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# NATURE RESERVES: DO THEY CAPTURE THE FULL RANGE OF AMERICA'S BIOLOGICAL DIVERSITY?

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*Abstract.* Less than 6% of the coterminous United States is in nature reserves. Assessment of the occurrence of nature reserves across ranges of elevation and soil productivity classes indicates that nature reserves are most frequently found at higher elevations and on less productive soils. The distribution of plants and animals suggests that the greatest number of species is found at lower elevations. A preliminary assessment of the occurrence of mapped land cover types indicates that ~60% of mapped cover types have <10% of their area in nature reserves. Land ownership patterns show that areas of lower elevation and more productive soils are most often privately owned and already extensively converted to urban and agricultural uses. Thus any effort to establish a system of nature reserves that captures the full geographical and ecological range of cover types and species must fully engage the private sector.

*Key words: biodiversity; coterminus United States; elevation; endangered species; gap analysis; land use; nature reserves; public lands; soil productivity.*

## Introduction

Human transformation of the world's landscapes is increasing at an ever accelerating pace (Vitousek et al. 1986, Sisk et al. 1994). These changes have led, in turn, to the extinction and endangerment of a growing number of species (May et al. 1995) and loss of their natural areas. The U.S. endangered species list has increased from 178 species in 1976 to 1743 species in 1999 (U.S. Fish and Wildlife Service 1976, 1999). The Nature Conservancy lists 267 species in the United States as extinct or presumably extinct and 3170 species as imperiled (Stein and Flack 1997). In the United States, 126 ecosystems have been identified as being threatened or endangered (Noss et al. 1995).

These problems are occurring in spite of the fact that the United States has an extensive system of nature reserves in national parks, national wildlife refuges, and designated wilderness areas. In addition, large areas of lands administered by the Bureau of Land Management, Forest Service, and the various states are managed, at least in part, for the protection of biodiversity. These public lands have management restrictions that provide some protection from anthropogenic change, assist in maintenance of ecosystem functions, serve as population sources and reserves, and provide areas in which ecosystems may be restored. Existing reserves and other public lands may well be inadequate for protecting biodiversity against excessive habitat loss, simply because many of the resources at risk occur preferentially on multiple-use public or privately owned lands. Preliminary assessments of the distribution of threatened and endangered species suggest that >90% of such species occur on private lands, with 66% having >60% of their area on private lands (U.S. Government Accounting Office 1995, Groves et al. 2000).

Proposals for a set of reserves that would represent the full range of biological diversity on the planet date back at least to 1890, when Frederick Von Mueller addressed the Australian Association for the Advancement of Science, stating that ''choice areas and not necessarily very extensive should be reserved in every great country for some maintenance of the original vegetation and therewith for the preservation of animal life concomitant to particular plants'' (as cited in Scott 1999). In 1917, a similar vision was articulated in the United States when the National Research Council made a request to the Ecological Society of America to prepare ''a listing of all preserved and all preservable areas in North America in which natural areas persist'' and to ''urge the reservation of such areas as needed immediate attention'' (cited in Shelford 1926). The

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TABLE 1. Distribution of land in the coterminous United States among five soil productivity classes (soil 1 is the most productive, and soil 5 is the least productive) and seven elevation zones (each spanning 615 m).

| Soil class | 0–615 m | | 616–1230 m | | 1231–1845 m | | 1846–2460 m | |
|---|---|---|---|---|---|---|---|---|
| | km² | % | km² | % | km² | % | km² | % |
| 1 | 53 838 | 0.7 | 184 385 | 2.4 | 485 487 | 6.4 | 375 350 | 5.0 |
| 2 | 273 099 | 3.6 | 792 550 | 10.5 | 761 538 | 10.1 | 484 636 | 6.4 |
| 3 | 163 208 | 2.2 | 261 105 | 3.4 | 483 381 | 6.4 | 296 297 | 3.9 |
| 4 | 14 094 | 0.2 | 136 967 | 1.8 | 200 636 | 2.6 | 184 852 | 2.4 |
| 5 | 1 012 | 0.0 | 74 606 | 1.0 | 97 242 | 1.3 | 129 483 | 1.7 |
| Total | 505 251 | 6.7 | 1 449 613 | 19.1 | 2 028 284 | 26.8 | 1 470 618 | 19.4 |

*Note:* Both the area and the percentage of total reserved land area are provided for each combination of soil class and elevation zone, as well as for marginal totals.

