Wildlife-Habitat Relationships in California's Oak Woodlands: Where Do We Go from Here?[1]

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Abstract: We discuss management goals and research directions for a comprehensive study of wildlife in California's oak woodlands. Oak woodlands are under intensive multiple use, including urbanization, recreation, grazing, fuel wood cutting, and hunting. Research in oak woodlands is thus complicated by these numerous, often competing, interests. Complicating understanding of resource requirements of wildlife is the historic emphasis on the use of these woodlands for grazing by domestic livestock and consumptive wildlife (game). The introduction of exotic wildlife species has further impacted the oak woodland environment. We review ecological principles that must be considered when developing any management plan for oak-woodland wildlife, including habitat selection, the ecological niche, spatial and temporal aspects of resource use, and ecological scale. We outline a research program that: (1) develops research and management goals based on sound ecological concepts, (2) recognizes the scale-dependence of research results and management decisions, and (3) considers the acceptable level of accuracy and precision to be achieved. We suggest that maintenance of biological diversity at the watershed level is an attainable goal. A wider range of practicing field scientists must be involved in future research and management decisions.

Oak woodland describes a diverse vegetation type that includes numerous species of trees, shrubs, grasses, and forbs. These plants provide a varying array of food for wildlife, including arthropods, seeds, and fruits, and numerous other habitat components, including roost and nest sites, and cover. Further, these resources vary both within and between seasons; this variation usually changes between years depending upon environmental conditions. The types, amounts, and distribution of resources determine, in part, the types, abundance, and distribution of wildlife present (Block and Morrison 1990).

These complex relationships make it difficult to accurately predict the resource requirements of specific wildlife species. Models of wildlife-habitat relationships are further complicated by human-induced variations in resource abundance and species composition, including: grazing changes the amount, composition, size, and shape of grasses and forbs, thus potentially changing competitive relationships and population regulation; hunting and predator control could change predator-prey relationships; recreation increases stress on wildlife; and land conversion for housing reduces the absolute area of land available.

Numerous people have conducted research on wildlife in oak woodlands during the past 100 years. These studies have ranged from anecdotal natural history accounts to detailed analyses of resource use. Most of these studies have been species- and site-specific, and as such, provide limited data that can be used to manage oak woodlands. In response to increased human impacts on oak woodlands, and in response to public interest in oak-woodland wildlife, the California Department of Forestry and Fire Protection (CDFFP) and the University of California initiated a research program to address the many changes facing oak woodlands (the Integrated Hardwood Range Management Program [IHRMP]).

Given the varied and diverse nature of research, and the ever-increasing impacts upon oak woodlands, we think it is essential that present management goals and research directions be evaluated with regard to ecological principles. Our specific objectives in this paper are (1) to review ecological concepts as background for research needs and field procedures, (2) to summarize what we need to know about wildlife in oak woodlands, and (3) to develop a foundation from which reliable research and management can proceed.

DEFINITIONS

Throughout this paper we refer to "oak woodlands" rather than the currently popular "hardwood rangelands" to describe areas in California dominated by species of *Quercus.* First, although many species of hardwoods co-occur with oaks, oaks are usually the dominant species by cover, biomass, and density. Plant ecologists usually refer to an area by its dominant or co-dominant species (e.g., pine-fir forest, which may contain 5-6 conifer species). Our field research was conducted in areas dominated by oaks; the term "hardwood" is appropriate when used to discuss hardwood-dominated areas in the general sense (e.g., the "hardwood" in IHRMP). In general, however, "rangelands" is an inappropriate descriptor in that range implies a specific, usually commercial, use. As noted above, oak woodlands, and more generally, hardwoods, are under intensive multiple use. "Rangelands" stems from historic, dominant activities of ranchers and range managers in these areas, but now suggests a rather narrow focus and is clearly inappropriate.

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RESEARCH IN OAK WOODLANDS

Current Research Direction

Most current research in California is complicated by numerous competing interests, from the standpoint of both the allocation of limited research dollars and conflicting public interests. The emphasis on commercial production of range animals, most notably cattle and sheep, has driven research efforts historically. One need only note the many university and government research stations that emphasize cattle production: Sierra Foothills Range Field Station of the University of California, for example, was established to "support livestock and agronomic productivity of foothill rangelands" (Raguse and others 1990). Only recently have new research topics, including wildlife research, been added to the goals of these stations. It is notable that this expanded research role was initiated to "accommodate increasing public concern about management of renewable natural resources" (Raguse and others 1990).

