Using Wildlife Species Richness to Identify Land Protection Priorities in California's Hardwood Woodlands[1]

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Abstract: A geographic information system was used to assess wildlife species richness (number of species) in valley-foothill hardwood habitats throughout California to set priorities for conservation attention. Species richness values were assessed and compared using three methods: one that included all species without considering canopy cover conditions and species preferences; a second that restricted the analysis to sensitive species; and a third that used sensitive species and considered canopy cover conditions and species canopy preferences. The identified locations of species rich areas were markedly altered with the inclusion of information on habitat structure and species sensitivity. Comparison of different species richness analyses showed that the greatest difference in areas identified in richness classes was produced when species sensitivity and canopy closure requirements were included. The largest areas of high species richness were in the southern Sierra Nevada foothills. Valley-foothill hardwood habitat is not well represented in reserved areas. Only 3.8 percent of a total 4.5 million acres were classified as reserved by virtue of ownership. Similarly, only 4.5 percent of the 1.1 million acres in the highest species richness class was reserved. Areas of sparse canopy closure supported the most species. Selecting conservation areas based solely on species richness would, however, omit species that favor or are restricted to denser canopy closure classes. Ensuring protection of the maximum number of species requires examining the distribution, size, and species composition of species rich areas identified. Site specific considerations are essential as a second step in the ranking of local habitats for management or protection.

Due to its varied topography, soils, and climate, California has one of the most diverse assemblages of plants, animals, and natural communities in the United States. In the course of the state's settlement, many habitats were altered by mining, grazing, timber harvest, and agricultural development. Despite regulation to reduce the impacts of these land uses, demands from a growing population has led to continued habitat degradation and loss.

Current causes of major habitat loss and disturbance are construction of housing, roads, industrial facilities, water storage and delivery systems, and mining. Habitat loss and fragmentation have contributed to the extinction of plant and animal species and subspecies, loss of unique plant communities, and substantial reductions in acreages of the more widely distributed habitats in many parts of the state (Jones and Stokes Associates 1987).

Perpetuation of wildlife species requires maintenance of the habitats that support them. Habitat maintenance can be accomplished through acquiring and managing lands by agencies or private groups, managing existing public and private lands for diversity values, regulating detrimental private land uses, and providing incentives for private habitat protection. Common to all these approaches is a need to determine the specific areas of land that warrant action.

Nearly 12 percent of California has been designated as parks, refuges, and wilderness (California Department of Forestry and Fire Protection 1988), but these reserves do not equally protect all cover types. High elevation cover types are well protected in designated wilderness areas. In contrast, cover types such as ponderosa pine, blue oak-digger pine woodland, montane hardwood, valley-foothill hardwood, valley riparian, coast scrub, annual grassland, and perennial grassland each has less than 8 percent of its total acreage in reserved status (California Department of Forestry and Fire Protection 1988).

One systematic approach proposed to address conservation of biological communities and their constituent species involves protecting a sufficient amount and juxtaposition of habitat that support all taxa before individual species decline to the point of endangerment (Scott and others 1987). Early protection of species rich areas is more effective and less costly than deferring action to recover individual species after they are nearly eliminated (Scott and others 1988).

Species richness analysis recently has been proposed as a technique for assessing biological diversity and establishing priority areas for land protection. Kepler and Scott (1985), Scott and others (1987), and Davis and others (1990) outlined the utility of geographic information systems to identify species rich areas and to assemble and analyze diverse data for specific geographic regions.

Habitat structural characteristics such as tree canopy height and crown closure are recognized as important determinants of habitat quality for vertebrate species (Airola 1988). Previous attempts to identify species rich areas, however, have been based on the distribution of species ranges and general habitat types. Inclusion of mapped vegetation structure information (e.g. canopy cover) could significantly refine maps of predicted species

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distributions. In addition, species sensitivities to land uses and other factors have not always been considered in identifying species richness areas. If sensitivities of species to land uses is not considered, resilient and widespread species could disproportionately influence the selection of species rich areas to the detriment of localized and sensitive species.

The species richness approach uses existing information on the distribution of wildlife species to identify areas that support high numbers of species as candidate sites for protection. Underlying this method is the assumption that protecting habitat areas that support the largest number of species will provide the greatest level of protection for all species. In this way, the species richness method contrasts with an approach that emphasizes protecting those sites occupied by rare species (Scott and others 1988).