Ecological Society's Committee on the Preservation of Natural Areas discharged these duties, in part, with a report to the National Research Council in 1920 (Anonymous 1920). In 1926, Victor Shelford's *A Naturalist's Guide to the Americas* added additional detail to the 1920 report, but no action was taken. Fifty years later, Dassmann (1972) restated the call for a network of biological reserves encompassing areas representative of the ecosystems of the world. However, this proposal was never acted upon (Scott 1999).

There have been several recent attempts to assess the degree to which public lands represent the species and ecosystems of the United States. One study indicated that perhaps one-third of all potential vegetation types found in the United States do not occur on public lands (Crumpacker et al. 1988). Other broad-scale assessments suggest that perhaps 50–85% of mapped land cover types do not have 10% of their area in nature reserves (Caicco et al. 1995, Davis et al. 1995, 1998, Edwards et al. 1995, Merrill et al. 1996, Smith 1997, Redmond et al. 1998, Stoms et al. 1998).

Conservation scientists have suggested that at least 10–12% of the world's area be dedicated to nature reserves (Miller 1984, Brundtland 1987). However, the land area needed to preserve the ecological processes and biological phenomena may be much larger in many situations (Odum 1970, Noss and Cooperrider 1994, Soulé and Sanjayan 1998). Additionally, all reserves do not contribute effectively or equally to the conservation of natural resources (Pressey 1995).

The increasing demand for land for human uses and the greater acquisition and maintenance costs limit the proportion of land that can be protected. Thus it is critical that future reserves be located where they will contribute most to the protection of biodiversity (Sullivan and Shaffer 1975, Pressey et al. 1993, Pressey 1994).

In the absence of complete resource inventories, it is difficult to gain a national perspective on how completely the nation's biodiversity is represented in existing reserves. However, examining the way lands within or outside of nature reserves are distributed with respect to geophysical characteristics of the U.S. landscape may provide some clues (National Research Council 1993). Using this approach, we quantified the distribution of existing reserves in the coterminous United States with respect to elevation and soil productivity. We hypothesized that:

1) Existing reserves in the coterminous United States would be concentrated in regions of marginal economic value such as areas of high elevation and lower soil productivity.

2) As a result, significant elements of biodiversity would be underrepresented in reserves.

3) The majority of anthropogenic landscapes would be at lower elevations and in more productive soils.

## METHODS

Maps of biological reserves and of land stewardship designations for the coterminous United States were obtained from several sources (McGhie 1997; Gap Analysis Program Moscow, Idaho). These data were

TABLE 2. Distribution of lands in nature reserves in the coterminous United States among five soil productivity classes (soil 1 is the most productive, and soil 5 is the least productive) and seven elevation zones.

| Soil class | 0–615 m | | 616–1230 m | | 1231–1845 m | | 1846–2460 m | |
|---|---|---|---|---|---|---|---|---|
| | km² | % | km² | % | km² | % | km² | % |
| 1 | 758 | 0.19 | 1 592 | 0.40 | 1 422 | 0.35 | 2 188 | 0.55 |
| 2 | 3 559 | 0.89 | 14 058 | 3.51 | 9 059 | 2.26 | 7 656 | 1.91 |
| 3 | 6 488 | 1.62 | 11 202 | 2.79 | 14 112 | 3.52 | 11 072 | 2.76 |
| 4 | 2 279 | 0.57 | 1 862 | 0.46 | 7 357 | 1.83 | 14 714 | 3.67 |
| 5 | 594 | 0.15 | 5 773 | 1.44 | 19 124 | 4.77 | 30 720 | 7.66 |
| Total | 13 678 | 3.42 | 34 487 | 8.60 | 51 074 | 12.73 | 66 350 | 16.55 |

*Note:* Both the area and the percentage of total reserved land area are provided for each combination of soil class and elevation zone, as well as for marginal totals.

