Spatiotemporal Dynamics of Endangered Species Hotspots in the United States

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Abstract: *Given limited resources, many researchers advocate focusing conservation efforts on hotspots, geographical areas with high numbers of species (i.e., richness), endemic species, rare or threatened species, and/or high levels of threat to species survival. The hotspot approach is an efficient and simple way to conserve species diversity, assuming that hotspots do not change over space or time. We tested whether hotspots change across space and time using a database of endangered and threatened species listed by the U.S. government from 1967 to 1999. We determined hotspots based on the cumulative set of species listed for three overlapping and successively longer time periods: 1967–1979, 1967–1989, and 1967–1999. We used minimum area complimentarity analysis, which selected the smallest set of areas (in our study, U.S. counties) needed to represent a chosen set of species. Over time, the number of endangered and threatened species in the United States increased from 76 in 1967 to 1123 in 1999. As the number of species increased over time, hotspots changed in two ways: the number of hotspots increased and the rank of hotspots shifted. Hotspots increased from 84 in 1979, to 166 in 1989, to 217 in 1999. Only 63 of these counties were designated as hotspots in all three periods. The remaining changes resulted from addition and deletion of counties as hotspots over time. Some counties were removed from the list or changed in relative rank from one time period to the next regardless of their rank. Counties added as hotspots could rank anywhere on the list, and they were not merely low-ranking counties added to represent one or a few species. Therefore, hotspots serve as a useful tool for guiding conservation efforts but, given their spatiotemporal variability, do not represent a final solution.*

Dinámica Espaciotemporal de Areas Críticas para Especies en Peligro en los Estados Unidos

Resumen: *Dada la escasez de recursos, muchos investigadores abogan por enfocar los esfuerzos de conservación hacia áreas críticas, áreas geográficas con alto número de especies (i.e. riqueza) y/o alto número de especies endémicas, raras o amenazadas y/o con altos niveles de amenaza para la sobrevivencia de especies. El enfoque de área crítica es una manera simple y eficiente de conservar la diversidad de especies, suponiendo que las áreas no cambian en el espacio y tiempo. Para probar si las áreas críticas cambian en el tiempo y el espacio utilizamos una base de datos de especies amenazadas y en peligro enlistadas por el gobierno de Estados Unidos de 1967 a 1999. Determinamos áreas críticas basadas en el conjunto acumulativo de especies enlistadas en tres períodos de tiempo sobrepuestos y sucesivamente más largos: 1967–1979, 1967–1989 y 1967–1999. Utilizamos el análisis de complementariedad de áreas mínimas, que selecciona el conjunto más pequeño de áreas (condados) requeridas para representar a un conjunto determinado de especies. El número de especies amenazadas y en peligro se incrementó de 76 en 1967 a 1,123 en 1999. Mientras el número de especies se incrementó con el tiempo, las áreas críticas cambiaron de dos maneras: el número de áreas incrementó y el rango de áreas cambió. El número de áreas críticas incrementó de 84 en 1979 a 166 en 1989 y 217 en 1999. Solo 63 de estos condados fueron designados como áreas prioritarias en los tres períodos. Los cambios restantes resultaron de la adición o supresión de condados como áreas prioritarias. Se removieron condados de la lista o fueron cambiados de rango relativo de un período al siguiente independientemente de su rango. Los condados añadidos como áreas prioritarias podían ser clasificados en cualquier*

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lugar de la lista y no eran meros condados de clasificación baja que fueron agregados para representar a una o a unas cuantas especies. Por lo tanto, las áreas prioritarias son una herramienta de utilidad para guiar los esfuerzos de conservación pero no representan una solución definitiva debido a su variación en el espacio y el tiempo.

Introduction

The continued expansion of human activities around the globe (Vitousek et al. 1997) places more and more species at risk of extinction (Ehrlich 1988), thereby increasing the rate of biodiversity loss (Wilson 1988). A case in point is the number of threatened and endangered species listed in the United States, which has increased from 76 in 1967 to 1123 in 1999 (Fig. 1; USFWS 1999*a*). The large number of threatened and endangered species listed in 1999 illustrates a primary problem for conservationists around the world: how to conserve species given limited resources. One solution to this problem has been to assign conservation priority to hotspots. Originally coined by Myers (1988, 1990) over a decade ago, the term *hotspots* has come to mean geographical areas with high concentrations of species (i.e., richness), endemic species, rare or threatened species, and/or high levels of threat to species survival (Myers 1988; Mittermeier et al. 1998; Reid 1998).