The valley-foothill hardwood habitat[3] was selected for this study due to its wide distribution (4.5 million acres) and small amount of total acreage in reserved status (167,000 acres; 3.8 percent). Much of this cover type (7 percent of total acreage) was converted to urban and agricultural uses during 1950-1980 (California Department of Forestry and Fire Protection 1988). Regeneration of several dominant tree species in this habitat may not be adequate to maintain their presence over time (Tietje and Schmidt 1988). Over half of the state's 600 terrestrial vertebrate species find hardwood-dominated habitats important for breeding (Ohmann and Mayer 1987).

The goal of this study was to compare several approaches to identifying areas of species richness within valley-foothill hardwood habitat. Objectives were to: 1) conduct a species richness analysis for valley-foothill hardwood habitat that accounts for species preference for different canopy closure classes; 2) identify areas of high species richness as priority areas for future habitat protection; 3) compare results of our approach to one that does not consider canopy closure preferences and species sensitivities; and 4) assess adequacy of protection of species rich areas under existing land ownership patterns.

METHODS

The ARC/INFO geographic information system (GIS) maintained by the California Department of Forestry and Fire Protection's Forest and Rangeland Resources Assessment Program (FRRAP) was used to develop the vegetation and land use information for the analysis. Data layers within the GIS consisted of WHR (Wildlife Habitat Relationships) species range maps, valley-foothill hardwood distribution by canopy closure class, and land ownership information. The California WHR system (Airola 1988) provided basic information on habitat relationships of wildlife species.

Species Maps

Range maps for the 91 wildlife species that find optimum breeding habitat within valley-foothill hardwood habitat were obtained from the California WHR system. Because the generalized species range maps encompass habitat types other than valley-foothill hardwood habitat, for this analysis, we refined species' breeding distributions by intersecting species range maps with the distribution of valley-foothill hardwood (Pillsbury and others 1990).

Ranges for each species were further refined to include only canopy closure classes mapped by Pillsbury and others (1990) that were rated as optimal for breeding in the WHR database (Airola 1988).

Habitat Maps

We used a digital version of Pillsbury and others' (1990) map of California's hardwoods. Polygons supporting blue oak (*Quercus douglasii*), interior (*Q. wislizenii*)/canyon live oak (*Q. chrysolepis*), coast live oak (*Q. agrifolia*), and valley oak (*Q. lobata*) vegetation types were considered as WHR valley- foothill hardwood habitat (Mayer and Laudenslayer 1988). The canopy closure classes used by Pillsbury and others (1990) were modified to match those of WHR (table 1). Although some imprecision was introduced in this translation, it still served to refine the distribution of optimal breeding habitat based on differences in vegetation structure over alternative mapping systems such as CALVEG (Parker and Matyas 1979).

Land Ownership

GIS land ownership information was digitized from 1979 Bureau of Land Management Surface Management Status Maps (1:100,000 scale) updated by using the most current National Forest maps. Ownerships that contained valley-foothill hardwood habitat were categorized as reserved or unreserved based on level of habitat protection as follows:

Reserved	Unreserved
Calif. Dept. of Parks and Recr.	Calif. Dept. of Forestry and Fire Protection
Calif. Dept. of Fish and Game	Other State lands
U.S. Fish and Wildlife Service	Bureau of Indian Affairs
National Park Service	Bureau of Reclamation
U.S. Forest Service	Bureau of Land Management
Wilderness Areas	U.S. Forest Service (other)
Research Natural Areas	Department of Defense
Special Areas	Private Lands
City/County/Regional Wildland Parks	

Identification of Key Species

We identified key species as those most likely to be affected by habitat loss in the valley-foothill hardwood type. These species should be expected to receive the greatest emphasis in

[3]As defined by Airola (1988) and Mayer and Laudenslayer (1988) for the Wildlife Habitat Relationships System and distinguished from cover type.

Table 1—***Translation used to convert Pillsbury and others (1990) canopy cover classes to WHR classes.***

	Canopy Closure				
Source	Scattered	Sparse	Open	Moderate	Dense
Pillsbury and others (1990)	<10 pct	10-33 pct	N/A	34-75 pct	>76 pct
WHR (Mayer and Laudenslayer 1988)	N/A	10-24 pct	25-39 pct	40-59 pct	>60 pct

identifying areas for possible protection (Diamond 1976, Rapoport and others 1986).