TABLE 1. Extended.

| 2461–3075 m | | 3076–3690 m | | >3690 m | | Total | |
|---|---|---|---|---|---|---|---|
| km² | % | km² | % | km² | % | km² | % |
| 85 888 | 1.1 | 9 148 | 0.1 | 23 | 0.0 | 1 194 119 | 15.8 |
| 349 757 | 4.6 | 93 048 | 1.2 | 8 819 | 0.1 | 2 763 447 | 36.5 |
| 331 468 | 4.4 | 174 462 | 2.3 | 92 468 | 1.2 | 1 802 389 | 23.8 |
| 273 945 | 3.6 | 156 914 | 2.1 | 69 844 | 0.9 | 1 037 252 | 13.7 |
| 260 480 | 3.4 | 152 026 | 2.0 | 64 700 | 0.9 | 779 549 | 10.3 |
| 1 301 538 | 17.1 | 585 598 | 7.7 | 235 854 | 3.1 | 7 576 756 | 100.0 |

combined into a spatial database providing boundaries and management status for more than 2500 reserves and other publicly owned areas, including national parks, national forests, designated wilderness areas, national wildlife refuges, Indian reservations, and county parks. We selected those areas having permanent protection from conversion of natural land cover, corresponding to the S1 and S2 management categories in the national Gap Analysis Program (Scott et al. 1993). When represented in Albers equal-area, conical projection using a 1-km² minimum mapping unit, these protected lands total 421 643 km².

We created a predicted soil productivity map based on the five factors generally thought to influence soil fertility: hydrologic soil grouping, depth to bedrock, rock fragment volume, available water capacity, and surface slope (Miller and White 1998). Initially, each of these factors was arbitrarily stratified into three or four categories and ranked from highest to lowest potential effect on soil productivity. They were then spatially overlaid and combined to produce a single number based on the sum of all variable rankings. The resulting map represented potential soil productivity for each 1-km² cell within the coterminous United States. The values were divided into five categories of productivity, with 1 being the highest and 5 the lowest (Fig. 1).

A basic map of life zones based on elevation and latitude was produced for the coterminous United States using a 1-km² digital elevation grid and an elevational adjustment of 0.625 m/km north (Stevens 1992). Key West, Florida was set as the baseline elevation. We then divided the resulting ''equivalent elevations'' (hereafter referred to simply as elevation, in meters) into seven 615-m (2000-ft) zones (Fig. 2).

We used Bailey's (1994) ecological regionalization to distinguish three broad ecological domains: the Western Humid Temperate, Eastern Humid Temperate, and Dry Temperate domains. Bailey (1994) distinguishes the southern Florida peninsula as the Humid Tropical Domain. Considering the limited extent of this domain, and in order to simplify the analysis, we combined the Eastern Humid Temperate and the Humid Tropical Domains and refer to them as ''Eastern Humid Domain.'' We combined soils, elevation, ecological zones, and management status maps to determine the land area in each soil × elevation class for the coterminous United States, for lands in nature reserves, and for the lands in the S1 and S2 management categories within the three ecological domains.

To examine current land use within each soil × elevation class, we combined the grids of soil productivity and elevation with a map of 1993 land use as represented in the U.S. Geological Survey's North American Land Cover Characteristics Database, Version 1.2 (Loveland et al. 1995). Land use/land cover was mapped at 1-km² resolution using AVHRR satellite imagery acquired between April 1992 and March 1993. We used the Anderson et al. (1976) classification scheme (modified Level 2), and considered six of the 24 land use/land cover classes as converted habitats. These include: (1) urban and built-up land, (2) dryland cropland and agriculture, (3) irrigated cropland and pasture, (4) mixed dryland/irrigated cropland and pas-

TABLE 2. Extended.

| 2461–3075 m | | 3076–3690 m | | >3690 m | | Total | |
|---|---|---|---|---|---|---|---|
| km² | % | km² | % | km² | % | km² | % |
| 872 | 0.22 | 174 | 0.04 | 0 | 0.00 | 7 006 | 1.75 |
| 5 703 | 1.42 | 2 616 | 0.65 | 517 | 0.13 | 43 168 | 10.76 |
| 18 629 | 4.64 | 18 191 | 4.54 | 19 795 | 4.94 | 99 489 | 24.81 |
| 21 273 | 5.30 | 20 586 | 5.13 | 25 769 | 6.43 | 93 840 | 23.40 |
| 43 098 | 10.75 | 26 555 | 6.62 | 31 705 | 7.91 | 157 569 | 39.29 |
| 89 575 | 22.33 | 68 122 | 16.98 | 77 786 | 19.41 | 401 072 | 100.00 |

