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ORIGINAL PAPER

Assessing protection for imperiled species of nevada, U.S.A.: are species slipping through the cracks of existing protections?

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Abstract To assess whether imperiled species are covered by existing protections in the biologically-rich state of Nevada, U.S.A., we compared the distribution of reserves with known imperiled species occurrences. For species poorly represented in reserves, we determined whether they were receiving alternate protection under the U.S. Endangered Species Act or voluntary conservation plans. A majority (212, 55%) of Nevada's 384 imperiled species had fewer than 25% of occurrences in reserves and most (282, 68%) had fewer than 50% of occurrences in reserves. Of imperiled species with less than 25% or fewer than two occurrences in reserves, only 9% are currently receiving alternate protection from the Endangered Species Act or voluntary plans. These results suggest that providing protection for imperiled species in Nevada will require both an expansion of the existing reserve system, which currently covers 14% of the state, and protection of more species under the Endangered Species Act or other programs. By dividing Nevada into equal-sized hexagons and scoring each of these hexagons based on a rarity-weighted richness index of imperiled species occurrences, we identified 19 imperiled species hot spots in Nevada. No imperiled species occurrences were protected in seven (37%) and less than half were protected in 11 (58%) of these hot spots. Protecting these areas could provide important additional protection for imperiled species in Nevada. Evaluations of protective measures for biological diversity should include the full suite of protections, including both reserves and laws and regulations.

Keywords Imperiled species · Reserves · Endangered Species Act · Hot spot

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Abbreviations
ESA Endangered Species Act

Introduction

Strategies for protecting imperiled species consist of two primary approaches—protecting habitat in reserves, which may or may not have been specifically designed for this purpose (Fleishman et al. 2006), or providing direct protection to the species in question through regulation or policy, which in the U.S. primarily occurs under the auspices of the Endangered Species Act (ESA). Although a number of studies have evaluated the effectiveness of reserves for protecting various aspects of biological diversity from genes, to species, to ecological processes (e.g. Scott et al. 2001; Pressey et al. 2002; Rodrigues et al. 2004; Gaston et al. 2006), this is the first study to evaluate whether the combination of reserves and regulations cover known imperiled species.

Numerous methodologies for designing reserves to protect biological diversity have been developed by conservation biologists (see Margules and Pressey 2000; Cabeza and Moilanen 2001; Gaston and Rodrigues 2003; Siitonen et al. 2002; Rothley et al. 2004). To date, few large-scale reserve systems have been created utilizing such methods (Prendergast et al. 1999; Fleishman et al. 2006). Rather, reserves have typically been designated opportunistically based on local politics for a wide variety of reasons, including protection of scenic quality, opportunities for solitude, pristine ecosystems and in some cases, biological diversity (Fleishman et al. 2006). With a system of reserves designated over time under a variety of laws, the state of Nevada, U.S. is no exception to the above pattern. Nevertheless, this system of reserves forms a primary basis for protecting biological diversity in Nevada.

The ESA is widely acknowledged as one of the most comprehensive laws for protecting species ever enacted (Bean and Rowland 1997; Soulé et al. 2005). Before species can receive the substantial protections of the Act, they must first be formally added to the list of threatened and endangered species and for this reason, listing of species is a key process of the Endangered Species Act (Stanford Environmental Law Society 2001). Almost since its inception, the program for listing of species, which for non-marine species is administered by the U.S. Fish and Wildlife Service, has suffered problems, including large backlogs of species known to require protection, lack of funding, and political interference in listing decisions (Tobin 1990; Wilcove et al. 1993; Ando 1999; Greenwald et al. 2005). These problems have resulted in long delays in species receiving protection and ultimately in only a small percentage of imperiled species being protected to date (Greenwald et al. 2005).

In this paper, we assess the degree to which imperiled species in the state of Nevada are covered by existing protections by comparing the distribution of imperiled species occurrences from the Nevada Natural Heritage Program with existing reserves. For species poorly represented in existing reserves, we determined if they were receiving alternate protection under the ESA or other measures. We further identified hot spots of imperiled species occurrences as a first step towards identifying areas where protection in reserves may help ensure the survival of imperiled species.

