



August 17, 2015

Shawna Purvines, Principal Planner
El Dorado Community Development Agency
Long Range Planning Division
2850 Fairlane Court
Placerville, CA 95667

Re: Comments on notice of preparation for general plan amendments to biological resources plan components

Ms. Purvines:

We have reviewed the notice of preparation (NOP) for the biological resources policy update to the general plan (GP) and offer the following comments on behalf of the California Native Plant Society and Center for Sierra Nevada conservation.

1) Changes in Objectives 7.4.1 and 7.4.2 and Associated Policies

We raised in earlier comments a concern about the lack of integration between objectives and policies. We remain concerned that the project description in the NOP and supporting documents still does not provide the integration provided by the existing general plan. The project description in the NOP also does not clearly define some terms, e.g., "special-status vegetation communities" or more specifically the "vegetation communities" to which the mitigation ratios in Policy 7.4.2.8 will apply. We ask that the assumptions about which "vegetation communities" that will be subject to the mitigation ratios be clearly stated and evaluated in the draft environmental impact report (DEIR).

We also think that the emphasis on Pine Hill plants in Policy 7.4.1 without providing equal emphasis on other species protected by state and federally de-emphasizes the commitment in the GP to other protected species. The lack of emphasis on other protected species is illustrated by Policy 7.4.2.1 which commits only to coordinating wildlife programs with state and federal agencies. The affirmation from the County in the existing Objective 7.4.1 protect all state and federally recognized rare, threatened or endangered species and their habitat consistent with state and federal law should be retained in the proposed action and preferred alternative.

"Large expanses of native vegetation" are to be "conserved" through the programs implemented in the GP (Policy 7.4.2.8) yet it is unclear which policies under Objective 7.4.2 specifically implement this direction. Fragmentation of habitats through the development centered along Highway 50 has long been known to be a significant impact. We ask that the

DEIR evaluate the impacts of the project description and alternatives on their potential to fragment existing areas of native vegetation in the county. When evaluating expanses of native vegetation, we also ask that you consider habitat patches of all sizes and not arbitrarily limit the evaluation to patches of certain size or exclude areas based on parcel size.

2) In-lieu Fee to Conserve Oak Woodlands

The NOP indicates the County's intent to use the Oak Resources Management Plan and supporting policies to provide an option that allows a project proponent to mitigate for all projects impacts by paying a fee in-lieu of any other mitigations requirements. We do not believe that this mitigation approach in the project description is legally sufficient to reduce significant impacts of development to the extent feasible. We come to this conclusion since the in-lieu fee program does not address mitigation in the area where the principle impacts occur – the Highway 50 development corridor.

Presently, the in-lieu fee program does not include any Priority Conservation Areas (PCAs) in the central portion of the county near Highway 50. Yet we know from presentations made by to the Board of Supervisors (BOS) in February 2015 that there are biological "shortfalls" in the existing PCA system. The analysis provided indicated that the estimated impacts to woodland values cannot be mitigated only by the PCAs. In response, the BOS agreed to allow conservation to occur on lands outside the PCAs and would establish criteria for identifying additional conservation areas.

Having agreed that the locations of the existing PCAs were not by themselves sufficient to address impacts to oak woodlands, the proposed in-lieu fee program (designed solely on the cost to acquire lands in the PACs) is not sufficient to mitigate the impacts on oak woodlands in the areas where development is expected. Because the in-lieu fee does not incorporate the higher cost of the "additional areas" needed to make the PCA strategy sufficient, payment of an in-lieu fee alone cannot be assured to reduce impacts to the extent feasible. Also, the ORMP only states that conservation outside of the PCAs may occur, but fails to identify when it must occur due to the location of project related impacts.

We propose the following as mitigation measures to provide for conservation and to feasibly lessen impacts on oak woodlands:

- Require a combination of on-site mitigation and in-lieu fee for those projects in the central portion of the county that contribute to impacts on oak woodlands; or
- Develop PCAs in the central portion of county that reduce impacts from fragmentation in the central portion of the County and incorporate the acquisition costs of these areas into the in-lieu fee program.

There may well be other options for mitigation measures. Our principle point is that for the in-lieu fee program to be relied upon it must include the costs of all the lands needed to make the

program sufficient to meet the conservation objectives and planning requirements for oak woodlands. We also believe that it is necessary to mitigate project impacts as close as possible to the area of impact.

3) Analysis of the Impacts of Development on Oak Woodland Fragmentation

We ask that you complete a spatial analysis of potential impacts of development on oak woodlands that utilizes the current condition as the baseline. We ask that you not limit the characterization of current condition by arbitrarily defining “large” patches of oak woodland or constraining the sizes of the parcels considered. We note that by accepting in the draft ORMP land dedications of 5-acres or greater having conservation value, any analysis of impacts should include patches of oak woodland at least this size and greater. We would argue that depending on the woodland type (e.g., rarity) and location, patches smaller than 5 acres can be biologically significant.

We also ask that the spatial analysis take into account the variety of woodland types encountered in the county (e.g., species and woodland density). We have attached information on habitat values of oak woodland of various types to inform the evaluation of existing condition and potential impacts.

4) The Project Description is not Stable

Simultaneous with this amendment of the biological policies and objectives is a targeted GP amendment and zoning ordinance update (TGPA/ZOU). Changes as a result of that process have the potential to increase the impacts on oak woodland resources. We ask that the DEIR analyze both the existing GP and the changes proposed in the TGPA/ZOU to ensure that the analysis for this proposal covers the range of conditions that may be in existence upon implementation.

Conclusion

We believe the project description still lacks clarity about the habitat that will be conserved under objective 7.4.2. We also identified a fundamental flaw in the design of the in-lieu fee program, i.e., its failure to adequately address the “shortfall” in the existing PCAs. We believe these deficiencies are sufficiently severe that the project description should be revised to provide remedies prior to completing a DEIR.

We appreciate the opportunity to comment on the proposed changes to the general plan. Please include us on future notifications as the process moves forward. Please contact Sue Britting, if you have questions or wish to discuss our comments.

Sincerely,



Susan Britting, Ph.D.
Conservation Chair
El Dorado Chapter
PO Box 377
Coloma, CA 95613



Karen Schambach
President
Center for Sierra Nevada Conservation

Attachments: Guidelines for Managing California’s Hardwood Rangelands (1996)

Saving, S. C., & Greenwood, G. B. (2002). The potential impacts of development on wildlands in El Dorado County, California. In *Proceedings of the 5th Symposium on California’s Oak Woodlands: Oaks in California’s Landscape*. USDA Forest Service Gen. Tech. Rep. PSW-GTR-184 (pp. 443-461).

*Guidelines for
Managing California's
Hardwood Rangelands*



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CALIFORNIA DEPARTMENT OF FISH & GAME

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ON THE COVER: Oaks on a foggy morning — Murphy's Laurelwood Ranch, Sonoma County, California. Photograph courtesy of Michael Brigham, Photographix, 131 E. First Street, Cloverdale, CA 95425. Inside photographs by Michael Brigham, Richard B. Standiford, and Douglas R. McCreary.