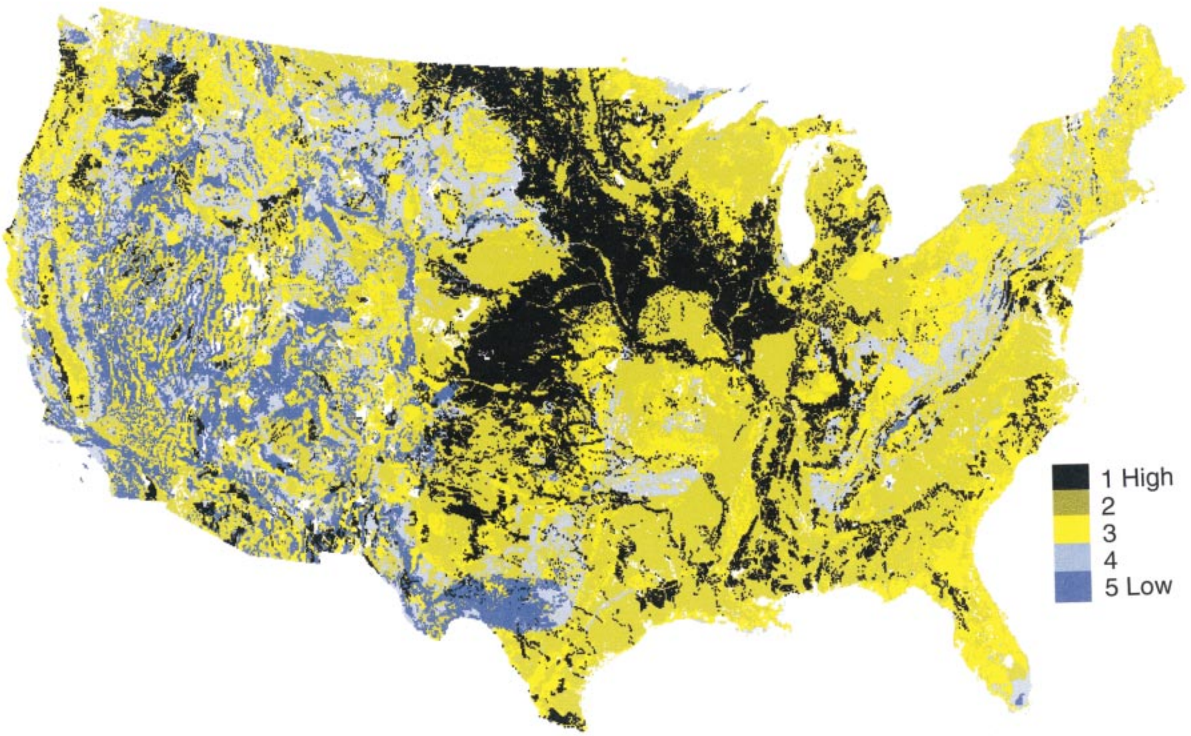


FIG. 1. Map of predicted soil productivity classes derived from soil fertility, hydrologic soil grouping, depth to bedrock, rock fragment volume, availability of water capacity, and surface slope (Miller and White 1997). The minimum mapping unit was 1 $km^2$. Areas with highest soil productivity are rated as 1, and those with the lowest as 5.