We used the state of Nevada, U.S. as a case study because with 14% of the state in reserves, Nevada has a higher proportion of reserved land than most states or countries, and thus is as likely as anywhere to have reserves that sufficiently protect imperiled species. Nevada is also rich in biological diversity with more species than 40 other states and has a

high rate of endemism, making it important for the conservation of biological diversity both nationally and globally (Stein et al. 2000).

Methods

To create an overall coverage of reserves in Nevada, we obtained and combined Geographic Information System layers for all reserves in Nevada, including designated wilderness, wilderness study areas, national parks, national wildlife refuges, research natural areas, areas of critical environmental concern, national conservation areas and Nature Conservancy preserves (Fig. 1). Although these various designations were created under different laws and mandates, they all roughly correspond to what others have classified as highly protected areas (Duffy et al. 1999) or "status 1 and 2" areas as defined by the "Gap Analysis Project," meaning that most or all activities that result in resource degradation are prohibited and they are managed to maintain natural character (USGS National GAP Analysis Program 2005; Strittholt et al. 2006).

To quantify the degree to which imperiled species occur in existing reserves, we obtained data from the Nevada Natural Heritage Program (NNHP) on occurrences of critically imperiled (G1 or S1) and imperiled (G2 or S2) species and determined the number and proportion of occurrences in reserves for each species (for a complete description of how species are classified as critically imperiled and imperiled see: http://www.natureserve.org/explorer/ranking.htm). We chose to focus on species rather than another aspect of biological diversity, such as ecological communities or processes, because species are discrete entities for which there is available occurrence data (see Fleishman et al. 2006 for further discussion) and because existing laws to protect biological diversity, such as the Endangered Species Act, focus on species.

For critically imperiled and imperiled species that were poorly represented in reserves (defined as <25% of occurrences in a reserve or two or less occurrences in a reserve), we determined whether they were protected by the Endangered Species Act or voluntary state conservation plans. Such plans have been enacted by the Nevada Department of Wildlife for a number of species and are voluntary agreements committing the state, private landowners, the U.S. Fish and Wildlife Service, and other partners to take various actions to conserve species (see http://www.ndow.org/wild/conservation/).

We identified hot spots of known occurrences of imperiled species, and determined whether these hot spots overlap with existing reserves. Following methodology outlined in Chaplin et al. (2000), we divided Nevada into equal area hexagons as our analytical unit, ensuring comparison of equally sized areas. We chose to use hexagons that are 5 km on a side for a total of 64.9 km^2. This size was chosen to be large enough to smooth unsystematically collected data, but small enough to avoid inclusion of multiple habitat types, helping to ensure that variation in the distribution of imperiled species as it actually occurs on the landscape drives identification of the hot spots, rather than placement of the hexagons.

Within each hexagon, we assigned each imperiled species occurrence a score, or weight, based on the inverse of the number of hexagons occupied by the species (Chaplin et al. 2000). If a species occurs in only one hexagon, that species receives a score of 1 for each occurrence in a hexagon. If a species occurs in 20 hexagons, then that species receives a score of 0.05 for each location in a particular hexagon. The sum of all individual species scores in a hexagon, referred to as the "rarity weighted richness index" (RWRI) score, provides an index of imperiled species richness that factors in the importance of the area to