Key species were identified using a two-step process from the original list of 91 species that found optimum breeding habitat in the valley-foothill hardwood type. First, the WHR database was used to calculate for each species the percent of: one degree of latitude and one degree of longitude blocks occupied in California, WHR habitat types occupied, WHR habitat types for which at least one stage was rated as optimal for breeding, and total WHR habitat stages rated as optimal for breeding for all habitat types occupied. Percentage values were then summed and species ranked by their cumulative scores. Species with low scores were preliminarily identified as key species. This procedure eliminated those species that occupied large geographic ranges and found optimum breeding conditions in many habitats and seral stages.

The preliminary list of key species was modified further to reflect species' tolerance to habitat disturbance, susceptability to avian competitors (e.g., starling and brown-headed cowbird), by requirements for important habitat elements that may be altered management actions (e.g., cavities for nesting), whether a native species or introduced, and legal or management status (California Department of Fish and Game 1990). Application of these criteria resulted in the deletion of the American crow (*Corvus brachyrhynchos*), scrub jay (*Aphelocoma coerulescens*), wild turkey (*Meleagris gallopavo*), fallow deer (*Cervus dama*), and wild pig (*Sus scrofa*) and addition of western bluebird (*Sialia mexicana*), ash-throated flycatcher (*Myiarchus cinerascens*), burrowing owl (*Athene cunicularia*), and long-eared owl (*Asio otus*).

Species Rich Areas Identified by Different Methods

The effect of using canopy closure information and selection of key species on the outcome of the species richness analysis was conducted by calculating the extent of overlap between areas mapped in equivalent species richness classes (high, high- moderate, moderate, low) for all 91 species, 41 key species, and 41 key species with canopy closure information. If the locations of areas identified in each richness class were similar for each analyses, it would indicate that the additional efforts needed to identify key species and canopy cover requirements and to map canopy structure classes may not be worth performing in future efforts to identify areas of species richness in the valley-foothill hardwood habitat type.

Species richness class ranges were first determined for the 41 key species/canopy closure analysis by plotting number of species against canopy closure. The resulting histograms defined the range for each species richness class. To compare the overlap in species rich areas identified under the three analyses it was necessary to ensure that each species richness class contained similar acreages for the 91 species and 41 key species analyses. Therefore, the acreage within each species richness class for the 41 key species/canopy closure analysis was used to define the cut points for species richness classes for the 91 species and 41 key species maps. The extent of overlap between equivalent species richness classes was then compared for each of the three analyses as a measure of map similarity.

RESULTS

Procedures for the Identification of Species Rich Areas

Species rich areas were identified statewide for each of the three analyses. The central Sierra Nevada foothills provide an example to illustrate the changes that occur in the location of species rich areas when canopy closure and species sensitivity is considered. Species rich areas in the central Sierra were identified for all 91 species (without considering species sensitivity or canopy closure information) and occurred primarily at middle elevations (fig. 1). The addition of species sensitivity information to the analysis did not substantially change the distribution of species rich areas (fig. 2). The addition of canopy closure information, however, markedly altered the distribution of species rich areas by largely eliminating previously identified areas of high species richness from this region (fig. 3).

The three analyses were evaluated by comparing the agreement in the assignment of acreage to equivalent richness classes, using the analysis with the 41 key species and canopy closure as the standard for comparison (fig. 4). Restricting the analysis to key species without canopy closure information did not substantially alter the assignment of acreages to species richness classes. Assignments made by all 91 species and the 41 key species, however, differed substantially from that made by an analysis of key species in concert with canopy closure information.

The largest blocks of high richness area were in the Sierra Nevada foothills in Mariposa, Madera, Fresno, Tulare, and Kern Counties. Substantial but scattered concentrations of these areas were found in the central Coast Range from Contra Costa County south to San Diego County. More isolated areas of high species richness were in Tehama County and the inner Coast Range in Yolo and Glenn Counties.