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Table of Contents

| | |
|--|----------|
| <i>Preface</i> | <i>i</i> |
| Part I – The Hardwood Rangeland Resource | |
| Chapter 1 - Setting Goals for Hardwood Rangeland Management | 1 |
| Chapter 2 - Oaks and Habitats of Hardwood Rangelands | 8 |
| Chapter 3 - Resource Assessment and General Hardwood Rangeland Values | 18 |
| Chapter 4 - Oak Woodland Wildlife Ecology, Native Plants, and Habitat Relationships | 34 |
| Part II – Hardwood Rangeland Management | |
| Chapter 5 - Livestock and Grazing Management | 51 |
| Chapter 6 - Developing Recreational Sources of Income from Oak Woodlands | 68 |
| Chapter 7 - Open Space and Private Land Solutions to Hardwood Conservation | 78 |
| Chapter 8 - Resource Evaluation for Forest Products | 82 |
| Part III – Sustaining Hardwood Rangelands | |
| Chapter 9 - Sustainable Management of Hardwood Rangelands: Regeneration and Stand Structure Considerations - | 98 |
| Chapter 10 - Fire in California’s Hardwood Rangelands | 110 |
| Chapter 11 - Erosion Control | 115 |
| Appendices | |
| Appendix A - Vertebrate Wildlife Species and Habitat Associations | 120 |
| Appendix B - Sensitive Plant Species on Hardwood Rangelands | 146 |
| Appendix C - Sources of Assistance | 158 |
| Appendix D - References | 162 |
| Appendix E - Glossary of Terms | 170 |

Technical Coordinator: Richard Standiford
Editor: Pamela Tinnin

Contributing Authors (Listed Alphabetically):

| | |
|---|--|
| Ted Adams, UCD | Doug McCreary, UC - IHRMP |
| James Bartolome, UCB | Neil McDougald, UC - IHRMP |
| Mike Connor, UC Sierra Foothill Research & Extension Center | Kevin Shaffer, CDF&G |
| Lee Fitzhugh, UCD | Tom Scott, UC - IHRMP |
| Bill Frost, UC - IHRMP | John Shelly, UC Forest Products Laboratory |
| Barry Garrison, CDF&G | Richard Standiford, UC - IHRMP |
| Mel George, UCD | Bill Tietje, UC - IHRMP |
| Greg Giushi, UC - IHRMP | Bob Timm, UC Hopland Research and Extension Center |
| John Maas, UCD | |



Chapter Three

Resource Assessment and General Hardwood Rangeland Values

Primary authors: Richard Standiford, Univ. of California, Berkeley; and Barry Garrison, Calif. Dept. of Fish and Game

General Assessment of Property

Once you have completed an assessment of the goals for your hardwood rangeland property, it is necessary to assess the various resources to determine if it is possible to accomplish these goals, and where management activities should be directed. In this chapter, we will present two general worksheets. Worksheet 3-1 gives a framework for evaluating the overall hardwood rangeland property, while worksheet 3-2 will help you assemble basic information about your hardwood stands. Most of the information for 3-1 is easily available from a general reconnaissance of the property, as well as an evaluation of maps and aerial photos. The section on sources of assistance gives advice on ordering maps and photos if you do not already have these. You should plan on completing this entire resource assessment exercise because it can provide a foundation upon which sound land management actions may be built. This is a good activity for all family members or parties interested in a particular property to participate in together. The information gained in this exercise will ensure that everyone has a common base of knowledge about the existing resources on a property.

18



Stand Level Assessment

Once you have completed the general property assessment in Worksheet 3-1, take a look at the information in table 3-1 for some general resource enterprises that may work on your property. These possible enterprises can be compared with those which fit in with your goals developed from the worksheets in chapter 1, to decide on the management potential for your hardwood rangeland property. Then you will be able to direct your attention to detailed discussions in chapters 4 through 9 of this book on various hardwood rangeland enterprises. You may need to collect additional information for a detailed assessment of the individual enterprises. This should help guide your decision about which types of management activities will be best for your situation.

Seen at left is a large madrone tree located on a ranch in Sonoma County. In the background are black oak trees. Madrone trees frequently occur on montane hardwood rangelands.



Worksheet 3-1. Hardwood Rangeland Property Assessment

General Property Information

Property name _____ Parcel size _____ acres Elevation _____ feet

Describe how property was acquired (date, method acquired, original purchase price/basis)

Current Property Value _____

Nature of ownership

- Sole Joint Partnership Other _____

Property location (describe general location of property; use local maps where possible)

Accessibility (describe road access to various parts of the property and locate on map/photo)

Adjacent land uses (describe all adjacent land uses)

- Ag./open space Suburban Rural Residential Urban Public land Protected Areas

Topography (show on map/photo)

Acres on slopes less than 30% _____ Acres on slopes greater than 30% _____

Distance to markets

Distance to urban areas/clientele base for hunt clubs and customers for firewood: _____ miles

Distance to livestock markets: _____ miles

Other markets: _____ miles

Legal/political/social constraints (list ordinances, deed restrictions, zoning, and neighbor concerns affecting property)

Water

Sources of water (describe all sources of water on property and locate on map/photo where appropriate)

- Ponds Water troughs Springs Intermittent streams Perennial streams
 Wells Irrigation ditch Municipal water source Other _____

Water quality concerns (describe and locate areas with specific water quality concerns)

General Vegetation Information

Acres by general vegetation cover types (locate vegetation types on map/photo)

- Grassland _____ acres Oak woodlands _____ acres Shrubland _____ acres
Irrigated agric. _____ acres Residential areas _____ acres Wetlands/riparian zones _____ acres
Other forested type _____ acres Other () _____ acres



Worksheet 3-1. Hardwood Rangeland Property Assessment (cont.)

Current Management/Economic Uses

Grazing/livestock (check current enterprises that apply, and general information below)

- Cow/ealf Stocker Sheep; ewe/lamh Lease grazing to others
- Other livestock _____

Current livestock inventory: ____ head on ____ acres

Season of use (check all that apply): Fall Winter Spring Summer

Other sources of forage: Public land lease Private lease Another ranch Other _____

Tree harvest (describe current tree harvest and marketing programs)

Type of wood products sold: Firewood Sawtimber Biomass Other _____

Species of tree sold: Blue oak Live oak Foothill pine Other _____

Harvest ____ cords every ____ years on ____ acres

Hunt Club (describe any hunt club activities you have)

Game species hunted: Deer Turkey Other gamebirds Pigs Elk Other _____

Lease description (describe hunt club economic arrangement)

20

List other economic uses of hardwood rangeland property

Capital improvements (list of all capital improvements and show on map/photo)

| Buildings | Fencing | Road systems | Other Improvements |
|-----------|---------|--------------|--------------------|
| | | | |

Resource Constraints

Soils (list all soil series, general productivity, and constraints)

Erodible areas (list all eroded and erodible areas and locate on map/photo where possible)