Complicating and inhibiting understanding of noncommercial resources in oak woodlands has been the emphasis of the California Department of Fish and Game (CDFG) towards consumptive wildlife. Few species of wildlife inhabiting oak woodlands are classified as game. Most information available on the distribution and abundance of nongame species in oak woodlands has been provided by various naturalists and university researchers. Recently, however, CDFG has reacted to increasing public concern for a more holistic approach to wildlife management by expanding their relatively small nongame branch through initiation of the Natural Heritage Program. However, in many management programs, the predominant nongame species are assumed to benefit from management practices initiated for their game counterparts. As we discuss below, this assumption has no basis in ecological theory and knowledge.

Much of the problem with management of oak woodlands is that most of the land is privately owned. Thus, it is understandable that resource agencies and extension branches of universities have responded historically to the predominant, commercially oriented user groups in these lands. Further, implementation of management activities on oak woodlands are complicated by private land ownership rights. Recognizing this, the California Board of Forestry and the University of California (Extension) have initiated steps to conduct research and educate the public on a more holistic basis than previously seen. Of course, all wildlife species are under the purview of the U. S. Fish and Wildlife Service (USFWS) and CDFG, regardless of land ownership, although they can do little concerning habitat management without the cooperation of the private landowner or land-management agency.

Management of oak woodlands is complicated by restricted knowledge, emphasis on only a limited set of resources, and land ownership. Underlying the difficulty in applying a more holistic approach to resource management is uncertainty on defining the *goals* of this management and the appropriate spatial scale that should be applied to this management. Should the goal be maintenance of "natural" species diversity on all or part of the land base? And how can these decisions be applied to an increasingly fragmented landscape? We think that answers to the issues we have raised and the questions we have posed can be found only after a sound framework has been established, based on the ecological principles that structure and organize the oak-woodland ecosystem. Below we review some of these principles.

ECOLOGICAL CONCEPTS

Habitat

The foundation of wildlife-habitat relationships is the clear definition and determination of the factors that comprise "habitat." Much confusion exists in the literature over the definition of habitat. Wildlife habitat is defined by the animal itself; that is, the complex association of interrelated factors used by an individual (and, collectively, the population) defines habitat. Determination of the specific factors that comprise this habitat, and their functioning and mechanisms of influence and control of animals, is the goal of wildlife-habitat-relationships studies. This broad definition of habitat can—and usually does—vary by age and sex, time and space, populations (i.e., ecotypes), and the like (Block and Morrison 1990). These variations are influenced by innate and learned abilities of animals, and natural and human-induced changes in the environment (including biotic and abiotic factors). Habitat is composed of all of the many factors that supply the life requisites, including plant structure and floristics, food, and water. Exploitation of these items comprises "resource use" by the species. Numerous other factors, including disease, predators, and competitors, affect the use of habitat by individuals in specific locations at specific times.

By contrast, "vegetation type" refers to human-defined categories of plant structure and floristics that do not necessarily equate to habitat. This is an important distinction, as researchers and managers often try to force wildlife-habitat relationships to fit their own vegetation categories.

Ecological Niche

Related to resource exploitation is the concept of the niche. Simply, the niche of an animal is the total suite of environmental factors to which the animal is adapted, including food, competitors and predators, vegetation structure and floristics, weather conditions, and numerous other factors. The interrelated and multifaceted nature of these factors has been recognized conceptually by Hutchinson's n-dimensional niche hypervolume (Hutchinson 1957), and statistically through multivariate analy-

ses (Green 1971, Verner and others 1986). Thus, only through careful and detailed evaluation of the niche of an animal can full understanding of its resource requirements be obtained.

Spatial and Temporal Variation

As previously mentioned, habitat (and more generally, resource) use is scale-dependent. At the geographic level, we know that resource use varies according to local environmental conditions. Thus, resource use often varies dramatically between areas. And because environmental conditions are seldom synchronized among areas, patterns of resource use likewise vary (Morrison and others 1990).

Nuttall's Woodpeckers (*Picoides nuttalli*), for example, occur in oak woodlands throughout the state. We studied resource use by this woodpecker at four locations ranging along a latitudinal gradient of 800 km from southwest Riverside County, north to Yuba County (see Block 1989, In press). Tree species used for foraging differed among study areas as the birds used different combinations of blue (*Q. douglasii*), valley (*Q. lobata*), California black (*Q. kelloggii*), interior live (*Q. wislizenii*), canyon live (*Q. chrysolepis*), and Engelmann (*Q. garryana* var. *brewers*) oaks and gray pine (*Pinus sabiniana*) (table 1). Patterns of tree-species use differed both spatially and seasonally. Had we restricted study to only one location and one season, we would have reached different conclusions regarding patterns of resource use than we did having studied this species across different locations within its geographic range.

Ecological Scale

Our descriptions of habitat depend largely on the scale at which we record our measurements. We know that plot size, for example, influences subsequent descriptions of the plant community (e.g., density). It is becoming increasingly evident that different animals perceive their environment—and thus select habitat—at different scales; techniques are available that acknowledge this (Ludwig and Reynolds 1988).