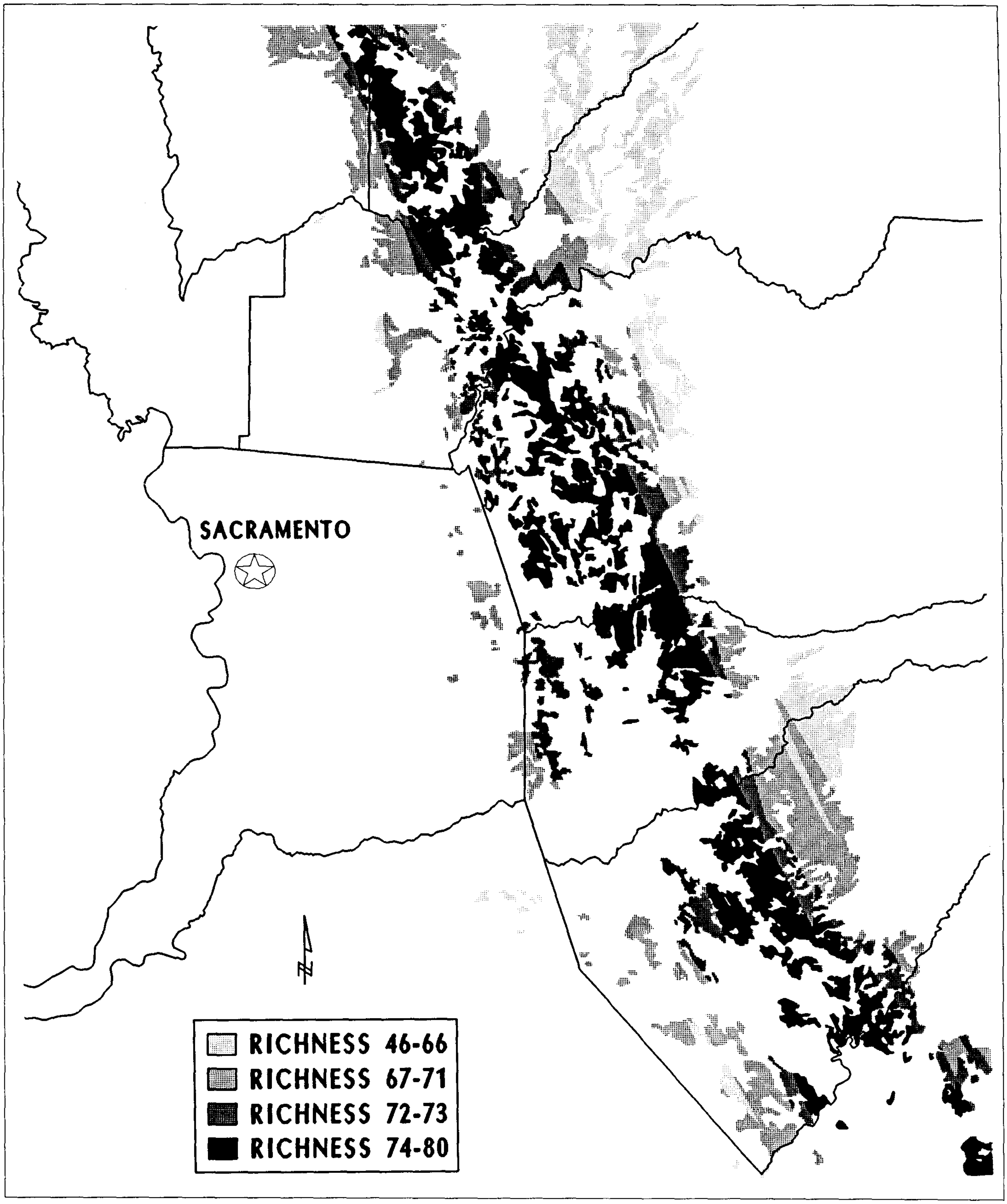

Figure 1—Distribution and extent of species–rich areas for 91 breeding species in the central Sierra Nevada foothills.