Threatened and endangered plant and animal species



Table 3-1. Matrix of resource assessment and management enterprises (for assessment chapter)

| Assessment Criteria | Livestock grazing | Hunt club/ recreation | Conservation land | Wood products | Specialty products |
|------------------------|---|---|--|---|---|
| Parcel size | >25 acres | >500 ac (deer); >100 ac. (turkeys) | >100 ac. | >100 ac. | Depends on product |
| Cover type and pattern | Must have patches of open or low density woodlands for forage | Mixture of dense and open woodlands with large patches of dense connected woodlands | Must have some special cover type being lost near property or a highly desirable habitat | Must have stands with over 40 percent cover | Sufficient amount of vegetation type for product |
| Water | Need water | Need water | May enhance value | Not important | May be important |
| Access | Not important | Need road system for transport | Not essential unless public access desired | Need road system for hauling | Need access for transportation and management |
| Adjacent land use | Urban uses may present social conflicts | Urban uses may present social conflicts: Rely on neighbors for some habitat needs | Opportunities are best in areas close to urban/residential areas | Urban uses may present social conflicts | Urban uses may present conflicts or opportunities depending on product |
| Topography | Most areas <50 pct. slope | Need areas with <50 pct. slope for access | Slope class has little effect | Operate only in areas with <30 pct. slope | Most likely need areas <30 pct. slope |
| Distance to market | Unlimited with new video marketing sales | Need to be <120 miles | Generally near to urban areas or areas with some adverse impact | <100 miles | Should be <100 miles to market to minimize transportation |
| Capital improvements | Fences, water facilities | Not critical | Not critical | Depends on product | Depends on product |
| Legal constraints | Local ordinances. T&E species | T&E species. hunting regulations | Often restricts future land use; may be constraints on compatible enterprises | Local ordinances. T&E species, deed restrictions. Forest Practice Act | Need to check health codes, zoning restrictions, T&E species |
| Resource constraints | Need residual biomass | Species of interest should be present in sufficient numbers to support harvest (i.e. turkeys, deer, etc.) | Presence of critical habitat or threatened and endangered species may enhance value | Site must be capable of regeneration from seedlings or sprouting | Need to ensure that "product" management does not disrupt site ecological processes |



Assessing Legal Concerns

Today's land management must often comply with numerous laws and regulations that are imposed at all levels - local, state, and federal. Federal laws and regulations are implemented by either the federal agency which has jurisdiction, or are delegated to a state agency. State laws and regulations for the most part are the responsibility of the jurisdictional agency, although responsibilities can be delegated to county or district agencies. Local ordinances are implemented by the county or district agency. An important part of an assessment is finding out which of these legal concerns apply to your situation, and what these require you to do. Some of the different types of laws and regulations you should be investigating are described, as well as where you might find more information.

Water: Water rights and water quality are both the responsibility of the California State Water Resources Board, who further delegate the water quality responsibilities to nine Regional Water Quality Control Boards. Federal laws such as the Federal Clean Water Act, Safe Drinking Act, and Coastal Zone Act are tailored for implementation in California by the Porter-Cologne Act. Water rights are involved when considering pond or spring development and diversions for water supplies. Water rights applications and information for land parcels are obtained at the county recorder's office. Stream water diversions require a "1603 permit" from the California Department of Fish and Game. Water quality considerations for hardwood rangelands most often involve nonpoint source pollution factors, including sedimentation, nutrients, and/or pathogens. Riparian vegetation management is frequently considered along with these other nonpoint source pollution factors.

Wetlands: Wetlands jurisdiction is confusing and landowners and managers should check to see what issues are of local concern and which agency is involved. Laws and regulations are under a state of revision. For most agricultural lands, the Natural Resources Conservation Service (NRCS) has the lead role for wetlands management. In some cases, the Army Corps of Engineers, the US Fish and Wildlife Service, or the California Department of Fish and Game may be the lead agency.

22

Air Quality: Any burning activities are under the jurisdiction of local Air Quality Management Districts (AQMD). Check with your local AQMD to determine air quality restrictions that would apply to management of your hardwood rangelands.

Wildlife: The County Agricultural Commissioner handles issues related to controlled materials for predator control. The California Department of Fish and Game is responsible for issuing predation permits for some animals (deer, mountain lions, bear, etc.), and for setting regulations over hunting and fishing. Furthermore, the Department protects species listed as threatened, endangered, or protected by state law, and it has general jurisdiction and public trust responsibility for the state's fish and wildlife and their habitats.

Timber: Most tree species on hardwood rangelands are currently not considered "commercial species" and are not subject to the Forest Practice Rules administered by the State Board of Forestry. However, a number of counties and cities have ordinances that affect the harvest of oak trees on rangelands. Several other counties have voluntary oak tree harvesting guidelines and suggested best management practices. Check with local experts to see what local rules and guidelines apply to your area.

Endangered Species: Both federal and state laws list plants and animals that are threatened or endangered. The US Fish and Wildlife Service has jurisdiction over the federally listed species, while the California Department of Fish and Game has jurisdiction of those listed by the state (see Appendix A and B). Specific circumstances may prohibit certain management practices or changes in land use if they affect a listed plant or animal. Check locally with California Department of Fish and Game, U.S. Fish and Wildlife Service, or UC Farm Advisors for the situation in your area. This is discussed in more detail in chapter 4.

Archaeological Sites: There is increasing public concern about preserving historically and culturally significant



sites. The presence of such sites may impact proposed changes in land use or management. County planning, Community Colleges, State Colleges, and local museums are good sources of information on archaeological sites in your area.

Land Use: A number of land use related issues may influence certain management decisions. The California Land Conservation Act (Williamson Act) contracts with certain counties to provide tax relief for agreeing to not develop land for 10 years. County General Plans often have restrictions on parcel size, land use, and zoning. Easements for utilities, conservation, open space, and wildlife habitat are becoming more common. Other laws and ordinances to be aware of are those relating to the right to farm and fence, trespass laws, as well as private property rights laws.

Livestock: There are a number of laws relating to livestock including: animal identification (branding) law; laws relating to diseases such as TB and brucellosis; and laws concerned with the disposal of dead animals. Your local agricultural commissioner can provide information on each of these.

Professional Certification: The State Board of Forestry has the licensing authority over natural resource professionals to protect the natural resources of the state and to protect the public interest by ensuring competent professional work. Designations for Certified Rangeland Managers (CRM) and Registered Professional Foresters are maintained by the State Board of Forestry. Details on qualifications, duties, and a list of certified professionals are available.

Values for Hardwood Rangeland Stands

Worksheet 3-2 helps you to collect basic information on hardwood rangeland cover type, canopy cover, slope class, and associated habitat elements, and will allow you to look up some general ecological and managerial recommendations. Table 3-2 shows how the information on tree cover type and canopy density can be used to refer you to a specific description. For example, if your stand is a blue oak woodland with a 50 percent canopy cover, you would go to the description for site C, found on page 11 of this chapter.

Each of the 12 broad site descriptions gives general recommendations and assessments on four categories: oak cover/forestry; recreation; wildlife diversity; and grazing. These are based on some very broad statewide conclusions from practical experiences and research studies. These descriptions, assessments, and recommendations are intended to guide you through some general ideas on the potential uses for hardwood rangeland stands on your property. As you evaluate these recommendations, the rainfall zone, slope class, and presence of wildlife habitat elements such as snags, riparian zones, or downed woody debris, which you are assessing in worksheet 3-2, will allow you to refine these recommendations. These general recommendations must be followed up with site specific information for your local area. Chapters 4 through 9 will help you develop this site specific information for your property.