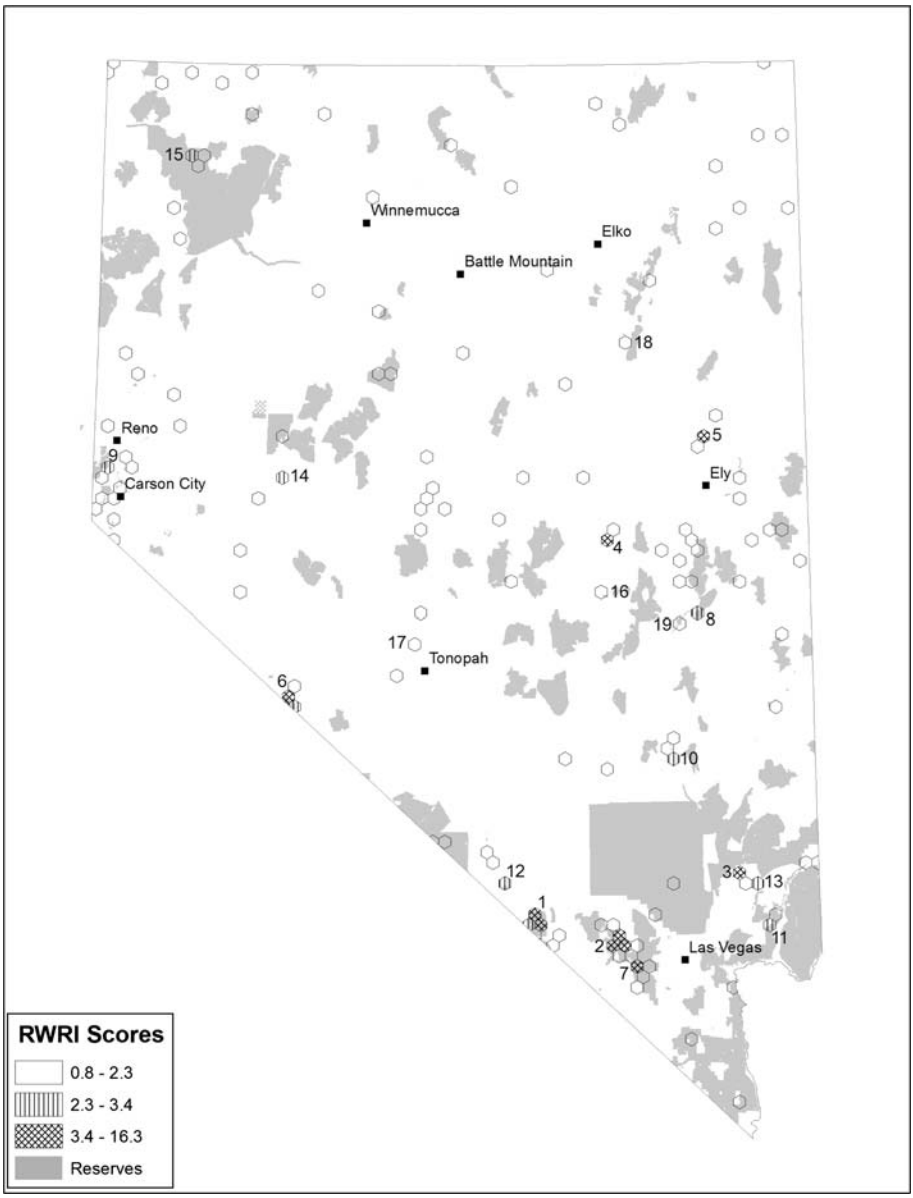

Fig. 1 Hot spots of imperiled species locations and reserves in the state of Nevada, USA

the survival of the individual species, as determined by how many other hexagons in which they occur (Chaplin et al. 2000).

For hexagons with RWRI scores >0.0, we determined whether any of the hexagon was protected in a reserve. For hexagons with RWRI scores >2.0, we also quantified the proportion of imperiled species locations protected in reserves. We considered areas with an RWRI >2 to be hot spots based on their infrequency and substantial number of unique imperiled species.

Results

According to the Nevada Natural Heritage Database, there are 384 imperiled or critically imperiled (G1, G2, S1, S2) species in Nevada. The NNHP database contained a total of 3,031 occurrences of these species with an average of just under 9 occurrences per species and a range of 1–132 occurrences. Of these 384 imperiled species, nearly half, 180 (47%) have no occurrences in reserves (Fig. 2). Species lacking occurrences in reserves were not limited to species with only 1 or 2 overall occurrences, but also included 47 species with five or more occurrences (Fig. 3). An additional 82 (21%) species have fewer than 50% of occurrences in reserves, including 72 species with five or more occurrences (Figs. 2 and 3). Most species, 313 (82%), have fewer than five occurrences in reserves (Fig. 4). A total of 122 (32%) species have greater than 50% of occurrences in reserves, including 55 that have greater than five occurrences (Figs. 1 and 2).