Hotspot analysis has been performed for a variety of taxa at a number of spatial scales. For example, hotspot analysis has been used to identify geographic regions of high species richness by the U.S. GAP analysis program (Kiester et al. 1996), to set priorities for endemic and rare bird conservation (Balmford & Long 1994), and to define regions with the greatest numbers of threatened and endangered species (Dobson et al. 1997; Flather et al. 1998; Griffin 1999). Although previous studies have expanded our knowledge and helped draw attention to geographic locations of concern, all have identified hotspots at only one point in time and have not consid-

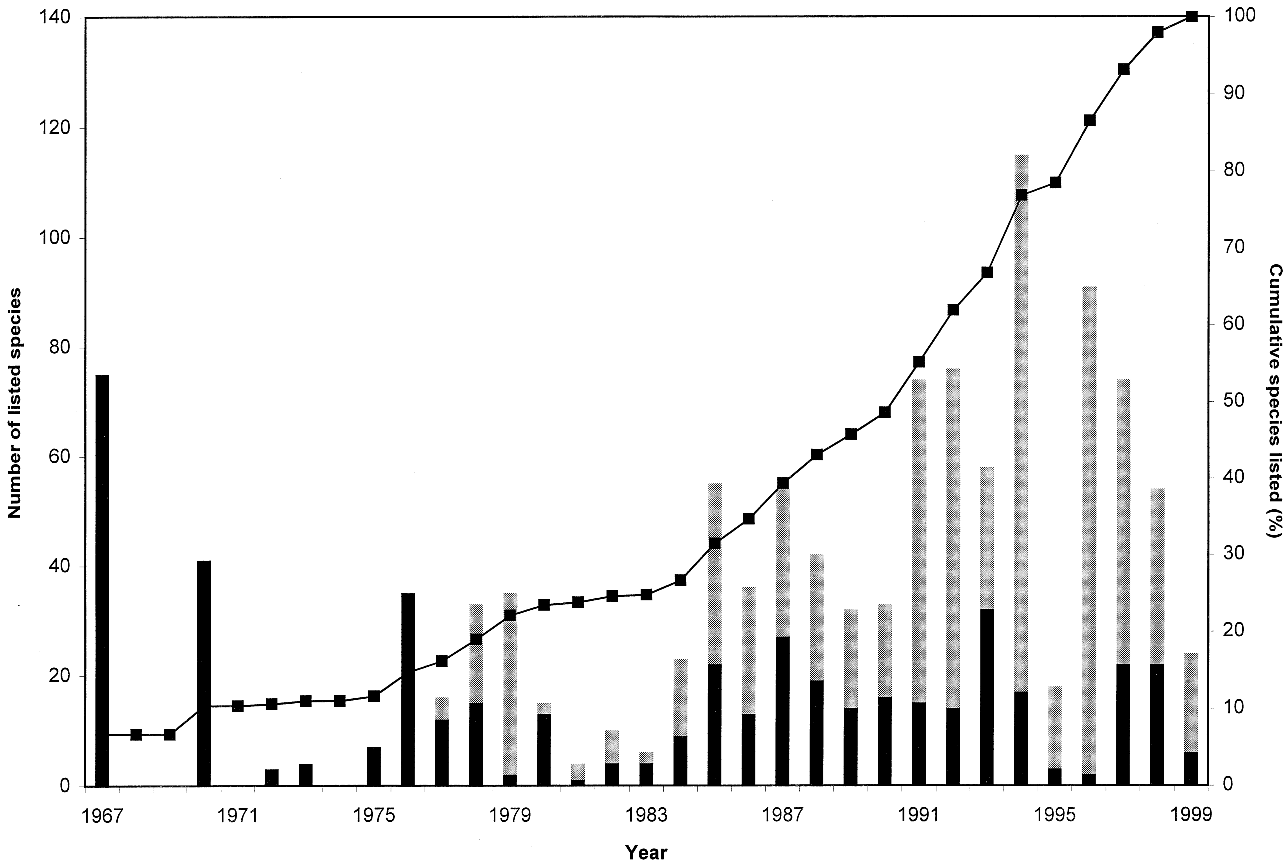

Figure 1. Number of threatened and endangered species listed in each year according to classification as animals (black) and plants (gray), and the cumulative number of species listed per year (line). Numbers do not include the 18 species delisted since inception of the U.S. Engangered Species Preservation Act in 1967.

ered potential spatiotemporal changes in hotspot locations. Currently, no studies exist that have explicitly quantified shifts in location or changes in intensity of hotspots over time. Conservationists need to understand the potential spatiotemporal dynamics of hotspots before setting conservation priorities. The importance of spatiotemporal dynamics can be illustrated by this simple question: If new hotspots develop or are found, should allocation of limited resources be shifted from old locations to new locations?

To address the question of whether hotspots of threatened and endangered species change in space and time, we considered the distribution of species listed as threatened or endangered (hereafter referred to as listed species) by the U.S. government in the 50 United States. Our rationale in choosing to study listed species was two-fold. First, distribution data for listed species are known and available from the U.S. government. Second, listed species require the most immediate action to prevent extinction (Wilcove et al. 1993). In delineating which geographic areas are hotspots, we chose complimentarity analysis because it is an efficient method for finding the minimal area needed to represent a chosen group of species (Pressey et al. 1993; Csuti et al. 1997; Reid 1998). We also chose complimentarity analysis for consistency with other studies that used the listed-species database (Dobson et al. 1997; Ando et al. 1998).