Table 3-2. Classification for hardwood rangeland sites based on tree cover type and canopy cover.

| Tree Cover Type | Tree Canopy Cover | | | |
|--|-------------------|----------|----------|-----------|
| | 10 - 24% | 25 - 39% | 40 - 59% | 60 - 100% |
| Blue oak woodland, blue oak-foothill pine woodland | A | B | C | D |
| Valley oak woodland | E | F | G | H |
| Coastal oak woodland, montane hardwood | I | J | K | L |



Worksheet 3-2. Hardwood Rangeland Stand Assessment

Property name

Location of Stand (describe general location on property, use maps where possible)

| | | | | | |
|---|---|--|---|--|-------------------------------|
| Acres in Stand | Elevation | | | Soil Series | |
| Aspect | <input type="checkbox"/> North | <input checked="" type="checkbox"/> South | <input type="checkbox"/> East | <input type="checkbox"/> West | |
| Av. Annual Rainfall | <input type="checkbox"/> <15" | <input type="checkbox"/> 15 - 25" | <input type="checkbox"/> 25 - 35" | <input type="checkbox"/> >35" | |
| Slope Class | <input type="checkbox"/> Gentle (<30%) | | <input type="checkbox"/> Steep (>30%) | | |
| Erosion | <input type="checkbox"/> None | <input type="checkbox"/> Sheet/rill | <input type="checkbox"/> Gullies | | |
| Ground cover | <input type="checkbox"/> <25% | | <input type="checkbox"/> 25 - 50% | <input type="checkbox"/> 51 - 75% | <input type="checkbox"/> >75% |
| Tree Cover Type | <input checked="" type="checkbox"/> Blue oak woodland, Blue oak-foothill pine woodland <input type="checkbox"/> Valley oak woodland <input type="checkbox"/> Coastal oak woodland, montane hardwood | | | | |
| Tree Canopy Cover | <input type="checkbox"/> Minimal (<10%) | <input type="checkbox"/> Sparse (10 - 24%) | <input type="checkbox"/> Open (25 - 39%) | | |
| | <input type="checkbox"/> Moderate (40 - 59%) | <input type="checkbox"/> Dense (60 - 100%) | | | |
| Average Tree Size | <input type="checkbox"/> Seedling (<1 in. DBH) | | <input type="checkbox"/> Sapling (1 - 6 in. DBH) | | |
| | <input type="checkbox"/> Pole (6 - 11 in. DBH) | | <input type="checkbox"/> Small tree (11 - 24 in. DBH) | | |
| | <input type="checkbox"/> Med./Large tree (>24 in. DBH) | | <input type="checkbox"/> Multi-layered | | |
| Tree Mortality | <input type="checkbox"/> None | | <input type="checkbox"/> Light (<5 % trees) | <input type="checkbox"/> Heavy (>5% trees) | |
| Regeneration status (check all that apply) | <input type="checkbox"/> none evident | | <input type="checkbox"/> Small seedlings (<1' tall) | <input type="checkbox"/> Large seedlings (1 - 3' tall) | |
| | <input type="checkbox"/> Saplings (3 - 10' tall) | | | | |
| Shrub canopy cover | <input type="checkbox"/> Minimal (<10%) | <input type="checkbox"/> Sparse (10 - 24%) | <input type="checkbox"/> Open (25 - 39%) | | |
| | <input type="checkbox"/> Moderate (40 - 59%) | | <input type="checkbox"/> Dense (60 - 100%) | | |
| Shrub age class (yrs. since fuel reduction) | <input type="checkbox"/> <5 years | | <input type="checkbox"/> 5 - 15 years | <input type="checkbox"/> 15 - 25 years | |
| | <input type="checkbox"/> >25 years | | | | |
| Habitat elements (check all that apply) | <input type="checkbox"/> Brush piles | | <input type="checkbox"/> Snags | <input type="checkbox"/> Dead and down logs | |
| | <input type="checkbox"/> Riparian zones | | | | |
| Water sources | <input type="checkbox"/> None | | <input type="checkbox"/> Perennial streams | <input type="checkbox"/> Intermittent streams | |
| | <input type="checkbox"/> Springs | | <input type="checkbox"/> Water developments | <input type="checkbox"/> Other _____ | |

Threatened and endangered plants and animals present:



Site A: Blue oak woodland, blue oak foothill pine woodland; 10 – 24 percent canopy cover

Oak Cover/Forestry Assessment:

Oak volume ranges from 20 to 170 cubic feet per acre, and 10-year growth rate ranges from 2 to 40 cubic feet per acre. These are not good areas for commercial harvesting activities due to very low stocking and low growth rates. Many open blue oak savannahs lack oak regeneration, especially on low elevation and/or low rainfall zones. Managers should compare current levels of mortality to regeneration. In areas where mortality exceeds regeneration, it may be necessary to adopt management procedures to encourage regeneration.

Recreation Assessment:

These areas offer only limited opportunities for hunt clubs in their current condition because of low cover and acorn production. Medium populations of quail can be expected, which can be improved by providing additional water and cover with brush piles. It may be desirable to increase cover if feasible to improve habitat for deer and turkeys.

Wildlife Diversity Assessment:

These open blue oak savannah stands contain both grassland and woodland wildlife species. In general, the habitat is good for open grassland species such as western meadowlark, but marginal for woodland species such as Pacific-slope flycatchers. Habitat elements, such as riparian zones, snags, trees with cavities, and large woody debris, have an important effect on biodiversity by making habitats more complex. More complex habitats support greater numbers of wildlife. According to the California Wildlife Habitat Relationships system (CWHHR) there are 21 amphibian species, 33 reptile species, 73 mammal species, and 137 bird species which are predicted to occur in these habitats if various elements occur. If there are no riparian zones or sources of water, no snags or cavity trees, and no large woody debris or brush piles on the site, the number of vertebrate wildlife species predicted to occur in these habitats falls to 10 amphibian species, 31 reptiles, 39 mammals, and 101 bird species. This points to the importance of maintaining diversity in the habitat elements present in the stand to provide for the highest possible diversity of wildlife species.

25

Grazing Assessment:

Average forage production capability is 3,000 pounds per acre with a range from 1,500 to 4,500 pounds. In low rainfall areas, the presence of scattered trees has been found to increase overall range forage production. However, thistles and other undesirable plants may occur under the tree canopy, although this is not common. Potential for range improvement through seeding, fertilization, and grazing management may increase productivity where production is currently at the lower end of the scale and available soil and soil moisture is not limiting.

Site B: Blue oak woodland, blue oak foothill pine woodland; 25 – 39 percent canopy cover

Oak Cover/Forestry Assessment:

Oak volume ranges from 170 to 425 cubic feet per acre and the 10-year growth is 25 to 70 cubic feet per acre. These areas are generally not good for commercial firewood harvesting. The existing stocking level is good for diverse resource values, and managers should not take canopy density much lower. Some light thinning may be possible in dense clusters, but avoid using equipment on areas with over 30 percent slope to minimize erosion. Perhaps 40 to 85 cubic feet could be harvested per acre in higher productivity sites every 20 years. Many areas like these have an absence of oak regeneration, especially on low elevation and/or rainfall areas. Managers should assess current levels of mortality and compare this to seedling and sapling regeneration. In areas where mortality exceeds regeneration, it may be necessary to adopt management procedures to encourage regeneration.

Recreation Assessment:

These areas have good overall habitat for mule and black-tailed deer, wild pigs and California quail. Habitat can be improved by enhancing acorn production, planting legumes, and maintaining these through proper livestock and deer management. Any reductions in oak cover will also decrease habitat value for many desired game spe-



cies. Areas with slopes greater than 30 percent will have lower values for hunt clubs because of the difficult access.

Wildlife Diversity Assessment:

These blue oak woodland stands support both grassland and woodland wildlife species. In general, the habitat is fairly good for a large number of wildlife species. The occurrence of more complex habitats, through the presence of habitat elements such riparian zones, snags, trees with cavities, and large woody debris, has an important effect on biodiversity. There are 21 amphibian species, 31 reptile species, 64 mammal species, and 128 bird species which are predicted to occur by CWHR on the most diverse habitats in these stands. If there are no riparian zones or sources of water, no snags or cavity trees, and no large woody debris or brush piles on the site, the number of vertebrate wildlife species predicted to occur on these habitats falls to 10 amphibian species, 29 reptiles, 30 mammals, and 95 bird species. This points to the importance of maintaining diversity in the habitat elements present in the stand to provide for the highest possible diversity of wildlife species.