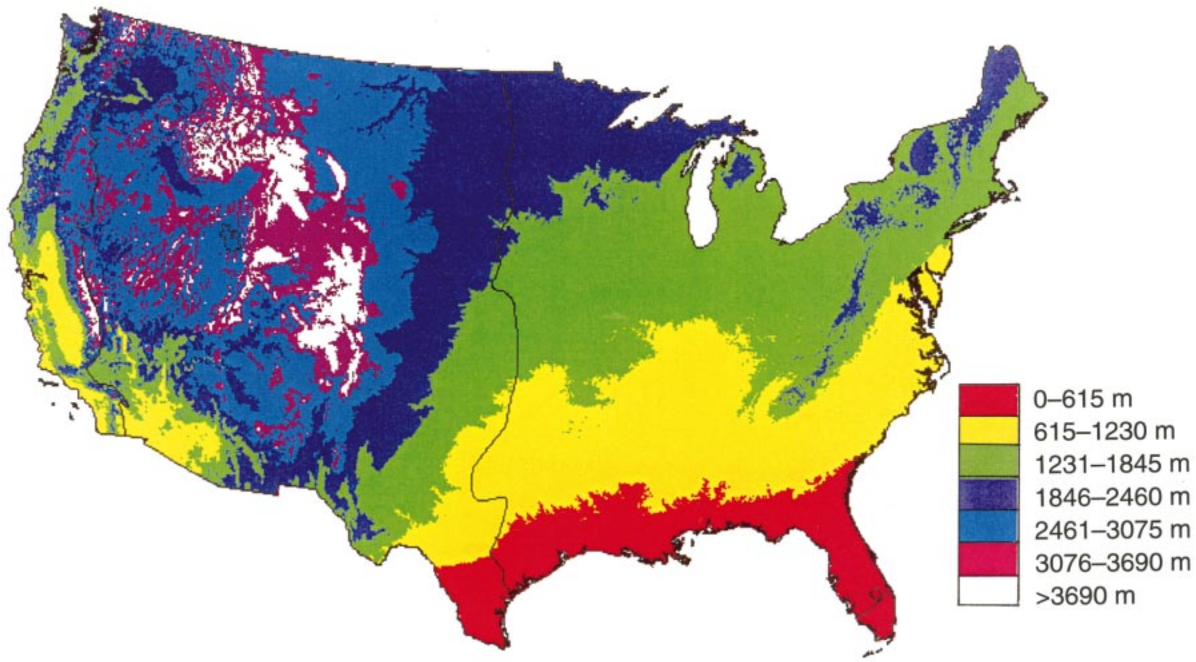


FIG. 2. Map of seven zones of elevation adjusted by latitude (see *Methods* for explanation). Lines separate geographic domains according to Bailey (1994).

TABLE 3. Percentage of each soil by elevation class (soil 1 is the most productive, and soil 5 is the least productive) in reserves for the Eastern Humid Domain (Bailey 1994).

| Soil class | 0–615 m | 616–1230 m | 1231–1845 m | 1846–2460 m | >2460 m | All elevations |
|---|---|---|---|---|---|---|
| 1 | 1.8 | 0.6 | 0.3 | 1.1 | 0.0 | 0.6 |
| 2 | 1.5 | 1.2 | 0.9 | 4.0 | 50.0 | 1.2 |
| 3 | 4.7 | 1.2 | 1.1 | 9.0 | 36.6 | 2.0 |
| 4 | 16.5 | 0.7 | 1.6 | 9.3 | 4.1 | 3.5 |
| 5 | 59.2 | 1.7 | 6.7 | 25.9 | 19.1 | 13.9 |
| All soils | 3.2 | 1.1 | 0.9 | 2.9 | 16.6 | 1.5 |

TABLE 5. Percentage of land area in each soil by elevation class (soil 1 is the most productive, and soil 5 is the least productive soil) in reserves for the Dry Temperate Domain (Bailey 1994).

| Soil class | 616–1230 m | 1231–1845 m | 1846–2460 m | 2461–3075 m | 3076–3690 m | >3690 m | All elevations |
|---|---|---|---|---|---|---|---|
| 1 | 0.2 | 1.8 | 2.5 | 0.8 | 7.2 | | 1.5 |
| 2 | 1.1 | 2.7 | 3.4 | 4.6 | 14.9 | 46.7 | 3.1 |
| 3 | 1.4 | 4.4 | 4.4 | 13.5 | 38.6 | 80.4 | 10.2 |
| 4 | 2.9 | 7.8 | 12.5 | 18.3 | 48.4 | 88.0 | 16.9 |
| 5 | 8.5 | 10.1 | 21.9 | 22.3 | 60.1 | 91.3 | 24.8 |
| All soils | 2.4 | 5.9 | 9.1 | 14.8 | 42.4 | 89.1 | 12.8 |

ture, (5) cropland grassland mosaic, and (6) cropland/woodland mosaic.

## RESULTS

For this analysis, the approximated area of the coterminous United States is 7 576 756 km². (Conversion of vector maps to raster grids and map reprojection cause area estimates to vary among input maps by 0.1–0.2%. The analysis area constitutes the area of overlap between all input maps.) About 72% of these lands are found at elevations below 2460 m (Table 1). Of the total area, 16% is mapped as Soil Productivity Class 1, and 60% is either Soil Class 2 or Class 3.

We identified 401 072 km² of lands in the coterminous United States in nature reserves, ~5% of the landscape (Table 2). These nature reserves are primarily located on areas with the least productive soils (almost 63% of the nature reserves are in soil productivity classes 4 and 5), and are found predominantly at mid-to-high elevations (>59% of the total reserved area lies at elevations >2460 m; Table 2).