The distribution of listed species, and consequently their hotspots, represents a combination of real changes in species endangerment and changes in the knowledge of endangerment. Over time, some species become endangered because of increased human effects, whereas others recover because of efforts to save them. Also, as knowledge accumulates, the status of some species changes: some are considered endangered or more endangered, whereas others are considered less endangered or not endangered at all. Attempting to identify and distinguish between real and perceived factors that cause change is beyond the scope of this paper.

Methods

We constructed a database of threatened and endangered species from the following sources: (1) the list of threatened and endangered species through October 1999 (USFWS 1999*a*), (2) the list of species removed from the endangered species list through October 1999 (USFWS 1999*b*), and (3) a database of listed and candidate species occurrence by county for the United States through August 1997 (USEPA 1997). Although the Endangered Species Act was not passed until 1973, the first year of listing was 1967 under the Endangered Species Preservation Act (Flather et al. 1994). We edited the county database to include only listed species in the continental United States, Alaska, or Hawaii. From the passage of the Endangered Species Protection Act to October of 1999, the U.S. federal government listed 1143 species as threatened or endangered whose range included all or part of the 48 continental United States, Alaska, and Hawaii (USFWS 1999*a*). Eight animal species had 2 or more populations listed separately for a total of 28 listed populations. Therefore, 1163 species and populations (i.e., separate listed units) were listed between 1967 and 1999 (1143 species + 20 additional populations [28 distinct populations − 8 species] = 1163 listed species and populations). During this period, 20 species and 1 of 2 listed populations of one species were delisted: 6 recovered, 7 went extinct, and 8 were removed because of scientific revision or new information (USFWS 1999*b*). Therefore, by October 1999 the total number of listed species was 1123 (1143 − 20), and the total number of listed species and populations was 1142 (1163 − 21).

Of the 1143 listed species, 65 did not occur in the county occurrence database (USEPA 1997): 23 were listed from 1967 to 1979, 2 were listed from 1980 to 1989, and 40 were listed from 1990 to 1999. Of the 65 missing species, 12 were delisted: 1 from 1967 to 1979, 8 from 1980 to 1989, and 3 from 1990 to 1999. Although county information was absent, presence/absence information at the state level was available for 53 species (USFWS 1999*a*). The missing species ranged throughout 36 states, the top six being Alabama (13), Florida (12), California (11), Georgia (8), and Texas and Washington (7 each). Fifty-nine species listed in the county occurrence database were not listed species (USFWS 1999*a*). An additional 593 records in the county occurrence database were removed because they were duplicates (e.g., two common names for the same species), were geographically incorrect (e.g., hawksbill sea turtle [*Eretmochelys imbricata]* in Worcester, Massachusetts), or contained conflicting information.

We determined hotspots that would represent all species listed by the end of three successively longer and overlapping time periods: 1967–1979, 1967–1989, and 1967–1999. By considering overlapping time periods, we effectively reset the status of a county for each time period analyzed. Consequently, the status of a county at the end of one time period had no bearing on its status at the end of a subsequent time period.

We calculated the cumulative richness of listed species (number of listed species) for each county for the final year of each of the three time periods (i.e., 1979, 1989, and 1999) using geographic information systems (ArcView 3.1 and Arc/Info 7.2.1, Environmental Systems Resources Institute, Redlands, California). Seven animal species had two or more distinct populations listed; we counted those individually listed populations as distinct species in our analysis. If a species was delisted, we excluded it from the analysis beginning 1 year after it was officially removed from the list. For example, Rydberg's milk-vetch (*Astragalus perianus)*, was listed in 1978 and delisted in 1989. Therefore, we removed it from

Figure 2. Spatiotemporal distributions of the number of listed species per county (key) for three time periods: (a) 1967–1979, (b) 1967–1989, and (c) 1967–1999.

consideration beginning in 1990, which means it was included in the hotspot analysis for the time periods 1967–1979 and 1967–1989 but excluded from the analysis for the time period 1967–1999. Therefore, the hotspot analysis for each period included all species listed from 1967 to the end of the time period in question (i.e., 1979, 1989, 1999), minus any species delisted at least 1 year prior to the end of the time period. We mapped cumulative listed species richness in a U.S. county coverage that came with ArcView. We also calculated county areas from that U.S. coverage based on an Albers North American equal-area conic projection. Cumulative listed species richness served as the starting point for our hotspot analysis.

We determined hotspots with an agglomerative, minimum-area complimentarity algorithm (Pressey et al. 1993; Dobson et al. 1997; Ando et al. 1998; Csuti et al. 1997) that identifies the minimum area, not necessarily contiguous, in which all species of interest are represented. The areas that make up the set are considered hotspots, typically because they harbor large numbers of endemic species (Pimm & Lawton 1998). The algorithm used an iterative two-step process. First, the algorithm selected the county with the highest listed species richness. If two or more counties had the same richness of listed species, the algorithm designated the county with the smallest area as the hotspot. Second, the algorithm recalculated listed species richness by subtracting each species found in the current hotspot for all other counties in which it occurred. The algorithm then repeated steps 1 and 2 from the remaining set of counties until all listed species were represented by at least one county.