Overall, there were 293 (76%) species with <25% or less than two occurrences in reserves. Of these, 18 (6%) are protected as threatened or endangered species under the Endangered Species Act and four potentially receive some protection through voluntary conservation agreements. An additional 15 species are protected under the Endangered Species Act, and have more than 25% and more than two occurrences in reserves.

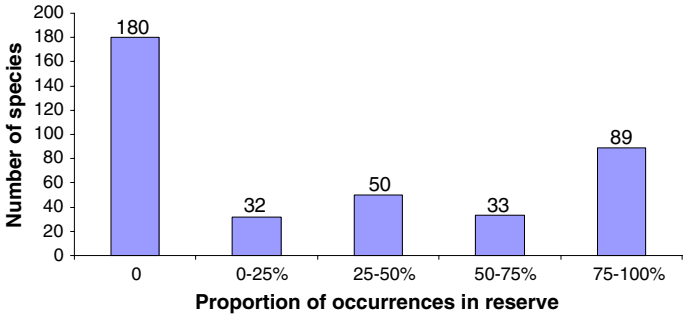

Fig. 2 Proportion of species occurrences in reserves for 384 imperiled species of Nevada

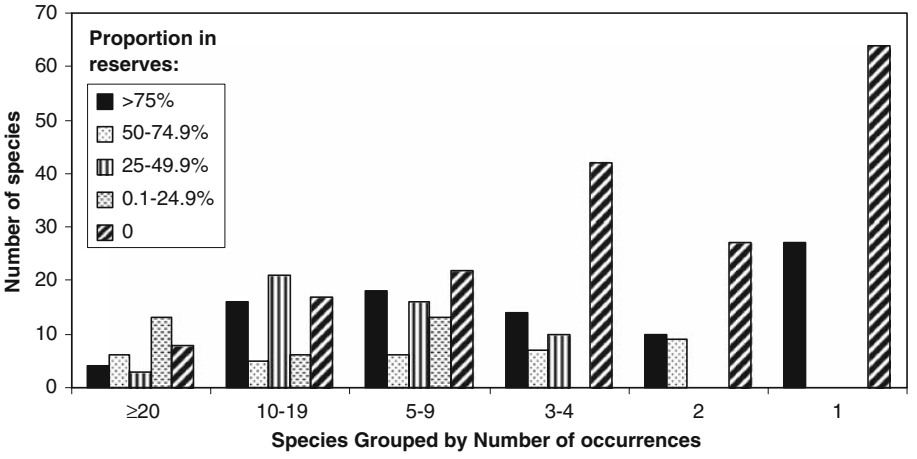

Fig. 3 Species grouped by the proportion of occurrences in reserves and by overall number of occurrences