Grazing Assessment:

Average forage production capability is 3,000 pounds per acre with a range from 1,500 to 4,500 pounds. In low rainfall areas, the presence of scattered trees has been found to increase overall range forage production. However, thistles and other undesirable plants may occur under the tree canopy, although this is not typical. Potential for range improvement through seeding, fertilization, and grazing management may increase productivity where production is currently at the lower end of the scale and available soil and soil moisture is not limiting.

Site C: Blue oak woodland, blue oak foothill pine woodland; 40 – 59 percent canopy cover

Oak Cover/Forestry Assessment:

Oak volumes range from 425 to 1200 cubic feet per acre. Ten year growth ranges from 50 to 130 cubic feet per acre. Firewood harvest potential exists, but avoid using equipment on slopes over 30 percent to minimize erosion. Harvest levels should approximately equal growth to maintain existing oak cover for diverse resource values. Approximately 85 to 250 cubic feet per acre can be harvested every 20 years from these stands. Ensure adequate oak regeneration after harvest.

Recreation Assessment:

These areas are excellent for medium to large populations of mule and black-tailed deer, squirrel, wild pigs, wild turkeys, mourning dove, and band-tailed pigeons. On areas with less than 30 percent slope, the terrain is excellent for hunter access. Careful tree thinning can complement game habitat. Where controlled fire can be used, it can help stimulate palatable shrub browse. Seeding clover and other legumes and maintaining it through grazing will benefit deer, turkey and quail.

Wildlife Diversity Assessment:

These blue oak woodland stands support a large number of wildlife species. The higher tree density makes these areas less desirable for open grassland species such as western meadowlarks and western kingbirds, but very desirable for woodland species such as Pacific-slope flycatchers and wild pigs. The occurrence of more complex habitats, through the presence of habitat elements such riparian zones, snags, trees with cavities, and large woody debris, has an important effect on biodiversity. 19 amphibian species, 28 reptile species, 64 mammal species, and 128 bird species are predicted to occur by CWHR on the most diverse habitats in these stands. If there are no riparian zones or water sources, no snags or cavity trees, and no large woody debris or brush piles on the site, the number of vertebrate wildlife species predicted to occur on these habitats falls to 10 amphibian species, 26 reptiles, 30 mammals, and 95 bird species. This points to the importance of maintaining diversity in the habitat elements present in the stand to provide for the highest possible diversity of wildlife species.

Grazing Assessment:

Average forage production capability is 2,000 pounds per acre with a range from 1,000 to 2,800 pounds. In areas with less than 20 inches of annual rainfall and during drought years on higher average rainfall areas, range productivity and forage nutritional value is often enhanced by the presence of this level of oak cover. In higher rain-



fall areas, the shading effect of the canopy suppresses total production. Thistles and other undesirable plants may occur under the tree canopy, although this is not typical. Potential for range improvement on slopes less than 30 percent through seeding, fertilization, and grazing management may increase productivity by two- to three-fold where production is currently at the low end of the scale. Tree thinning will increase forage production under the removed canopy in the higher rainfall zones of the state (over 20 inches per year).

Site D: Blue oak woodland, blue oak-foothill pine woodland; 60 – 100 percent canopy cover

Oak Cover/Forestry Assessment:

Oak volume ranges from 1200 to 3800 cubic feet per acre. Estimated growth ranges from 170 to 510 cubic feet per acre over 10 year. Firewood harvest can be carried out to permanently reduce cover and improve habitat for selected wildlife species and range productivity. Areas with less than 30 percent slope are a good place to prioritize for harvesting on the ranch. 500 to 2500 cubic feet per acre can be harvested from these stands to permanently reduce stands to 40 to 60 percent canopy cover after 20 years. If stand openings are absent, you may wish to make some small openings through the firewood operation to encourage blue oak regeneration.

Recreation Assessment:

These areas provide excellent habitat for mule and black-tailed deer, squirrel, wild pig, wild turkey, mourning dove, and band-tailed pigeons. On areas with over 30 percent slope, hunter access is too difficult for commercial operations. Thinning stands back to 50 percent cover in a patchy pattern can enhance deer habitat. Turkeys do best with a dense canopy, and California quail do best with less tree canopy, but both species prefer dense shrub layers and ample water sources.

Wildlife Diversity Assessment:

These dense blue oak woodland stands support a large number of wildlife species, although the higher tree density makes these areas undesirable for open grassland species. A few species such as Cooper's hawks and orange-crowned warblers, actually prefer the dense conditions found in these stands. The occurrence of more complex habitats, through the presence of habitat elements such riparian zones, snags, trees with cavities, and large woody debris, has an important effect on biodiversity. There are 19 amphibian species, 25 reptile species, 62 mammal species, and 102 bird species which are predicted to occur by CWHR on the most diverse habitats in these stands. If there are no riparian zones or sources of water, no snags or cavity trees, and no large woody debris or brush piles on the site, the number of vertebrate wildlife species predicted to occur on these habitats falls to 10 amphibian species, 23 reptiles, 28 mammals, and 77 bird species. This points to the importance of maintaining diversity in the habitat elements present in the stand to provide for the highest possible diversity of wildlife species. Some thinning may help enhance overall biological diversity.

Grazing Assessment:

Average forage production capability is 900 pounds per acre with a range from 500 to 1,500 pounds. The dense tree cover suppresses forage production, leaving less available for livestock operations. Thinning stands on slopes less than 30 percent will increase forage production under the removed canopy for about 15 years by 50 to 100 percent especially on poor sites. After tree thinning, seeding, fertilization, and grazing management may increase forage production. Little improvement potential exists on steeper slopes.

Site E: Valley oak woodland; 10 – 24 percent canopy cover

Oak Cover/Forestry Assessment:

Oak volume ranges from 40 to 340 cubic feet per acre. Growth ranges from 17 to 80 cubic over 10 years. The canopy in these open valley oak savannahs needs to be maintained. These areas are poor candidates for any harvest activity. Managers should encourage the recruitment of young seedlings to sapling size through management activities.

Recreation Assessment:

These areas offer only limited opportunities for hunt clubs in their current condition because of low shrub cover



and acorn production. Medium populations of quail can be expected, which can be improved by providing additional water and cover with brush piles. It may be desirable to increase cover, if feasible, to improve habitat for deer and turkeys.

Wildlife Diversity Assessment:

These open valley oak savannah stands contain both grassland and woodland wildlife species. In general, the habitat is good for open grassland and open woodland species such as western meadowlark, and marginal for woodland species such as Pacific-slope flycatcher. The presence of more complex habitats, through the presence of habitat elements such riparian zones, snags, trees with cavities, and large woody debris, has an important effect on biodiversity. There are 19 amphibian species, 32 reptile species, 72 mammal species, and 132 bird species which are predicted to occur by CWHR on the most diverse habitats in these stands. If there are no riparian zones or sources of water, no snags or cavity trees, and no large woody debris or brush piles on the site, the number of vertebrate wildlife species predicted to occur on these habitats falls to 8 amphibian species, 30 reptiles, 38 mammals, and 99 bird species. This points to the importance of maintaining diversity in the habitat elements present in the stand to provide for the highest possible diversity of wildlife species.