We prepared lists of counties that comprised the set of hotspots at each of the three times analyzed: 1979, 1989, and 1999. The complimentarity algorithm ranked each hotspot in order based on the number of unique species a hotspot represented. From those ranks we calculated the relative rank of each county (absolute county rank/number of total hotspots $\times$ 100) and the relative change in rank (e.g., [relative rank in time 2] $-$ [relative rank in time 1]). A positive relative rank change indicated a change from a lower rank to a higher rank (e.g., 34 to 6); a negative relative rank change indicated a change from a higher rank to a lower rank (e.g., 15 to 63).

We used nonparametric tests to determine whether counties differed in their status (retained, added, or removed) based on their ranks. We did this in two ways. Within time periods, we used Mann-Whitney U tests (Sokal & Rohlf 1981) to test the following null hypotheses: (1) absolute ranks of retained counties equal absolute ranks of removed counties, and (2) absolute ranks of retained counties equal absolute ranks of added counties. Between time periods, we used Wilcoxon's signed ranks test (Sokal & Rohlf 1981) to test the following null hypotheses: (1) relative ranks of retained counties in time 1 equal relative ranks of retained counties in time 2, and (2) relative ranks of constant hotspots in time 1 equal relative ranks of constant hotspots in time 2. We used relative county ranks for tests between time steps because the number of hotspots changed over time.

Results

Across the United States, listed species richness and the number of hotspots increased over time (Fig. 2). The number of counties containing at least one listed species increased from 2620 in 1979 to 2849 in 1999 (Table 1; Fig. 2). By 1999 over 90% of the counties in the United States harbored at least one listed species. Concomitant with the increase in listed species richness was an increase in the number of hotspots required to represent them (Table 1; Fig. 3). In 1979, 84 hotspots were needed to capture all listed species, whereas by 1989 and 1999, 166 and 217 were needed, respectively (Table 1). Total hotspot area doubled from 1979 to 1999 but still represented only 14.4% of the total area of the United States by 1999. The complimentarity analysis identified 63 counties as "constant" hotspots, or counties that occurred as hotspots in each of the three time periods.

Hotspots changed over time in both location and intensity. The largest change in location stemmed from the addition of counties over time to accommodate more listed species (Table 2; Fig. 3). Counties were also removed from the list of hotspots (Table 2; Fig. 3). Furthermore, hotspots shifted in rank (Appendix 1). Some counties, particularly all counties in Hawaii and several counties in southern California, remained relatively "hot" over time. Hawaii, Hawaii was first, first, and fifth, respectively, in 1979, 1989, and 1999. Conversely, the rank of many counties varied dramatically over time. For example, Cedar, Missouri, was not ranked as a hotspot in 1979, was ranked thirty-first out of 166 counties in 1989, and was unranked again in 1999 (Appendix 1). The largest positive change in relative rank was Highlands, Florida, which increased 98%, from not being a hotspot in 1979 to being ranked second in 1989. The largest negative change in relative rank was Hancock,

Table 1. Summary statistics for listed species hotspots over three time periods in the 50 United States.*

	Year ending		
	1979	*1989*	*1999*
Species			
total listed	227	501	1078
no. added		274	577
Counties			
no. with $\geq$1 species	2620	2792	2849
percentage of total counties	83.4	89.9	90.7
total area with at least one listed species (km^2)	7,341,005	7,632,380	7,843,943
percentage of total U.S. area	79.0	82.2	84.4
Hotspots			
total	84	166	217
total area (km^2)	635,486	1,038,016	1,337,136
percentage of total U.S. area	6.84	11.17	14.40

**Species are either unique species or, in the case of some vertebrates, distinct populations. The 50 states are comprised of 3140 counties with a total area of 9,289,371 km^2.*