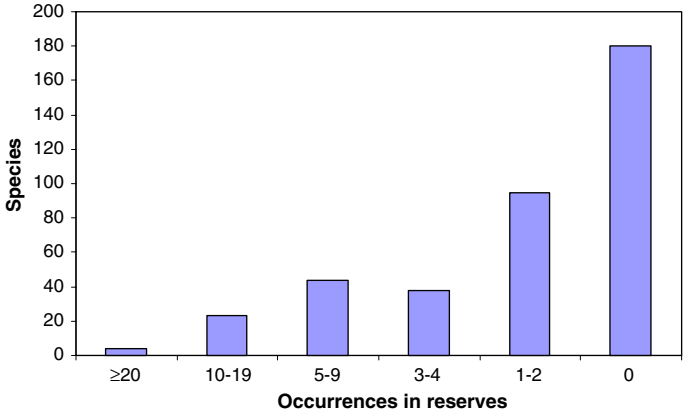

Fig. 4 Number of species grouped by the number of occurrences in reserves

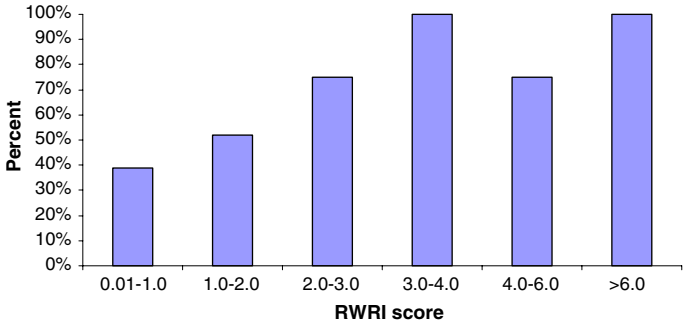

Fig. 5 Proportion of hexagons with some reserve area by RWRI score

Of the 4,582 hexagons we designated in Nevada, 1163 (25.4%) contained records of imperiled species with RWRI scores ranging from 0.035 to 16.4. The majority of hexagons with imperiled species records (1,050, 90.3%) had scores of 0–1. One hundred and thirteen hexagons had scores >1 and 26 had scores >2. Hexagons with a RWRI score >1 occupy 2.5% of Nevada and hexagons with a RWRI >2 occupy 0.6% of Nevada. The proportion of hexagons with at least some area in a reserve generally increased with RWRI score (Fig. 5).

Based on hexagons with RWRI scores >2, we identified 19 hot spots of imperiled species locations in Nevada with four areas containing more than one hexagon (Fig. 1). Protection for these hot spots varied with the percent of the area protected ranging from 0 to 100% with an average of 30% (Table 1). Less than half the area was protected in 13 of the hot spots. Likewise, the percentage of imperiled species locations protected within hot spots ranged from 0 to 100% with an average of 39%. None of the locations were protected in seven of the hot spots and less than half of the locations were protected in 11 of the hot spots. A substantial portion of points were protected within several hot spots even though only a small percentage of the hexagon was protected, indicating a hot spot smaller than the hexagon. In particular, 75% of the imperiled species were protected at Big Dune even though only 11% of the hexagon area was protected and 33% of species locations were protected in Moapa Valley even though only 3% of the hexagon area was protected.

Table 1 Hot spots of imperiled species in Nevada, percent of hot spot area protected, percent of reserve locations protected, and RWRI score

Place name	Reserve area (%)	Occurrences in reserve (%)	RWRI score
1. Ash Meadows NWR	79.0	97.3	16.4
2. Spring Mountains	62.3	49.0	6.5
3. Moapa Valley	2.8	34.2	6.2
4. Duckwater Reservation	0.2	0.0	4.6
5. Steptoe Ranch	0.0	0.0	4.0
6. White Mountains	36.7	62.5	4.0
7. Rainbow Mtn Wilderness	96.6	100.0	3.4
8. Far South Egans Wilderness	50.6	66.7	3.2
9. Mount Rose	35.0	18.8	3.2
10. Pahranagat Creek	0.1	9.1	3.0
11. Muddy Mountains	50.0	77.8	2.6
12. Big Dune	11.3	100.0	2.5
13. Muddy River	1.6	0.0	2.5
14. Sand Mountain	0.0	0.0	2.4
15. Soldier Meadow	100.0	100.0	2.3
16. Railroad Valley	5.3	0.0	2.1
17. Crescent Dunes	0.0	0.0	2.1
18. Ruby Mountains	2.5	0.0	2.1
19. White River	29.3	71.4	2.0

Discussion

Our analysis found that a majority of the 384 critically imperiled and imperiled species in Nevada are poorly represented in existing reserves, with 55% having less than 25% of known occurrences found in reserves. Species occurrences in the NNHP database were not systematically collected and survey effort may have been biased by access, land ownership, species appeal, funding or other factors. Despite this limitation, it is unlikely that many of the species covered by this study have substantially more occurrences in reserves. By definition, imperiled species are narrow endemics or otherwise rare, and thus not likely to occur in many additional areas. In addition, although location data from the Nevada Natural Heritage Program was not systematically collected, substantial effort has gone into ensuring that it is comprehensive and reliable.