Grazing Assessment:

Average forage production capability is 3,500 pounds per acre with a range from 2,000 to 5,000 pounds. In low rainfall areas, the presence of scattered trees has been found to increase overall range forage production. Thistles and other undesirable plants may occur under the tree canopy, although this is not typical. Potential for range improvement through seeding, fertilization, and grazing management may increase productivity where production is currently at the lower end of the scale and available soil and soil moisture is not limiting.

Site F: Valley oak woodland; 25 – 39 percent canopy cover

Oak Cover/Forestry Assessment:

Oak volume ranges from 340 to 1100 cubic feet per acre. Ten year growth ranges from 60 to 150 cubic feet per acre. Although these are not good areas for commercial harvesting, there is some potential for light thinning due to the relatively high productivity of valley oak stands. It may be desirable to utilize trees being lost to mortality if not needed to provide snags in the stand. Perhaps 40 to 170 cubic feet per acre could be harvested every 20 years on slopes less than 30 percent. The existing stocking level is good for diverse resource values, and managers should not take canopy density much lower. Attempts should be made to encourage recruitment of oak seedlings to sapling size through management practices. Rapid growth of seedlings is possible.

Recreation Assessment:

These areas have good overall habitat for mule and black-tailed deer, wild pigs and California quail. Habitat can be improved by enhancing acorn production, planting clover and other legumes, and maintaining these through proper livestock and deer management, and enhancing shrub cover. Any reductions in oak cover will also decrease habitat value for most commercial game species. Areas with slopes greater than 30 percent will have lower values for hunt clubs because of the difficult access.

Wildlife Diversity Assessment:

These valley oak woodland stands have both grassland and woodland wildlife species. In general, the habitat is fairly good for a large number of wildlife species. The occurrence of more complex habitats, through the presence of habitat elements such riparian zones, snags, trees with cavities, and large woody debris, has an important effect on biodiversity. There are 19 amphibian species, 30 reptile species, 71 mammal species, and 128 bird species which are predicted to occur by CWHR on the most diverse habitats in these stands. If there are no riparian zones or sources of water, no snags or cavity trees, and no large woody debris or brush piles on the site, the number of vertebrate wildlife species predicted to occur on these habitats falls to 8 amphibian species, 28 reptiles, 37 mammals, and 96 bird species. This points to the importance of maintaining diversity in the habitat elements present in the stand to provide for the highest possible diversity of wildlife species.



Grazing Assessment:

Average forage production capability is 3,000 pounds per acre with a range from 1,500 to 4,500 pounds. In low rainfall areas, the presence of scattered trees has been found to increase overall range forage production. However, thistles and other undesirable plants may occur under the tree canopy, although this is not typical. Potential for range improvement through seeding, fertilization, and grazing management may increase productivity where production is currently at the lower end of the scale and available soil and soil moisture is not limiting.

Site G: Valley oak woodland; 40 – 59 percent canopy cover

Oak Cover/Forestry Assessment:

Oak volume ranges from 1100 to 2900 cubic feet per acre. Ten year growth ranges from 120 to 420 cubic feet per acre. Some thinning on a sustainable basis is possible, especially in stands with large numbers of small trees to improve individual tree growth rate. There is some possibility to utilize harvested trees for solid wood products, such as white oak lumber or barrel staves. 170 to 680 cubic feet per acre could be harvested every 20 years on stands with less than 30 percent slope. It is important to ensure that adequate oak regeneration results after the harvest.

Recreation Assessment:

These areas are excellent for medium to large populations of mule and black-tailed deer, squirrel, wild pigs, wild turkeys, mourning dove, and band-tailed pigeons. On areas with less than 30 percent slope, the terrain is excellent for hunter access. Some careful tree thinning can complement game habitat. Where controlled fire can be used, it can help stimulate palatable shrub browse. Seeding clover and other legumes and maintaining these through grazing, as well as increasing shrub cover, will benefit deer, turkey and quail.

Wildlife Diversity Assessment:

These valley oak woodland stands support a large number of wildlife species. The tree density makes these areas less desirable for open grassland species such as western meadowlarks and western kingbirds, but very desirable for woodland species such as Pacific-slope flycatchers and orange-crowned warblers. The occurrence of more complex habitats, through the presence of habitat elements such riparian zones, snags, trees with cavities, and large woody debris, has an important effect on biodiversity. There are 17 amphibian species, 27 reptile species, 63 mammal species, and 123 bird species which are predicted to occur by CWHR on the most diverse habitats in these stands. If there are no riparian zones or sources of water, no snags or cavity trees, and no large woody debris or brush piles on the site, the number of vertebrate wildlife species predicted to occur on these habitats falls to 8 amphibian species, 25 reptiles, 29 mammals, and 93 bird species. This points to the importance of maintaining diversity in the habitat elements present in the stand to provide for the highest possible diversity of wildlife species.

Grazing Assessment:

Average forage production capability is 2,000 pounds per acre with a range from 1,000 to 2,800 pounds. On such sites, the shading effect of the canopy usually suppresses total production. Thistles and other undesirable plants may occur under the tree canopy, although this is not typical. Potential for range improvement on slopes less than 30 percent through seeding, fertilization, and grazing management may increase productivity by two- to three-fold where production is currently at the low end of the scale. Tree thinning will increase forage production under the removed canopy in the higher rainfall zones of the state (over 20 inches per year).

Site H: Valley oak woodland; 60 – 100 percent canopy cover

Oak Cover/Forestry Assessment:

Oak volume ranges from 2900 to 5100 cubic feet per acre. Estimated ten year growth rate ranges from 220 to 420 cubic feet per acre. Harvest could be carried out to increase individual tree diameter and crown growth rate on areas with less than 30 percent slope and high stem density and small diameter trees. This may help improve acorn production and create conditions favorable for seedling establishment. Seedlings are likely to be absent or very slow growing due to little sunlight reaching the ground. Harvest levels of 420 to 1700 cubic feet per acre can be



carried out every 20 years. There is some possibility to utilize harvested trees for solid wood products, such as white oak lumber or barrel staves. It is important to ensure that adequate oak regeneration results after the harvest.

Recreation Assessment:

These areas offer good opportunities for habitat for mule and black-tailed deer, western gray squirrel, wild pig, wild turkey, mourning dove, and band-tailed pigeons. On areas with over 30 percent slope, hunter access is too difficult for commercial operations. Thinning stands to 50 percent cover in a patchy pattern may enhance deer habitat if shrub cover is increased. Turkeys do best with a dense canopy, and California quail do best with somewhat less canopy.

Wildlife Diversity Assessment:

These dense valley oak woodland stands support a large number of wildlife species. The tree density makes these areas undesirable for open grassland species. A few species such as orange-crowned warblers and house wrens, actually prefer the dense conditions found in these stands. The occurrence of more complex habitats, through the presence of habitat elements such riparian zones, snags, trees with cavities, and large woody debris, has an important effect on biodiversity. There are 17 amphibian species, 24 reptile species, 61 mammal species, and 96 bird species which are predicted to occur by CWHR on the most diverse habitats in these stands. If there are no riparian zones or sources of water, no snags or cavity trees, and no large woody debris or brush piles on the site, the number of vertebrate wildlife species predicted to occur on these habitats falls to 8 amphibian species, 22 reptiles, 27 mammals, and 74 bird species. This points to the importance of maintaining diversity in the habitat elements present in the stand to provide for the highest possible diversity of wildlife species. Thinning may enhance biological diversity.