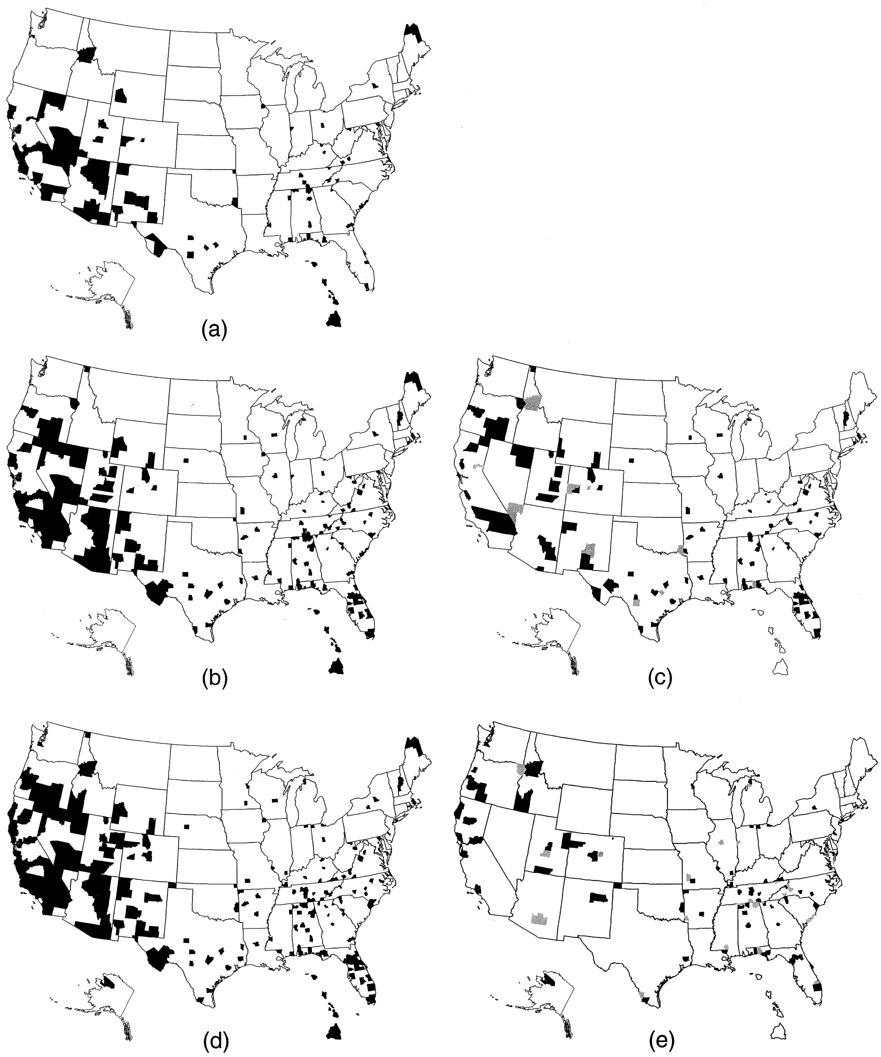

Figure 3. Hotspots (black filled counties) of listed species during three time periods: (a) 1967–1979, (b) 1967–1989, and (d) 1967–1999. Changes in hotspot locations showing counties added (black) and counties removed (gray): (c) 1979–1989 and (e) 1989–1999.

Tennessee, which decreased by 97%, from fifth in 1989 to not being a hotspot in 1999.

From the results of the Wilcoxon's signed-ranks tests and the Mann-Whitney *U* tests, we failed to reject the null hypothesis that county ranks were the same regardless of status (retained, added, or removed) except in one case. For example, the ranks of the 12 counties removed as hotspots versus the ranks of the 72 counties retained as hotspots from 1979 to 1989 did not differ significantly. This indicates that hotspots of high and low ranks had the same likelihood of being removed. Similarly, the ranks of the 76 counties added as hotspots versus the 141 counties retained as hotspots from 1989 to 1999 did not differ significantly. The added counties were as likely as retained counties to be ranked high by the complimentarity analysis, but we did reject the null hypothesis that the ranks of counties retained as hotspots and the ranks of counties added as hotspots from 1979 to 1989 were the same. In this case, retained hotspots were ranked higher on average (mean relative rank = 42.5) than added counties (mean relative rank = 56.9). This suggests that counties retained from 1979 to 1989 were "hotter" than newly identified counties. Finally, the relative ranks of constant hotspots did not differ between 1979 and 1989 and between 1989 and 1999 (Table 3).

Table 2. Number of hotspots retained, added, and removed for the three time periods analyzed.*

	Year ending		
Hotspots	*1979*	*1989*	*1999*
Retained	—	72	141
Added	84	94	76
Total	84	166	217
Removed	12	25	—

**Retained, number of counties designated as hotspots in both the previous and current time periods; added, number of counties not designated as hotspots during the previous time period but designated as hotspots during the current time period; removed, number of counties designated as hotspots in the previous time period but not designated as hotspots during the current time period.*

Table 3. Results of nonparametric tests used to determine whether status of a county differed based on rank.[a]

Hotspots	*Null hypothesis*	*Test value*	p
Retained[b]	relative rank 1979 (72) = relative rank 1989 (72)	−1.675	0.094
	relative rank 1989 (141) = relative rank 1999 (141)	0.299	0.765
Added[c]	retained 1989 (72) = added 1989 (94)	4494	0.0003[d]
	retained 1999 (141) = added 1999 (76)	6045	0.119
Removed[c]	1979 absolute rank of counties retained, 1979–1989 (72) = removed 1979 (12)	452	0.798
	1989 absolute rank of counties retained, 1989–1999 (141) = removed 1989 (25)	1425	0.128
Constant[b]	relative rank 1979 (63) = relative rank 1989 (63)	−1.567	0.117
	relative rank 1989 (63) = relative rank 1999 (63)	−0.255	0.798

[a] *Definitions of retained, added, and removed counties are the same as in Table 2. Constant hotspots are those counties designated as hotspots in all three time periods. Numbers in parentheses indicate the number of counties being compared.*
[b] *Wilcoxon's signed ranks test; compares relative ranks.*
[c] *Mann-Whitney* U *test with one degree of freedom in all cases; compares absolute ranks.*
[d] *Rejected the null hypothesis.*

Discussion

Our study demonstrates that hotspots of listed species varied in the United States in two ways. First, the spatial arrangement of hotspots changed over time. Spatial change resulted mostly from the addition of counties to represent newly listed species, which increased three-fold from 1979 to 1999 (Table 1; Fig. 1). Some counties, however, were also removed from the list of hotspots during each time period. Second, hotspots shifted in relative importance over time. This shift included the addition and removal of counties as well as shifts in rank among counties that remained on the list from one time period to the next. The addition of counties to accommodate increasing numbers of listed species was expected, but the variability in the ranks of hotspots, including the removal of some hotspots, was not expected. Ideally, hotspots should be relatively constant over time in both composition and importance. Otherwise, their usefulness as a tool for conservation diminishes.