Only 11 of the 35 soil × elevation classes had ≥10% of their area in nature reserves. These were all located in the lower soil productivity classes and, with four exceptions, at elevations >2460 m. One of these exceptions was in soil productivity class 5 at the lowest elevation. This class occupies 1012 km², and 60% of the class occurs in Everglades National Park, Florida (Table 1).

The combined Eastern Humid Temperate and Tropical Domains occupy 3 448 314 km², or 45.5% of the coterminous United States, with 53 141 km² or 1.5% of this area occurring in nature reserves (Table 3). Roughly 86% of this area lies at <1845 m elevation. Six of the 25 available soil × elevation classes had >10% of their area in nature reserves, and these areas were skewed to the higher elevations and poorer soils (Table 3).

The Dry Temperate Domain comprises 3 639 344 km², or 48% of the coterminous United States, of which 285 355 km² (7.8%) is in nature reserves (Table 4). Eleven of the 35 potential combinations of soil productivity and elevation had ≥10% of their area in nature reserves. Nature reserve representation in the two highest soil productivity classes across all elevations amounted to 1.5% of the total area in such soils, in contrast to 20% reservation of the area in the lowest soil productivity class. Nearly one-third of equivalent elevations above 3680 m are reserved, compared to <10% for all other elevation zones (Table 4).

The Western Humid Temperate Domain covers 489 098 km², or 6.5% of the coterminous United States, of which 62 576 km² (12.8%) is dedicated to nature reserves (Table 5). Of the 30 observed soil productivity × elevation classes, 14 had ≥10% of their area in nature reserves, but the reserved area is concentrated at high elevations on unproductive soils (Table 5). Less than 5% of the area is reserved at elevations below 2460 m on the three most productive soil classes. In contrast, 18–91% of each category is reserved for the two least productive soil classes at elevations above 2460 m.

TABLE 4. Percentage of land area in each soil by elevation class (soil 1 is the most productive, and soil 5 is the least productive) in reserves for the Dry Temperate Domain (Bailey 1994).

| Soil class | 0–615 m | 616–1230 m | 1231–1845 m | 1846–2460 m | 2461–3075 m | 3076–3690 m | >3680 m | All elevations |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.1 | 2.6 | 0.2 | 0.4 | 1.0 | 1.3 | 0.0 | 0.5 |
| 2 | 0.1 | 6.6 | 1.8 | 1.6 | 1.5 | 2.3 | 5.7 | 2.0 |
| 3 | 0.3 | 18.7 | 10.7 | 4.4 | 4.5 | 7.4 | 20.7 | 8.2 |
| 4 | 1.3 | 2.3 | 8.4 | 6.0 | 6.4 | 10.5 | 34.8 | 10.2 |
| 5 | 55.5 | 7.9 | 27.0 | 23.9 | 16.1 | 15.2 | 44.1 | 19.8 |
| All soils | 0.3 | 8.2 | 6.3 | 4.8 | 16.6 | 9.4 | 30.3 | 7.8 |

TABLE 6. Occurrence of dominant cover types in status 1 and 2 Gap Analysis Program reserves (those areas dedicated to longer-term maintenance of biodiversity).

| State | No. mapped cover types | No. cover types with ≥10% in reserves | Percentage of cover types in reserves | Reference |
|---|---|---|---|---|
| Utah | 35 | 5 | 14.3 | Edwards et al. (1995) |
| Arkansas | 35 | 6 | 17.1 | Smith et al. (1998) |
| Maine | 29 | 5 | 17.2 | Krohn et al. (1998) |
| Wyoming | 36 | 13 | 36.1 | Merrill et al. (1996) |
| Montana | 44 | 16 | 36.4 | Redmond et al. (1998) |
| Idaho | 80 | 30 | 37.5 | Caicco et al. (1995) |
| New Mexico | 37 | 17 | 45.9 | Thompson et al. (1996) |
| California | 203 | 105 | 51.7 | Davis et al. (1998) |
| Total | 499 | 197 | 39.5 | |

*Note:* Information was obtained from state Gap Analysis Programs that had been completed.