Other studies have similarly found a poor correlation between reserves and imperiled species (e.g. Duffy et al. 1999; Deguise and Kerr 2006), suggesting our findings are not limited to Nevada. Duffy et al. (1999), for example, found that 75% of 32 rare vascular plants had <50% of their locations in highly protected areas in Alaska, and Deguise and Kerr (2006) found a lack of correlation between the density of reserves and species at risk in Canada. More broadly, a number of studies have found that existing reserves fail to include the full array of biological diversity (e.g. Margules and Pressey 2000; Scott et al. 2001; Pressey et al. 2002; Rodrigues et al. 2004).

Of species poorly represented in reserves, a minority (<8%) receive alternate protection under the ESA or through voluntary conservation agreements. These findings indicate most imperiled species in Nevada are not protected by either existing reserves or the ESA. One roadblock to protection of these species is that the rate at which species are added to the threatened and endangered list has dropped dramatically in the U.S. in the past 7 years. From 1974 to 2000, an average of 47 species were listed per year. Since 2001, however,

only an average of eight species per year have been listed, even though the budget for listing has steadily increased (Greenwald et al. 2005; USFWS 2007a). There are currently 280 species designated by the Fish and Wildlife Service as candidates for listing as threatened or endangered, meaning the agency has sufficient information to indicate that listing is warranted, but that protection is precluded by other actions to protect species of a higher priority (USFWS 2007a). In Nevada, there are currently 10 candidate species, including species such as the mountain yellow-legged frog (*Rana muscosa*), relict leopard frog (*Rana onca*) and elongate mud meadows springsnail (*Pyrgulosis notidicola*), which have on average been waiting for protection for 17 years (Greenwald et al. 2005). Protection of these species under the Endangered Species Act should be expedited.

A number of threats to Nevada ecosystems and imperiled species are on the rise and are likely to impact species both inside and outside reserves. The human population has risen by 25% since 2000 with corresponding increased demand for water in this arid region (U.S. Census Bureau 2007). The Southern Nevada Water Authority, for example, is currently moving ahead with plans to pump groundwater from a number of areas in the state, which is expected to lower water tables in a number of reserve areas, such as Great Basin National Park, as well as many non-reserve areas (SNWA 2007). This pumping is likely to impact dozens of imperiled species included in this study, such as sporting goods tryonia (*Tryonia angulata*), Devils Hole riffle beetle (*Stenelmis calida calida*), and Pahranaget Valley montane vole (*Microtus montanus fucosus*) (Deacon et al. 2007). Likewise, climate change is already leading to changes in western U.S. environments (Mote et al. 2005; Stewart et al. 2005; Running 2006), and is likely a severe threat to imperiled species in Nevada regardless of their occurrence in a reserve. For these reasons, all of Nevada's imperiled species should be considered for protection under the ESA.

Imperiled species of Nevada would also benefit from an expansion in existing reserves to cover the 19 hot spots of imperiled species occurrences. The majority of imperiled species locations were unprotected in 11 of the 19 hot spots. Several of these unprotected hot spots are threatened by recreation, urban development, livestock grazing, mining, invasive species and other factors. Off-road vehicle use at Sand Mountain, for example, has more than doubled since 1981, and is resulting in the destruction of habitat for rare species like the Sand Mountain Blue Butterfly (*Euphilotes pallescens arenamontana*) (U.S. Fish and Wildlife Service 2006). Adding these hot spots to Nevada's reserves would require protection of a small fraction of the total area of Nevada and could potentially forestall the need for additional protection for some of these species under the ESA and ultimately prevent their extinction. Such an approach has already been used in Nevada. Ash Meadows National Wildlife Refuge, which has the highest RWRI score, was protected as a refuge specifically to provide protection for imperiled species, including the Devil's Hole pupfish (*Cyprinodon diabolis*), Ash Meadows sunray (*Enceliopsis nudicaulis* var. *corrugate*), Ash Meadows naucorid (*Ambrysus amargosus*) and others (see USFWS 2007b).