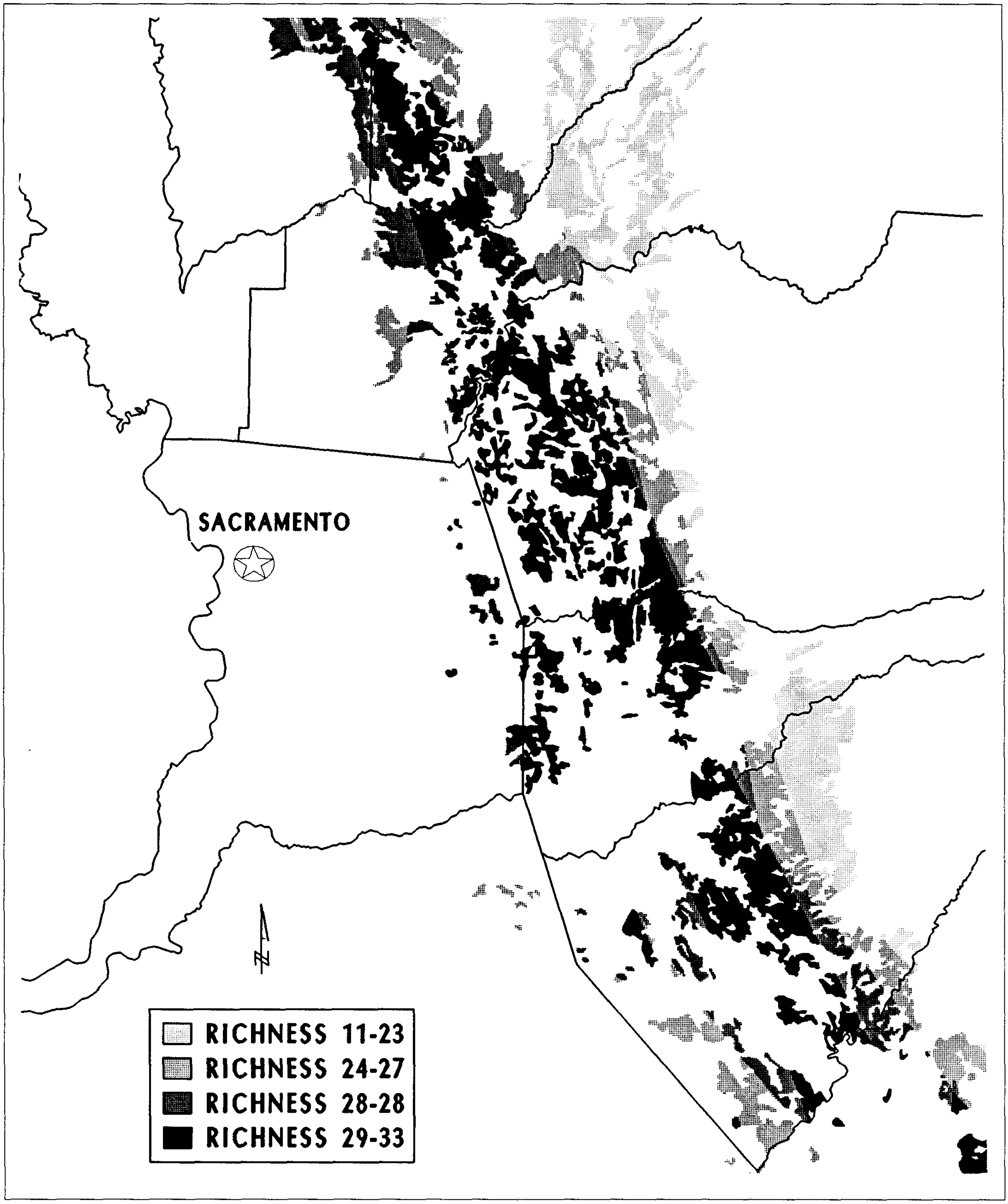

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Figure 2—Distribution and extent of species–rich areas for 41 breeding species in the central Sierra Nevada foothills.