TABLE 7. Percentage of coterminous U.S. land area in each soil by elevation class converted to urban and intensive agricultural use (Anderson et al. 1976) based on U.S. Geological Survey's North American Land Cover Characteristics data base (Loveland et al. 1995).

| Soil class | 0–615 m | 616–1230 m | 1231–1845 m | 1846–2460 m | 2461–3075 m | 3076–3680 m | >3680 m | All elevations |
|---|---|---|---|---|---|---|---|---|
| 1 | 38.2 | 33.1 | 75.7 | 72.3 | 25.3 | 14.8 | 0.0 | 62.3 |
| 2 | 59.8 | 30.9 | 47.8 | 44.7 | 15.7 | 7.2 | 1.5 | 38.0 |
| 3 | 57.0 | 27.7 | 17.9 | 18.1 | 5.7 | 4.9 | 2.2 | 18.5 |
| 4 | 50.5 | 19.0 | 9.4 | 7.8 | 6.3 | 2.7 | 1.4 | 8.6 |
| 5 | 7.4 | 24.5 | 3.2 | 2.6 | 2.6 | 1.5 | 0.9 | 4.5 |
| All soils | 56.2 | 29.2 | 41.5 | 38.1 | 9.2 | 4.0 | 1.6 | 29.7 |

## DISCUSSION

The distribution of nature reserves, whether examined across the entire landscape of the coterminous United States or by ecological zone, shows the same pattern. Nature reserves are largely limited to sites of higher than average elevation and less productive soils. Most of the larger nature reserves included in our analysis have been in existence for a relatively long time period. Many of the largest national parks were created in the early 1900s. Similarly, the national forests, which contain most of the legally designated wilderness areas, date from the early decades of the 20th century. It has been argued that, at the time these lands were set aside, they were considered ''the lands nobody wanted'' (Shands and Healy 1977). In other words, they were often opportunistically established because of their relative lack of value for commercial uses, human habitation, or because of scenic attributes or recreational value (Pressey 1994, 1995). Sullivan and Shaffer (1975) predicted that the result of such a reserve selection and establishment process would be a network of reserves that is very inefficient in terms of preserving a diversity of ecosystems and their associated resources.

A comprehensive assessment of the occurrence of natural vegetation types in nature reserves in the United States has yet to be completed. The small area dedicated to nature reserves on more productive soils at low elevations suggests that the existing network of nature reserves is inefficient in terms of its ability to

TABLE 8. Distribution of private lands in the coterminous United States among five soil productivity classes (soil 1 is the most productive, and soil 5 is the least productive) and seven zones of equivalent elevation.

| Soil class | 0–615 m | | 616–1230 m | | 1231–1845 m | | 1846–2460 m | |
|---|---|---|---|---|---|---|---|---|
| | km² | % | km² | % | km² | % | km² | % |
| 1 | 49 867 | 92.62 | 173 605 | 94.15 | 469 124 | 96.63 | 347 319 | 92.53 |
| 2 | 255 698 | 93.63 | 732 341 | 92.40 | 696 682 | 91.48 | 381 784 | 78.78 |
| 3 | 149 210 | 91.42 | 225 432 | 86.34 | 403 977 | 83.57 | 181 715 | 61.33 |
| 4 | 11 400 | 80.89 | 120 971 | 88.32 | 163 115 | 81.30 | 95 756 | 51.80 |
| 5 | 408 | 40.32 | 60 954 | 81.70 | 52 739 | 54.23 | 45 851 | 35.41 |
| Total | 466 583 | 92.35 | 1 313 303 | 90.60 | 1 785 637 | 88.04 | 105 425 | 71.56 |

*Note:* Both the area and the percentage of total land area in that category are provided for each combination of soil class and elevation.

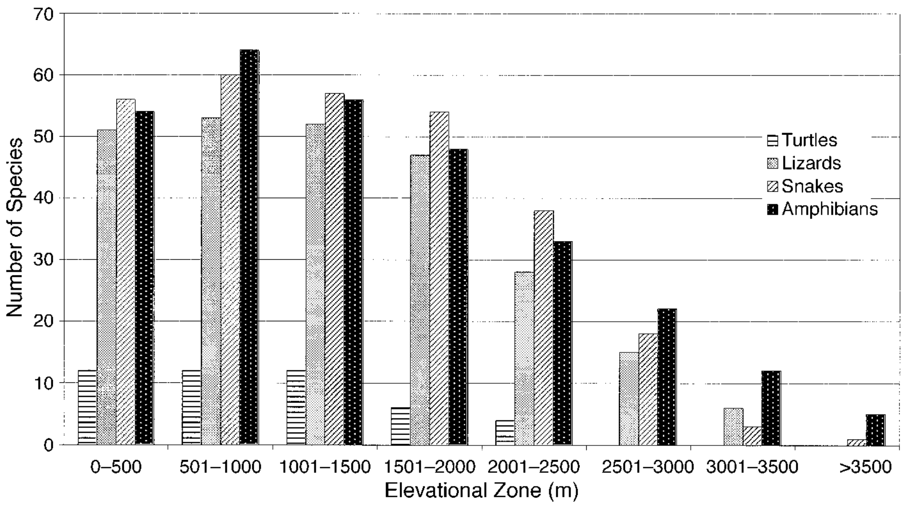


FIG. 3. Distribution of amphibians and reptiles in the western United States west of the 100th meridian as a function of elevation (Stebbins 1985).