Rather than proposing a novel landscape scale system of reserves (see Margules and Pressey 2000; Cabeza and Moilanen 2001; Fleishman et al. 2006), we have identified individual areas that support greater diversity and occurrences of imperiled species to encourage their inclusion in local efforts to create additional reserves. Such an approach may have a greater chance of obtaining protection for imperiled species in the absence of political will or legislation that would allow for creation of a new system of reserves across the landscape because it lends itself to opportunity based protective efforts that typically do not occur at a landscape scale. In general, reserve design and conservation planning should work within the framework of existing laws and policies, which typically do not allow for systematic designation of reserves across broad landscapes.

In a world where threats, such as climate change and groundwater withdrawal, transcend reserve boundaries, conservation planning should also focus on regulatory and legislative protection for individual species because such protection is tied to where species actually occur and encourages research and monitoring of individual species, often improving conservation. More effort could be placed on identifying species most in need of regulatory and legislative protection based on status, threats and lack of protection. In this paper, we have taken a first step in this direction by identifying imperiled species that are not currently covered by existing reserves.

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References

Ando A (1999) Waiting to be protected under the Endangered Species Act: the political economy of regulatory delay. J Law Econ 42:28–60. doi:10.1086/467417

Bean M, Rowland M (1997) The evolution of national wildlife law, 3rd edn. Praeger, Westport

Cabeza M, Moilanen A (2001) Design of reserve networks and the persistence of biodiversity. Trends Ecol Evol 16:242–248. doi:10.1016/S0169-5347(01) 02125-5

Chaplin S, Gerrard R, Watson H, Master L, Flack S (2000) The geography of imperilment. In: Stein B, Kutner L, Adams J (eds) Precious heritage: the status of biodiversity in the United States. Oxford University Press, New York

Deacon J, Williams A, Deacon William C, Williams J (2007) Fueling population growth in Las Vegas: how large-scale groundwater withdrawal could burn regional biodiversity. Bioscience 57:688–698. doi:10.1641/B570809

Deguise I, Kerr J (2006) Protected areas and prospects for endangered species conservation in Canada. Conserv Biol 20:48–55. doi:10.1111/j.1523-1739.2005.00274.x

Duffy D, Boggs K, Hagenstein R, Lipkin R, Michaelson J (1999) Landscape assessment of the degree of protection of Alaska's terrestrial ecosystems. Conserv Biol 13:1332–1343. doi:10.1046/j.1523-1739.1999.98063.x

Fleishman E, Noss R, Noon B (2006) Utility and limitations of species richness metrics for conservation planning. Ecol Indic 6:543–553. doi:10.1016/j.ecolind.2005.07.005

Gaston K, Rodrigues L (2003) Reserve selection in regions with poor biological data. Conserv Biol 17:188–195. doi:10.1046/j.1523-1739.2003.01268.x

Gaston K, Charman K, Jackson S, Armsworth P, Bonn A, Briers R, Callaghan C, Catchpole R, Hopkins J, Kunin W, Latham J, Opdam P, Stoneman R, Stroud D, Tratt R (2006) The ecological effectiveness of protected areas: the United Kingdom. Biol Conserv 132:76–87. doi:10.1016/j.biocon.2006.03.013

Greenwald N, Suckling K, Taylor M (2005) The listing record. In: Goble D, Scott M, Davis F (eds) The Endangered Species Act at thirty: renewing the conservation promise volume 1. Island Press, Washington, DC

Margules C, Pressey R (2000) Systematic conservation planning. Nature 405:243–253. doi:10.1038/35012251

Mote P, Hamlet A, Clark M, Lettenmaier D (2005) Declining mountain snowpack in western North America. Bull Am Meteorol Soc 86:39–49. doi:10.1175/BAMS-86-1-39