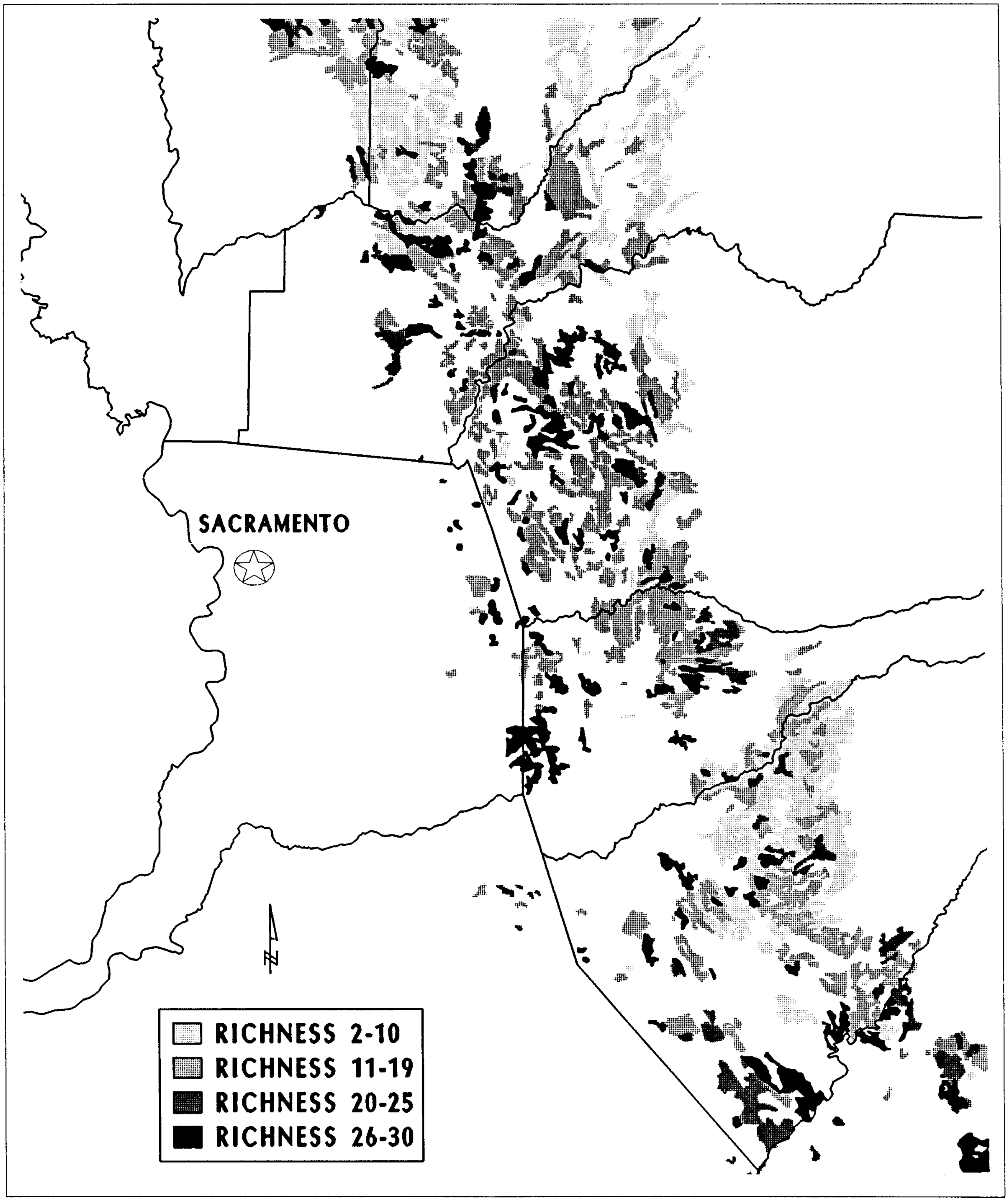

Figure 3—Distribution and extent of species–rich areas for 41 key breeding species including optimal canopy closure for breeding in the central Sierra Nevada foothills.

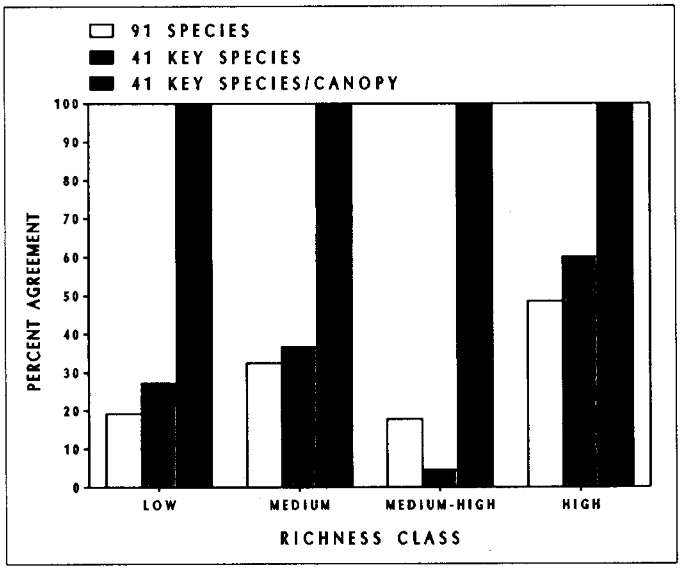

Figure 4—Predictive agreement of three different species richness methodologies by richness class for a statewide analysis of valley–foothill hardwood habitat.