Table 1—*Relative frequencies (pct) of tree species used by Nuttall's woodpeckers at four locations in California*[1].

Tree species	SFRFS	SJER	TR	SRPP	TOTAL
Blue oak	66.2	39.7	57.1	0.0	51.0
Live oaks[2]	18.0	26.3	9.0	17.3	19.0
California black oak	1.0	0.0	4.9	0.0	2.0
Valley oak	0.0	0.0	29.0	0.0	7.0
Engelmann oak	0.0	0.0	0.0	82.7	4.0
Gray pine	14.8	34.0	0.0	0.0	17.0

[1]Sample size: Sierra Foothill Range Field Station (SFRFS; n = 157); San Joaquin Experimental Range (SJER; 162); Tejon Ranch (TR; 111); Santa Rosa Plateau Preserve (SRPP; 23); sexes combined.
[2]Live oaks include interior live, canyon live, and coast live oaks.

Exotic Species

Critical to maintenance of biological diversity is the question of exotic species. Exotics fall into several categories based on their mode of introduction into regions previously unoccupied. Many native species are expanding their ranges within California because of human-induced habitat changes. Notable here are the chestnut-backed chickadee (*Parus rufescens*) and green-tailed towhee (*Pipilo chlorura*). Other species, native to North America but previously unknown in California, now breed within its borders, including the Virginia opossum (*Didelphis marsupialis*) and barred owl (*Strix varia*). These are not true "natural" expansions based on evolutionary changes by the species or natural changes in the environment. Several species that are not native to North America have invaded California, including the well-known European starling (*Sturnus vulgaris*) and house sparrow (*Passer domesticus*). Finally, many species have been introduced directly into the state to promote increased hunting opportunities, including northern bobwhite (*Colinus virginianus*), white-tailed ptarmigan (*Lagopus leucurus*), chukar (*Alectoris graeca*), ring-necked pheasant (*Phasianus colchicus*), and wild turkey (*Meleagris gallopavo*); the latter two species occur in oak woodlands.

Thus, the study of habitat relationships involves describing the numerous environmental factors that are encountered by an animal; this is complicated by temporal and spatial variation in the availability and use of these factors. It is wrong to think that simple descriptions of habitat use can be translated into meaningful management plans except at the most superficial level. Gross categorizations that violate these basic ecological principles, regardless of the size and sophistication of the computer system used to retrieve and manipulate data, are inappropriate. And because habitat describes only part of the environment used by an animal, we should more appropriately be referring to this area of research as "wildlife-resource-use relationships." Vegetation-habitat may form the foundation upon which other factors operate, but still describes only part of the activities of the animal. The Wildlife-habitat Relationships (WHR) data base and Habitat Suitability Index (HSI) models are examples of procedures designed to simplify natural systems. As we discuss below, all study and modeling of wildlife must clearly state and justify a specific and acceptable level of precision and accuracy.

EXTERNAL STRUCTURE OF RESEARCH PROGRAM

Historically, research efforts in oak woodlands have been limited to short term (1-3 years), species- and location-specific descriptions of vertebrate natural history, especially game species. Most of these studies do, indeed, provide useful knowledge on resource use. Unfortunately, gaps in our knowledge are the rule rather than the exception. Few validated studies of resource-

use relationships are available.

The current "hardwood range" program has begun to address wildlife issues in oak woodlands by funding studies on basic habitat relationships and geographic scale, riparian woodlands, and urbanization. Unfortunately, these studies were not integrated in their goals or approach, all were short term, and no follow-up validation of initial results was funded (discussed in more detail below). The program has, however, allowed us to accumulate valuable data and provide direction for future research. To further advance our understanding of wildlife in oak woodlands, a well-organized research program is needed that:

1. Develops goals based on sound ecological concepts.
2. Recognizes the scale-dependence of research results and management decisions.
3. States the acceptable level of accuracy and precision to be achieved.

The geographic-spatial scale at which the oak-woodland ecosystem functions should be used to set the limits to human management activities, especially if maintenance of biological diversity is the goal. (We define biological diversity as the number of species, and their distribution and abundance, over some defined area.) In fact, we think that maintenance of biological diversity at a reasonable, ecologically-sound level, is an attainable and desirable goal for oak woodlands. The level of examination-management should be sufficiently large to encompass all essential environmental factors and the home ranges of the largest vertebrates present. We follow U.S.D.A. Forest Service guides in recommending the watershed level. This level should maintain the properties of the ecosystem and thus maintain the diversity of the environment. Attempts to manage smaller parcels of land, apart from the whole system within which they are found, will likely fail. We must also acknowledge that all changes, both natural and human-induced, will alter resources and thus biological diversity. The goal should not be maintenance of a static system. Rather, the goal should be to allow a dynamic system to function naturally without being forced into an unnatural state by improper management activities.