Prendergast J, Quinn R, Lawton J (1999) The gaps between theory and practice in selecting nature reserves. Conserv Biol 13:484–492. doi:10.1046/j.1523-1739.1999.97428.x

Pressey R, Whish G, Barrett T, Watts M (2002) Effectiveness of protected areas in north-eastern New South Wales: recent trends in six measures. Biol Conserv 106:57–69. doi:10.1016/S0006-3207(01)00229-4

Rodrigues A, Andelman S, Bakarr M, Boitani L, Brooks T, Cowling R, Fishpool L, da Fonseca G, Gaston K, Hoffmann M, Long J, Marquet P, Pilgrim J, Pressey R, Schipper J, Sechrest W, Stuart S, Underhill L, Waller R, Watts M, Yan X (2004) Effectiveness of the global protected area network in representing species diversity. Nature 428:640–643

Rothley K, Berger C, Gonzalez C, Webster E, Rubenstein D (2004) Combining strategies to select reserves in fragmented landscapes. Conserv Biol 18:1121–1131. doi:10.1111/j.1523-1739.2004.00180.x

Running S (2006) Is global warming causing more, larger wildfires? Science 6 July 2006. doi:10.1126/science.1130370

Scott M, Davis F, McGhie R, Wright R, Groves C, Estes J (2001) Nature reserves: do they capture the full range of American's biological diversity? Ecol Appl 11:999–1007. doi:10.1890/1051-0761(2001)011[0999:NRDTCT]2.0.CO;2

Siitonen P, Tanskanen A, Lehtinen A (2002) Method for selection of old-forest reserves. Conserv Biol 16:1398–1408. doi:10.1046/j.1523-1739.2002.00322.x

Soulé M, Estes J, Miller B, Honnold D (2005) Strongly interacting species: conservation policy, management, and ethics. Bioscience 55:168–176. doi:10.1641/0006-3568(2005)055[0168:SISCPM]2.0.CO;2

Southern Nevada Water Authority (2007) http://www.snwa.com/html/wr_gdp.html. Accessed August 6, 2007

Stanford Environmental Law Society (2001) The Endangered Species Act. Stanford University Press, Stanford

Stein B, Kutner L, Adams J (2000) Precious heritage: the status of biodiversity in the United States. Oxford University Press, New York

Stewart T, Cayan D, Dettinger M (2005) Changes toward earlier streamflow timing across western North America. J Clim 18:1136–1155. doi:10.1175/JCLI3321.1

Strittholt J, Dellasalla D, Jiang H (2006) Status of mature and old-growth forests in the Pacific Northwest. Conserv Biol 20:363–374. doi:10.1111/j.1523-1739.2006.00384.x

Tobin R (1990) The expendable future: U.S. politics and the protection of biological diversity. Duke University Press, Durham

United States Census Bureau (2007) http://quickfacts.census.gov/qfd/states/32000.html. Accessed August 6, 2007

United States Fish and Wildlife Service (2006) Endangered and threatened wildlife and plants, 90-day finding on a petition to list the Sand Mountain Blue Butterfly as threatened or endangered with critical habitat. Fed Regist 71:44988–44993

United States Fish and Wildlife Service (2007a) Endangered and threatened wildlife and plants, review of native species that are candidates or proposed for listing as endangered or threatened, annual notice of findings on resubmitted petitions, annual description of progress on listing actions. Fed Regist 72:69034–69106

United States Fish and Wildlife Service (2007b) http://www.fws.gov/desertcomplex/ashmeadows/quick-facts.htm. Accessed August 6, 2007

United States Geologic Survey National Gap Analysis Program (2005) Provisional digital land stewardship map for the Southwestern United States, Version 1.0. New Mexico Cooperative Fish and Wildlife Research Unit, New Mexico State University, Albuquerque

Wilcove D, McMillan M, Winston K (1993) What exactly is an endangered species? An analysis of the U.S. endangered species list: 1985–1991. Conserv Biol 7:87–93. doi:10.1046/j.1523-1739.1993.07010087.x