Grazing Assessment:

Average forage production capability is 1,200 pounds per acre with a range from 800 to 1,500 pounds. The dense tree cover suppresses forage production, leaving less available for livestock operations. Thinning stands on slopes less than 30 percent will increase forage production under the removed canopy for about 15 years by 50 to 100 percent at lower levels of current production. After tree thinning, improvement potential through seeding, fertilization, and grazing management may increase forage production. Little improvement potential exists on steeper slopes.

30

Site I: Coastal oak woodland, montane hardwood; 10 – 24 percent canopy cover

Oak Cover/Forestry Assessment:

Oak volume ranges from 35 to 250 cubic feet per acre and growth ranges from 17 to 50 cubic feet every 10 years. These areas are not good locations for firewood harvests due to very open stocking. Regeneration concerns are not as pronounced in live oak stands due to rapid resprouting in most areas of the state.

Recreation Assessment:

These areas may offer only limited opportunities for hunt clubs in their current condition because of low tree cover. Medium populations of quail can be expected, which can be improved by providing additional water and cover with brush piles. It may be desirable to increase cover if feasible to improve habitat for mule and black-tailed deer and turkeys. The presence of sprouting live oaks allows greater latitude in quail management than deciduous oaks with similar cover.

Wildlife Diversity Assessment:

These open live oak savannah stands contain both grassland and woodland wildlife species. In general, the habitat is good for open grassland species such as western meadowlark and western kingbirds, and marginal for woodland species such as Pacific-slope flycatcher and western gray squirrels. The presence of more complex habitats, through the presence of habitat elements such riparian zones, snags, trees with cavities, and large woody debris, has an important effect on biodiversity. There are 18 amphibian species, 35 reptile species, 74 mammal species, and 135 bird species which are predicted to occur by CWHR on the most diverse habitats in these stands. If there are no riparian zones or sources of water, no snags or cavity trees, and no large woody debris or brush



piles on the site, the number of vertebrate wildlife species predicted to occur on these habitats falls to 7 amphibian species, 33 reptiles, 38 mammals, and 101 bird species. This points to the importance of maintaining diversity in the habitat elements present in the stand to provide for the highest possible diversity of wildlife species.

Grazing Assessment:

Average forage production capability is 2,700 pounds per acre with a range from 1,800 to 4,000 pounds. Oak canopy in these lightly stocked areas may enhance forage production in low rainfall areas or during drought years. These low canopy levels have only minimal impact on forage production in higher rainfall zones, although thistles and other undesirable plants may occasionally occur under the tree canopy. Potential for range improvement through seeding, fertilization, and grazing management may increase productivity where production is currently at the lower end of the scale and available soil and soil moisture is not limiting.

Site J: Coastal oak woodland, montane hardwood; 25 – 39 percent canopy cover

Oak Cover/Forestry Assessment:

Oak volume ranges from 250 to 850 cubic feet per acre, with a ten year growth of 50 to 100 cubic feet per acre. Rapid regrowth of stump sprouts and fairly high growth potential of live oaks would allow some commercial harvest to take place. Harvest levels of 85 to 250 cubic feet per acre every 20 years are possible on areas with less than 30 percent slope. It is important to ensure that regeneration from seedlings or stump sprouts is adequate to replace trees being harvested.

Recreation Assessment:

These areas provide good overall habitat for deer, wild pigs and California quail. Habitat can be improved by enhancing acorn production, planting clover and other legumes and maintaining these through proper livestock and deer management, and enhancing shrub cover. Some selective thinning of dense stands may improve habitat for some game species, although leaving some denser areas will maintain habitat values for species using denser cover. If brush is present, brush piles can considerably improve quail habitat. Areas with slopes greater than 30 percent will have lower values for hunt clubs because of the difficult access.

Wildlife Diversity Assessment:

These live oak woodland stands support both grassland and woodland wildlife species. In general, the habitat is fairly good for a large number of wildlife species. The occurrence of more complex habitats, through the presence of habitat elements such riparian zones, snags, trees with cavities, and large woody debris, has an important effect on biodiversity. There are 18 amphibian species, 34 reptile species, 74 mammal species, and 131 bird species which are predicted to occur by CWHHR on the most diverse habitats in these stands. If there are no riparian zones or sources of water, no snags or cavity trees, and no large woody debris or brush piles on the site, the number of vertebrate wildlife species predicted to occur in these habitats falls to 7 amphibian species, 32 reptiles, 38 mammals, and 98 bird species. This points to the importance of maintaining diversity in the habitat elements present in the stand to provide for the highest possible diversity of wildlife species.

Grazing Assessment:

Average forage production capability is 2,500 pounds per acre with a range from 1,500 to 3,500 pounds. Tree cover will cause some suppression of winter and spring production except in areas of low rainfall. Thistles and other undesirable plants may sometimes occur under the tree canopy. Potential for range improvement on slopes less than 30 percent through seeding, fertilization, and grazing management may increase productivity by two- to three- fold where production is currently at the low end of the scale. Tree thinning may increase forage production under the removed canopy in the higher rainfall zones of the state (over 20 inches per year).

Site K: Coastal oak woodland, montane hardwood; 40 – 59 percent canopy cover

Oak Cover/Forestry Assessment:

Oak volume ranges from 850 to 2200 cubic feet per acre. Growth rates of 100 to 190 cubic feet per acre are expected every 10 years. These stands are excellent candidates for sustainable wood harvest operation if slopes are



less than 30 percent. There is some potential for utilization of trees for sawtimber in larger straight-stemmed trees. Harvest levels of 170 to 510 cubic feet per acre every 20 years are possible. It is important to ensure that regeneration from seedlings or stump sprouts are adequate to replace trees being harvested.

Recreation Assessment:

These areas are excellent for quail and moderately good for deer, wild pigs, wild turkeys, and band-tailed pigeons. On areas with less than 30 percent slope, the terrain is excellent for hunter access. Some careful tree thinning can complement game habitat, although some dense areas should be left for cover and breeding purposes. If brush is absent, brushpiles can improve quail habitat considerably. If possible, prescribed burning can stimulate shrub layer browse. Seeding clover and other legumes and maintaining it through grazing, and enhancing shrub cover will benefit deer, turkey and quail.

Wildlife Diversity Assessment:

These live oak woodland stands support a large number of wildlife species. The tree density makes these areas less desirable for open grassland species such as western meadowlarks and western kingbirds, but very desirable for woodland species such as Pacific-slope flycatchers and orange-crowned warblers. The occurrence of more complex habitats, through the presence of habitat elements such riparian zones, snags, trees with cavities, and large woody debris, has an important effect on biodiversity. There are 16 amphibian species, 30 reptile species, 66 mammal species, and 126 bird species which are predicted to occur by CWHR on the most diverse habitats in these stands. If there are no riparian zones or sources of water, no snags or cavity trees, and no large woody debris or brush piles on the site, the number of vertebrate wildlife species predicted to occur in these habitats falls to 7 amphibian species, 28 reptiles, 30 mammals, and 95 bird species. This points to the importance of maintaining diversity in the habitat elements present in the stand to provide for the highest possible diversity of wildlife species.

Grazing Assessment:

32 Average forage production is 2,000 pounds per acre, ranging from 1,000 pounds to 2,800 pounds. Forage production is usually suppressed by tree canopy except in low rainfall zones. Thinning may increase forage under some removed canopies by 100 to 200 percent. Brush understory may occur in some locations and is suitable for management burns. Potential for range improvement through seeding, fertilization, and grazing management may increase productivity where production is currently at the lower end of the scale and available soil and soil moisture is not limiting.

