categories. This suggests a potentially important link to Indicator 9 (Population Levels of Representative Species From Diverse Habitats Monitored Across Their Range) that should be explored (see Sieg and others 2003).

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APPENDIX A. The count and percentage of U.S. species that are listed as presumed (GX) or possibly (GH) extinct. Data from NatureServe (2002).

Taxon	All species			Forest-associated species		
	Presumed extinct (GX)	Possibly extinct (GH)	Total	Presumed extinct (GX)	Possibly extinct (GH)	Total
	Count (percent)			Count (percent)		
Vascular plants	11 (<0.1)	136 (0.8)	147 (0.9)	0[a] (0)	0[a] (0)	0[a] (0)
Vertebrates						
Mammals	1 (0.2)	1 (0.2)	2 (0.5)	0 (0)	0 (0)	0 (0)
Birds	20 (2.7)	10 (1.3)	30 (4.0)	14 (3.2)	9 (2.0)	23 (5.2)
Amphibians	1 (0.4)	2 (0.7)	3 (1.1)	0 (0)	1 (0.6)	1 (0.6)
Reptiles	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Fishes[c]	16 (1.5)	4 (0.4)	20 (1.9)	-[b]	-[b]	-[b]
Invertebrates						
Crustaceans[c]	2 (0.3)	8 (1.0)	10 (1.3)	-[b]	-[b]	-[b]
Freshwater mussels and snails[c]	42 (4.1)	82 (8.1)	124 (12.2)	-[b]	-[b]	-[b]
Insects[c]	5 (<0.1)	205 (3.0)	210 (3.0)	-[b]	-[b]	-[b]
Butterflies / skippers	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Grasshoppers[c]	0 (0)	21 (4.3)	21 (4.3)	0 (0)	8 (4.0)	8 (4.0)

[a] Includes trees only.
[b] Number of forest-associated species has not been determined for this taxonomic group.
[c] These taxonomic groups have a relatively high percentage of species that have not been assigned a conservation status rank (that is, GU or G? rank as defined in table 1). Consequently, the number of species in each class could change appreciably once a conservation status is assigned. The percent of species not assigned a rank by taxonomic group is as follows: Fishes – 8.9 percent; Freshwater mussels and snails – 7.6 percent; Crustaceans – 8.6 percent; Insects – 29.7 percent; Grasshoppers – 11.1 percent.

APPENDIX B. The count and percentage of U.S. species that are listed as critically imperiled (G1), imperiled (G2), and vulnerable (G3). Data from NatureServe (2002).

Taxon	All species				Forest-associated species			
	Critically imperiled (G1)	Imperiled (G2)	Vulnerable (G3)	Total imperiled and vulnerable (G1-G3)	Critically imperiled (G1)	Imperiled (G2)	Vulnerable (G3)	Total imperiled and vulnerable (G1-G3)
	---------- Count (percent) ----------				---------- Count (percent) ----------			
Vascular plants	1,109 (6.8)	1,388 (8.5)	2,591 (15.9)	5,088 (31.2)	10[a] (1.5)	19[a] (2.8)	36[a] (5.2)	65[a] (9.4)
Vertebrates								
Mammals	11 (2.6)	16 (3.9)	41 (9.9)	68 (16.4)	3 (1.3)	4 (1.8)	17 (7.5)	24 (10.6)
Birds	22 (3.0)	18 (2.4)	31 (4.2)	71 (9.6)	14 (3.2)	6 (1.4)	15 (3.4)	35 (7.9)
Amphibians	34 (12.8)	36 (13.6)	43 (16.2)	113 (42.6)	9 (5.1)	21 (11.9)	25 (14.1)	55 (31.1)
Reptiles	8 (2.8)	17 (5.9)	35 (12.1)	60 (20.8)	2 (1.0)	5 (2.6)	12 (6.3)	19 (9.9)
Fishes[c]	110 (10.5)	79 (7.5)	124 (11.8)	313 (29.9)	-[b]	-[b]	-[b]	-[b]
Invertebrates								
Crustaceans[c]	218 (27.7)	108 (13.7)	143 (18.2)	469 (59.6)	-[b]	-[b]	-[b]	-[b]
Freshwater mussels and snails[c]	361 (35.5)	124 (12.2)	105 (10.3)	590 (58.0)	-[b]	-[b]	-[b]	-[b]
Insects	692 (10.0)	582 (8.4)	638 (9.2)	1,912 (27.7)	-[b]	-[b]	-[b]	-[b]
Butterflies / skippers	10 (1.6)	30 (4.9)	80 (13.2)	120 (19.8)	3 (0.6)	18 (3.8)	64 (13.5)	85 (17.9)
Grasshoppers[c]	99 (20.4)	124 (25.6)	43 (8.9)	266 (54.8)	27 (13.5)	30 (15.0)	10 (5.0)	67 (33.5)

[a] Includes trees only.
[b] Number of forest-associated species has not been determined for this taxonomic group.
[c] These taxonomic groups have a relatively high percentage of species that have not been assigned a conservation status rank (that is, GU or G? rank as defined in table 1). Consequently, the number of species in each class could change appreciably once a conservation status is assigned. The percent of species not assigned a rank by taxonomic group is as follows: Fishes – 8.9 percent; Freshwater mussels and snails – 7.6 percent; Crustaceans – 8.6 percent; Insects – 29.7 percent; Grasshoppers – 11.1 percent.