Comparisons of the ranks of counties retained, added, and removed from the list of hotspots over time further suggest that a county's status as a hotspot varies over time. One might expect that most of the variability in hotspots, both county composition and rank, would occur within the lower ranks. Higher ranked counties, given higher listed species richness, should be less sensitive to the addition of newly listed species than lower ranked counties. Therefore additions, deletions, removals, and large changes in rank should be more likely among lower ranking counties. But no differences in absolute rank or relative rank were found among the sets of counties examined, except between the absolute rank of counties retained and counties added between 1979 and 1989 (Table 3).

The hotspot results would change if the 65 listed species not in the county occurrence database were included in the analysis, but the degree and direction of the change is uncertain. The listed species database included information on the states in which listed species ranged (USFWS 1999*a*). Those states having more counties as hotspots also had the highest richness of species not in the county database, including Alabama, California, Florida, Georgia, Texas, and Washington. Spatiotemporal variability of hotspots could increase if the added species tended to occur in counties with lower species richness, thereby making them hotspots or increasing their ranks. Conversely, the spatiotemporal variability of hotspots could decrease if the added species tended to occur in counties with higher species richness, thereby increasing the probability that they will remain hotspots or retain higher rank. Thirty-nine of these species were listed between 1990 and 1999, and 12 were delisted by 1999; thus, the largest effect occurred from 1989 to 1999.

What practical implications do these findings have for future conservation of listed species in the United States or in other regions where more species will likely become endangered over time? Hotspots were conceived as an efficient tool with which to maximize conservation efforts given limited resources. But the set of counties comprising hotspots changed over time for listed species in the United States. Delineating hotspots at one point in time did not prevent the emergence of new hotspots and did not guarantee that existing hotspots remained hotspots or retained their relative importance over time (Fig. 3). Conserving listed species requires making decisions that involve substantial resources, typically some form of active management (Foin et al., 1998), and a long-term commitment to protect suitable habitat. Given the small population sizes of most species at the time of listing (Wilcove et al. 1993), waiting until all information about all species is available to develop the most efficient solution based on hotspots is not practical. Therefore, hotspots should be treated as a useful tool that calls attention to particular areas with chronic conservation problems (e.g., southern Florida) and/or high numbers of endemic species (e.g., Hawaii) and that can improve conservation efforts. But, given their spatiotemporal variability, hotspots should not be considered a final solution.

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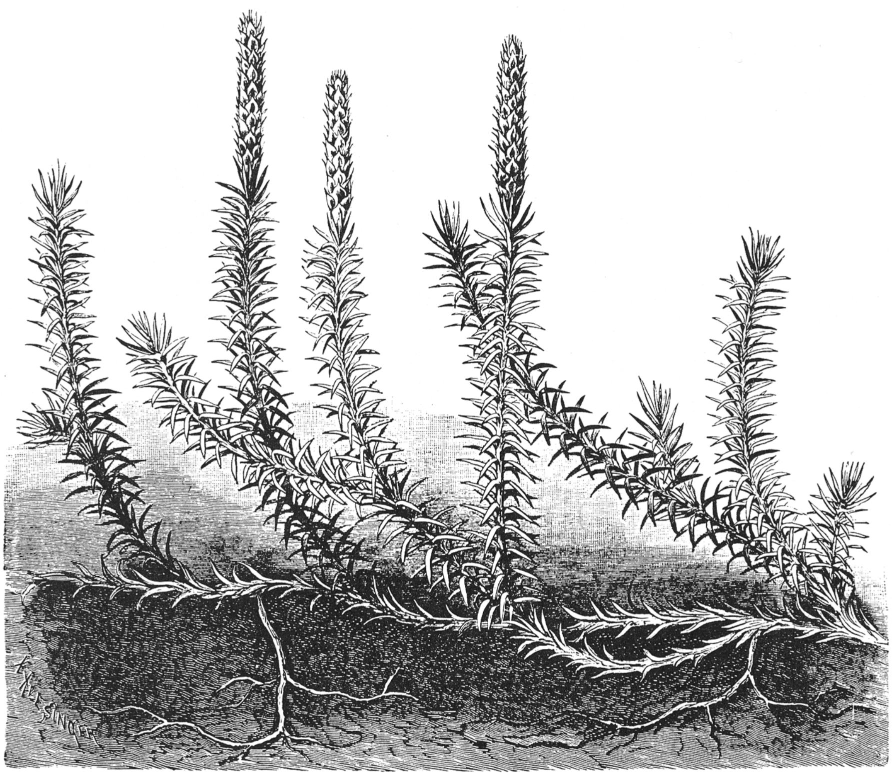

Appendix

Absolute rank and percent change in relative rank of counties listed as hotspots during the three time periods analyzed.