protect a representative sample of the nation's biodiversity. Based on our findings, we surmise that most low-elevation biota associated with the more productive soils are not adequately protected, and many are very likely not even represented in existing large nature reserves. Data from Gap Analysis studies in eight states support this contention (Table 6). Although the occurrence of the different vegetation types in nature reserves varied greatly, in no state did >52% of the vegetation types have ≥10% of their mapped distribution in nature reserves. Again, this 10% figure is arbitrary and may underestimate by as much as seven times how much area is needed to conserve biodiversity (Soulé and Sanjayan 1998). Thus the risk of species and ecosystem loss suggested by our assessment of the current distribution of nature reserves is probably understated.

We found that areas of low elevation were almost always underrepresented in nature reserves. This may have important bearing on our ability to protect animal species whose optimal habitat falls in these areas. For example, an examination of the distribution of amphibians and reptiles for the western United States (Stebbins 1985) found that the greatest number of species occurred below 2000 m (Fig. 3). In both the Dry Temperate and Western Humid Temperate Domains, these areas are least protected. Similar patterns of fewer species at higher elevations have been shown for plants and birds in Costa Rica and for mammals and birds in Nepal (Hunter and Yonzon 1993). Likewise, in terms of soils, we have found that very few of the most productive native habitats in the United States are well represented in nature reserves. Many of these areas have already been intensively developed for agriculture, timber production, and residential development, and opportunities for protection and/or restoration are increasingly limited. As summarized in Table 7, the estimated fraction of land converted nationwide is already 62% of the most productive soils, dropping steadily to <5% of the least productive. Similarly, 30–56% of land has been converted in elevation zones below 2460 m. Many species preferring such environments are already persisting in highly fragmented or marginal habitats. These may be areas where a species' ability to respond to environmental change may be limited. However, the value of peripheral populations to species has been well documented (Lesica and Allen-

TABLE 8. Extended.

| 2461–3075 m | | 3076–3690 m | | >3690 m | | Total | |
|---|---|---|---|---|---|---|---|
| km² | % | km² | % | km² | % | km² | % |
| 67 105 | 78.13 | 5 215 | 57.01 | 5 | 21.74 | 1 112 240 | 93.14 |
| 234 933 | 67.17 | 49 452 | 53.15 | 3 492 | 39.60 | 2 354 382 | 85.20 |
| 143 753 | 43.37 | 58 549 | 33.56 | 15 153 | 16.39 | 1 177 789 | 65.35 |
| 125 530 | 45.82 | 41 035 | 26.15 | 5 173 | 7.41 | 562 980 | 54.28 |
| 72 248 | 27.74 | 31 247 | 20.55 | 4 925 | 7.61 | 268 372 | 34.43 |
| 643 569 | 49.45 | 185 498 | 31.68 | 28 748 | 12.19 | 5 475 763 | 72.27 |

dorf 1995, Lomolino and Channell 1995). To preserve the full range of ecological and genetic variation in species, and thus maintain their potential to respond to varying conditions, we must establish a set of nature reserves that is representative of the natural variation found in the United States. The current system of nature reserves fails to do so.

Our findings show that the creation of a system of nature reserves that captures the full range of biodiversity in the United States will require a systematic approach that targets the low-elevation–high-productivity habitats. Others have reported similar results (Hunter and Yonzon 1993, Pressey 1995). Because many of these areas are in private ownership (Table 8), achieving a representative reserve system will have to fully involve the private sector in innovative strategies including conservation easements, tax incentives, and other means. In addition, the recently passed Refuge Improvement Act (Gergely et al. 2000), which calls for the U.S. Fish and Wildlife Service's National Wildlife Refuge System to be representative of the nations ecosystems, also provides an unprecedented opportunity for publicly owned lands to be more effective at protecting species not found within the current network of nature reserves.

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