Detailed studies are necessary that determine the influence of intentional and unintentional introductions of exotics on native wildlife (Pimm and Gilpin 1989). Like habitat changes, exotics perturb the environment. Although their impact on the environment is difficult to predict, numerous examples exist of the ecological changes caused by starlings, house sparrows, exotic deer, and numerous feral species. Whenever introduction of a new exotic is proposed, the burden of proof for the lack of impact to the system must clearly be placed on the proponents (Bratton 1988, Pimm and Gilpin 1989). The Wildlife Society has drafted language that notes that the introduction of exotic flora and fauna into ecosystems often has been more detrimental than beneficial, and that responsible agencies prevent the accidental introduction of exotics (*The Wildlifer* (240), May-June 1990:19).

An overall strategy is needed for evaluating resource relationships in oak woodlands that considers issues of temporal and spatial scales, levels of acceptable accuracy and precision, geographic scale of application of results, the question of exotics, and related issues. Research should not be dominated by historic, economic goals. We address this issue further in the last section of our paper.

INTERNAL STRUCTURE OF RESEARCH PROGRAM

The specific methods used to evaluate resource relationships are goal-dependent and must acknowledge temporal changes and be set in the appropriate spatial scale. Although it could be argued that different goals necessitate different methods, such views fail to acknowledge that (1) an integrated program should promote cooperation and thus compatibility of results, and (2) all studies can include a common, base method and still allow expansion into goal-specific methods as required. Unfortunately, current research in oak woodlands is fraught with differing and often contrasting methods. Methods used to count birds among the various studies previously funded by the "hardwood range" program are but one example. One study used short-duration counts at points along transects; another used much longer-duration counts placed differently from the first study; another has used intensive counts in fixed plots; yet another counted birds while driving slowly along roads; none of these methods can be safely compared to another. This is especially distressing because detailed studies *in oak woodlands* have been done to determine proper ways to conduct these counts, including development of a monitoring program (Verner 1987). Research results are determined, largely, by the methods used to collect the data. Many studies are available in both the wildlife- and plant-ecology literature that show that the number, size, and juxtaposition of plots, transect spacing, number of observers and their training, and numerous other aspects of methodology all interact to bias results (see Verner and others 1986, Morrison and others 1990). Guides for the use of appropriate and comparable methods should be established.

MANAGEMENT RESOLUTION: SYNTHESIS

We think that the goal of wildlife management in oak woodlands should be the conservation of biological diversity. Thus, composition of native species must be conserved. This requires protection of system interactions at all (trophic) levels, and necessitates management at a "landscape" level. A reasonable and manageable geographic scale appears to be at the watershed level, although this topic requires rigorous study. Research would then emphasize the mechanisms of biological diversity at this geographic scale. Also required is the exclusion of all additional exotics unless it can be shown, unequivocally,

that no unacceptable perturbations to the system will be caused by their introduction. Standards for retention of oaks (and all hardwoods) must be based on ecological knowledge, and not driven by narrow focused, recreational or economic interests.

Agency environments need to acknowledge these new goals. This requires clear and rigorous leadership by the Board of Forestry and implementation by CDFFP. Also required is a reorientation that recognizes (1) the importance of *all* species in the system, (2) that the system is extremely complex, and (3) that past emphasis on game and exotic species is both inappropriate, given public demand for wildlife protection, and deleterious to the integrity of oak woodland ecosystems. We are not suggesting that the absolute amount of time and money spent on game management be reduced. It is the small amount of effort placed on nongame *relative* to their game counterparts that requires change. Although this will obviously require new funding sources, we think that all wildlife biologists and managers in California could increase the amount of attention they give nongame species.

The "hardwood range" program has helped to provide critical, baseline data on wildlife-habitat relationships in oak woodlands. These data, and the methods used to collect them, can serve as a starting point for development of an overall, detailed strategy for further research. To accomplish this, all proposals for funding should be rigorously reviewed, and all scientists that wish to be part of the program should meet regularly to discuss past accomplishments and plan future studies. Practicing field scientists should be consulted to develop research priorities and organize field studies in a truly integrated manner. Administrators and nondirectly practicing scientists cannot be expected to adequately develop such a program. Such a program would:

1. Develop goals that embrace the concept of biological diversity, set these goals within reasonable and attainable spatial scales (e.g., watershed level), and specify acceptable error levels.

2. Develop a step-by-step research agenda that addresses each of the goals developed in (1); standards of specific methods would also be provided by qualified field scientists. Laboratory and field experimentation would likely be included.

3. Research results would be incorporated into management recommendations for the maintenance of biological diversity in oak woodlands at the appropriate spatial scale.

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