State	County	Absolute rank, 1979	Absolute rank, 1989	Relative rank change, 1979–1989 (%)*	Absolute rank, 1999	Relative rank change, 1989–1999 (%)
Alabama	Autauga		123	+	165	
	Baldwin		50	+++	78	
	Bibb				168	+
	Calhoun		125	+	96	+
	Cherokee		124	+	39	++
	Colbert				71	+++
	Crenshaw	61	126		167	
	Etowah	60	43	++	160	−−
	Greene		32	++++	31	
	Jackson	15	24			−−−−
	Lauderdale	23	44			−−−
	Limestone				97	++
	Madison		135		74	++
	Winston				72	+++
Alaska	Aleutians West				200	
	Northwest Arctic				217	
Arizona	Cochise	24	8	+	16	
	Coconino	84	16	++++	19	
	Gila		160		113	++
	Graham		51	+++	36	
	Navajo	26	82		115	
	Pima	37	55		47	
	Pinal	17	18			−−−
	Santa Cruz		144		192	
Arkansas	Benton				177	
	Grant				169	+
	Logan		134		175	
	Sevier		119	+		−
	Stone		65	+++	98	
California	Amador				95	++
	Contra Costa	7	33		32	
	El Dorado				43	+++
	Fresno	35	19	+	22	
	Humboldt				82	+++
	Inyo	18	15		37	
	Kern		80	++	64	
	Lake		145		106	+
	Los Angeles	2	3		14	
	Marin		113	+	69	+
	Mendocino	33	78		57	+
	Modoc		37	+++	59	
	Monterey	16	36		15	
	Nevada	68				
	Riverside	80	26	+++	63	
	Sacramento				183	
	San Benito		146		194	
	San Bernardino		85	++	6	++
	San Diego	74	157		10	++++
	San Francisco	38	86		20	++
	San Luis Obispo	71	153		21	++++
	San Mateo	19	13		67	−
	Santa Barbara	32	77		4	++
	Santa Clara				193	
	Santa Cruz				29	++++
	Shasta		155		202	
	Solano	65	68	+	33	+
	Sonoma				8	++++
	Tehama				45	+++
	Ventura				79	+++

continued

Appendix (continued)

State	*County*	*Absolute rank, 1979*	*Absolute rank, 1989*	*Relative rank change, 1979–1989 (%)**	*Absolute rank, 1999*	*Relative rank change, 1989–1999 (%)*
Colorado	Delta		49	+++	188	−−
	Douglas		69	++		−−
	Grand		74	++	107	
	Jackson		147		196	
	Lake	47		−−	140	+
	Mesa	10		−−−−		
	Park				80	+++
	Rio Blanco				111	++
District of Columbia	Washington		87	++	118	
Florida	Alachua				184	
	Bay				103	++
	Calhoun				161	+
	Dade		35	+++	44	
	Hernando		61	+++	94	
	Highlands		2	++++	7	
	Hillsborough		140		186	
	Indian River	55	42	+	68	
	Lake		141		189	
	Levy				187	
	Liberty	27	45		25	
	Marion		148		197	
	Martin		129	+		−
	Monroe	4	7		11	
	Okaloosa	67			181	
	Orange		71	++	75	
	Palm Beach				108	++
	Putnam				176	
	St. Johns		121	+	163	
	St. Lucie		116	+	156	
	Volusia		142		190	
	Walton		72	++		−−
Georgia	Bibb				129	++
	Brantley	51	107		150	
	Catoosa		92	++		−−
	Columbia		28	++++	50	
	Dawson				84	+++
	Glynn	48	101		89	
	Rockdale		89	++	120	
	Stephens	40	91		122	
	Whitfield				13	++++
Hawaii	Hawaii	1	1		5	
	Honolulu	6	6		1	
	Kauai	13	21		3	
	Maui	5	9		2	
Idaho	Boundary		73	++	105	
	Elmore				35	++++
	Idaho	36		−−	46	+++
	Owyhee				215	
Illinois	Monroe				66	+++
	Saline				139	+
	Tazewell		66	++		−−
Indiana	Lagrange				137	+
	Warren	44	99			−
Iowa	Dubuque	21	22		40	
Kentucky	Edmonson		95	++	86	
	Graves				158	+
	Hickman				130	+
	Mason	12	12		18	

continued

Appendix (continued)