Table 3—*Valley-foothill hardwood habitat type ownership by canopy closure class.*

Ownership	Canopy closure class-thousand acres			
Reserved	Dense	Moderate	Sparse	Total
Calif. Dept. Parks and Recreation	12	17	16	45
U.S. Forest Service	9	27	52	88
Other Public	5	13	16	34
Total Acres	26	57	84	167
Percent of Total Reserved	16	34	50	
Percent of Grand Total	0.6	1.3	1.9	
Unreserved				
Bureau of Land Mgmt	33	53	72	158
Dept. of Defense	2	33	70	105
U.S. Forest Service	39	106	176	321
Other Public	4	12	21	37
Private	529	1,405	1,768	3,702
Total Acres	607	1,609	2,107	4,323
Percent of Total Unreserved	14	37	49	
Percent of Grand Total	13.5	35.8	46.9	

Because most species were predicted by WHR to favor stands with sparse canopy closure (table 2), the addition of canopy closure data tended to identify as highest richness, areas in the southern part of the state where sparse canopy closure is most common. Conversely, the dense canopy closure class which is more common in the north state showed the lowest level of species richness and overall acreage.

Land Ownership of Species Rich Areas

The valley-foothill hardwood habitat is not well protected in California based on ownership (table 3). Approximately 3.8 percent of a total 4.5 million acres are reserved. If all Department of Defense lands are considered a reserved ownership, as suggested by Jensen (1983), the total increases to 6 percent. Eighty-two percent of the habitat acreage is privately owned. Although private sanctuaries and refuges were not classified as reserved in our analysis, they would not add significant acreage to the reserved total.

Areas with high species richness were also not well protected (table 4). Only 4.5 percent of the acreage in the highest species richness class was reserved. Similarly, 4.3 percent of the lowest species richness class, corresponding to the most dense canopy closure, is reserved.

Table 2—*Canopy closure associations for 41 key species finding optimum breeding habitat in the valley foothill hardwood habitat type.*

CANOPY CLOSURE	NUMBER OF SPECIES
Sparse	15
Sparse and Moderate	11
Sparse/Moderate/Dense	10
Moderate	0
Moderate and Dense	3
Dense	2
Total	41
Cumulative Total by Canopy Closure Class	
Sparse	36
Moderate	24
Dense	15

Table 4—*Species richness classes and ownership by percent of total acres for the 41 key species/canopy closure analysis.*

	Species Richness Class			
Ownership	2-10	11-19	21-25	26-30
Reserved				
Calif. Dept. Parks and Recreation	1.8	1.0	0.6	0.9
U.S. Forest Service	1.3	1.7	1.5	2.9
Other Public	1.2	0.6	0.8	0.7
Total	4.3	3.3	2.9	4.5
Unreserved				
Bureau of Land Management	5.6	3.4	4.2	1.9
Dept. Defense	0.4	2.0	4.1	2.7
U.S. Forest Service	7.5	6.8	8.1	6.8
Other Public	1.3	0.8	0.4	1.3
Private	80.9	83.7	80.3	82.8
Total	95.7	96.7	97.1	95.5
Total Acres (thousands)	680	1,726	978	1,121

DISCUSSION

Three attempts have been made to quantify the level of protection provided California's plant communities from a statewide or multi-ownership perspective. Klubnikin (1979) used Kuchler's (1977) map of potential natural vegetation of California to assess occurrence of vegetation types within parks and other reserved lands. Jensen (1983), inventoried the presence or absence of 65 natural communities within state and federal managed areas in each physiographic province of the state. California Department of Forestry and Fire Protection (1988) summarized the approximate percentage of each cover type reserved regionally and statewide. However, vegetation structure and wildlife habitat relationships information were not included in these analyses.

As Scott and others (1987) noted, the most obvious way to determine the current protection of biological diversity is to identify the occurrence of species and communities in protected areas. Our study tested the usefulness of incorporating canopy cover information and species sensitivity in identifying species rich areas. We interpreted differences in the location of high richness areas between our refined and the less detailed approach as evidence that the predictive ability of these maps were substantially changed by incorporating the mapped canopy closure values and species' preferences for canopy closure.