State	County	Absolute rank, 1979	Absolute rank, 1989	Relative rank change, 1979–1989 (%)*	Absolute rank, 1999	Relative rank change, 1989–1999 (%)
	McCreary				90	++
	Menifee	41		−−		
	Powell		93	++	123	
	Robertson		88	++	119	
Louisiana	Grant		130	+	171	
	Washington				73	+++
Maine	Aroostook	79	165		214	
Maryland	Calvert				126	++
	Harford	50	106		145	
	Somerset				49	+++
Massachusetts	Plymouth		132		173	
Michigan	Charlevoix		40	+++		−−−
	Emmet				38	++++
Minnesota	Chisago				147	+
	Steele		105	+	143	
Mississippi	Claiborne	54	109		151	
	Itawamba	57	112		154	
	Jackson	64	131		102	+
	Marion		64	+++		−−−
Missouri	Cedar		31	++++		−−−−
	Dade		111	+		−
	Greene				54	+++
Nebraska	Hooker		133		174	
Nevada	Clark	25		−−−		
	Elko		84	++	117	
	Humboldt	81	166		216	
	Lincoln	82	39	+++	48	
	Nye	83	4	++++	12	
	Washoe	77	54	++	114	
New Hampshire	Grafton		149		198	
	Sullivan		114	+	155	
New Jersey	Camden				125	++
New Mexico	Eddy	73	14	+++	58	
	Grant	72	79	+	112	
	Lincoln	75				
	McKinley		163		212	
	Otero		38	+++	61	
	San Juan	34	53		83	
	San Miguel				208	
	Socorro	78	164		62	+++
New York	Madison	63	128		170	
	Nassau				131	+
	Schuyler				134	+
North Carolina	Avery		27	++++		−−−−
	Burke		62	+++		−−−
	Cabarrus				135	+
	Columbus		47	+++	182	−−
	Franklin		110	+	152	
	Henderson	46	29	+		−−−−
	Hoke				138	+
	Lee		56	+++	128	−
	Martin				149	+
	Mitchell				23	++++
	Pasquotank		94	++	124	
	Swain	58	115		70	+
Ohio	Ottawa				85	+++
	Union	49	103		142	
	Williams				51	+++

continued

Appendix (continued)

State	*County*	*Absolute rank, 1979*	*Absolute rank, 1989*	*Relative rank change, 1979–1989 (%)**	*Absolute rank, 1999*	*Relative rank change, 1989–1999 (%)*
Oklahoma	Cimarron				199	
	Le Flore				77	+++
	McCurtain	29		−−−		
	Ottawa	53	59	+	92	
Oregon	Benton				172	+
	Douglas				210	
	Harney		83	++	116	
	Klamath				213	
	Lake		81	++	65	
	Lane		52	+++	60	
	Wallowa		151			
Rhode Island	Kent				121	++
	Washington		57	+++		−−−
South Carolina	Charleston	14	17			−−−−
	Greenville				41	++++
	Horry				27	++++
	McCormick		102	+	141	
Tennessee	Bedford	52	108		91	+
	Blount		118	+	162	
	Davidson	56	63	+	153	−
	Franklin	59	117		159	
	Hancock	3	5			−−−−
	Humphreys				157	+
	Lincoln		120	+		−
	Marion				24	++++
	Polk		41	+++	144	−−
	Rutherford				166	+
	Van Buren				127	++
	Wilson				53	+++
Texas	Aransas	8	96	−−	132	
	Brewster	11	20		28	
	Coke		70	++	104	
	El Paso	69	138		185	
	Fort Bend		136		178	
	Hardin				180	
	Hays	22	23		17	
	Jeff Davis	31	150	−−	110	+
	Kleberg		34	+++	34	
	Lee	62		−		
	Menard	66	137		179	
	Pecos		159		207	
	Presidio		154		201	
	Real		67	++	100	
	Robertson		46	+++	42	
	San Augustine		122	+	164	
	Starr				76	+++
	Travis		10	++++	26	
	Uvalde	28		−−−		
	Zapata		139			
Utah	Cache		143		191	
	Duchesne		152		81	++
	Emery		11	++++	30	
	Garfield		162		211	
	Kane				204	
	Sanpete				195	
	Sevier	30	75			−−
	Uintah				206	
	Utah	70	76	+	109	
	Washington	9	25		56	

continued

Appendix (continued)

State	County	Absolute rank, 1979	Absolute rank, 1989	Relative rank change, 1979–1989 (%)*	Absolute rank, 1999	Relative rank change, 1989–1999 (%)
Virginia	Augusta		48	+++	55	
	Giles		58	+++	88	
	Lee				146	+
	Northampton	39	90			−−
	Page		97	++	133	
	Patrick		60	+++	93	
	Pulaski	43	98		87	
	Scott				9	++++
	Smyth	20	30		148	−−
Washington	Thurston				101	++
	Wahkiakum	42		−−		
West Virginia	Monongalia	45	100		136	
	Tucker		104	+	52	+
Wisconsin	Waushara		127	+	99	+
Wyoming	Albany		158		205	
	Lincoln		156		203	
	Sublette	76	161		209	

**Percent changes in relative rank are indicated as follows: +, increased 21-40%; ++, increased 41-60%; +++, increased 61-80%; ++++, increased 81-100%; −, decreased 21−40%; −−, decreased 41−60%; −−−, decreased 61−80%; −−−−, decreased 81−100%.*