Use of canopy closure information identified stands with sparse cover as exhibiting highest species richness. These areas, however, are highly interspersed with other stands of dense canopy closure. Selecting areas for management based solely on species richness would omit key species that favor or are restricted to areas of dense canopy closure. Specific reserve areas selected for protection, if large enough, would usually include areas of each canopy closure class. The markedly smaller amount of acreage of dense canopy closure in the valley-foothill hardwood habitat also argues for the protection of examples of all canopy closure classes within regions if doing so adds to overall species richness.

The use of optimum habitat to define species distribution for the analysis is consistent with recommendations by Ruggiero and others (1988). Persistence of a species' population is determined by reproductive success and survival rates, which are both influenced by habitat suitability. Habitat suitability for species may be modified by succession or management actions. Therefore, habitat preferences may need to be more carefully considered as human activities alter habitat conditions. Reserve design and management must recognize the dynamics of vegetation change to maintain habitat quality for species of concern.

Several levels of more detailed data could be incorporated into the methodology to identify species rich areas at a statewide scale. These include addition of other vegetation structural components (e.g., tree size class), site specific locational data for threatened and endangered or other species of special concern, refinement in the definition of reserved areas, improvements in species-habitat relationship models, and inclusion of other species and sensitive plant communities. Conducting richness analyses for specific areas of the state (e.g., faunistic or biogeographic provinces [Udvardy 1969, Udvardy 1975]) could improve the identification and procedures for ranking species rich areas.

Consideration of other species groups, whose distributions are well known (e.g., trees [Griffin and Critchfield 1972], and fish [Moyle 1976]) could improve the species richness methodology. Similarly, species that occur in aquatic types that cross several terrestrial habitats could be incorporated. Lepidoptera have been recommended for inclusion in species richness analysis (Scott and others 1988), but maps of their ranges are not available for California (Davis and others 1990).

Areas of high species richness that we identified differed geographically in their wildlife species composition in that the highest species richness sites never supported more than 30 of the 41 key species (fig. 3). Thus, ensuring protection of the maximum number of species requires examining individual species distributions and selecting areas of high species richness that include all species.

Although the WHR database models have received extensive use, model evaluation has been infrequent and generally confined to information on the presence or absence of bird species. WHR model evaluations have indicated that substantial variation exists in the accuracy of predictions of species occurrence in habitats (England and Anderson 1985, Raphael and Marcot 1986, Dedon and others 1986, Avery and van Riper 1990). Predictions of species' habitat suitabilities within individual canopy closure classes of a habitat are less accurate (Airola 1988). WHR models are updated and verified by research and use of the system, test results reinforce the caveat that the models should be used with caution and are more reliable over large geographic areas (Raphael and Marcot 1986) as in this analysis.

This study examined a methodology to be used with current information as well as with future improvements to the WHR system. The methodology is valuable for identifying high species richness areas that may warrant retention to maintain the state's biological diversity. Once high richness areas are identified, they may be analyzed by resource allocation models such as CALPLAN (California Department of Forestry and Fire Protection 1988) to assess projected future conditions (e.g., probability of land conversion) to further evaluate management priorities.

Successful use of results of species richness analyses depends on several practical considerations. The areas of high species richness identified on a statewide basis should guide the selection of potential management areas. Site specific considerations, however, are highly important in ranking local habitats for protection. These considerations may include the:

1. size of available high quality habitat parcels;
2. presence of existing protection areas that can be augmented;
3. extent of connection with or isolation from other suitable habitats;
4. presence of important special habitat elements;
5. proximity to other habitats with high protection priorities;

6. effects of existing and future land uses occurring on adjacent lands;
7. the presence of highly sensitive species;
8. land and incentive program costs; and
9. public acceptance of land protection.

Combining the identification of species rich areas with current strategies that emphasize site protection for rare species and significant natural areas (Hoshovsky 1989) also will provide a more comprehensive conservation effort. As Scott and others (1988:p44) noted "it is easier and more cost-effective to protect intact, functioning ecosystems with their myriad species than to initiate emergency room conservation measures for one endangered species after another, or to wait until common species become endangered before acting to protect them." We believe that the use of habitat structure and species sensitivity information in species richness analyses to identify priority land areas enhances this proactive approach to species conservation.

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