Site L: Coastal oak woodland, montane hardwood; 60 – 100 percent canopy cover

Oak Cover/Forestry Assessment:

Oak volume ranges from 2200 to 5100 cubic feet per acre. Growth ranges from 190 to 310 cubic feet every 10 years. These very dense stands could benefit from thinning to improve overall biological diversity, acorn production, and forage yields. Restrict harvest to areas with less than 30 percent slope. Harvest levels of 510 to 1700 cubic feet per acre can be carried out every 20 years. There is some potential to utilize larger diameter logs for sawtimber, especially if boles have few branches. It is important to ensure that regeneration from seedlings or stump sprouts are adequate to replace trees being harvested.

Recreation Assessment:

These areas offer good opportunities for habitat for deer, western gray squirrel, wild pig, wild turkey, mourning dove, and band-tailed pigeons. On areas with over 30 percent slope, hunter access is too difficult for commercial operations. Thinning stands back to 50 percent cover in a patchy pattern may enhance deer habitat if shrub and herbaceous cover are improved. Turkeys do best with a dense canopy, and California quail do best with somewhat less canopy, but both prefer moderately dense shrub layers.

Wildlife Diversity Assessment:

These dense live oak woodland stands support a large number of wildlife species. The tree density makes these areas undesirable for open grassland species. A few species such as orange-crowned warblers, actually prefer the dense conditions found in these stands. The occurrence of more complex habitats, through the presence of habitat



elements such as riparian zones, snags, trees with cavities, and large woody debris, has an important effect on biodiversity. There are 16 amphibian species, 26 reptile species, 64 mammal species, and 99 bird species which are predicted to occur by CWHR on the most diverse habitats in these stands. If there are no riparian zones or sources of water, no snags or cavity trees, and no large woody debris or brush piles on the site, the number of vertebrate wildlife species predicted to occur in these habitats falls to 7 amphibian species, 24 reptiles, 28 mammals, and 76 bird species. This points to the importance of maintaining diversity in the habitat elements present in the stand to provide for the highest possible diversity of wildlife species. Some thinning may help enhance overall biological diversity.

Grazing Assessment:

Average forage production capability is 900 pounds per acre with a range from 500 to 1,500 pounds. The dense tree cover suppresses forage production, leaving less available for livestock operations. Thinning stands on slopes less than 30 percent will increase forage production under the removed canopy for about 15 years by 50 to 100 percent at lower levels of current production. After tree thinning, improvement potential through seeding, fertilization, and grazing management may also increase forage production. Little improvement potential exists on steeper slopes.



Chapter Four

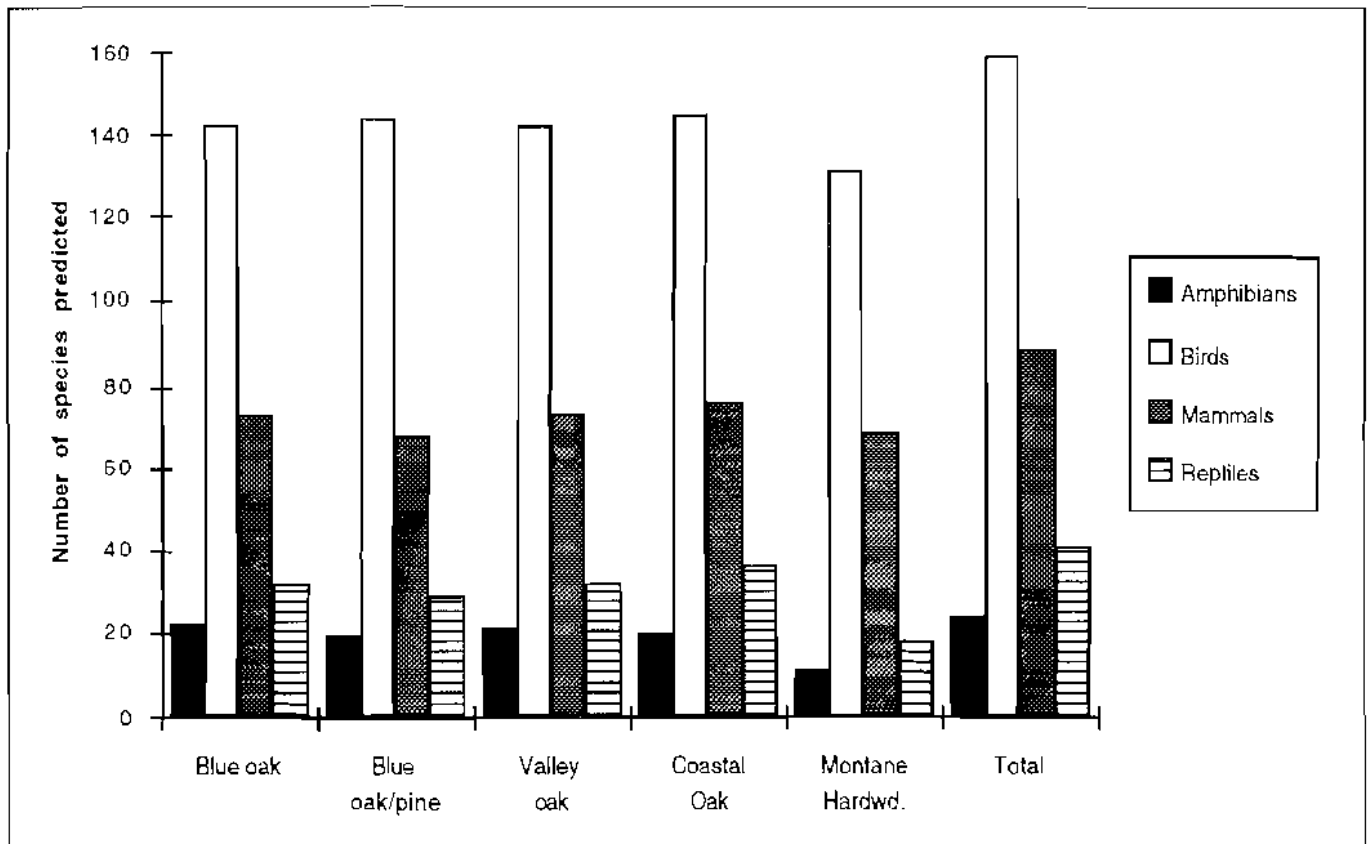
Oak Woodland Wildlife Ecology, Native Plants, and Habitat Relationships

Primary authors: Greg Giusti, Univ. of California, Mendocino Co.; Tom Scott, Univ. of California, Berkeley; Barry Garrison, Calif. Dept. of Fish and Game; and Kevin Shaffer, Calif. Dept. of Fish and Game

The five habitat types occurring in California's hardwood rangelands (also known as oak woodlands) provide habitat for at least 313 species of birds, mammals, reptiles, and amphibians; more than 2000 plant species; and an estimated 5000 species of insects. Figure 4-1 graphically shows the diversity of vertebrate wildlife species predicted for each of the five major habitat types described in chapter 2. A complete list of all 313 species and their habitat associations is given in Appendix A. The management and long-term sustainability of California's hardwood rangeland habitats will best be served if ecological components and their inter-relationships are recognized and addressed by owners and managers. This chapter provides information on oak woodland ecology

Figure 4-1. Numbers of amphibians, birds, mammals, and reptiles predicted to occur in the five California hardwood rangeland habitats by Version 5.0 of the California Wildlife Habitat Relationships System (CWHRS). This list only includes those species in the CWHRS System that are predicted to use one or more tree size and canopy cover classes for breeding, feeding, and/or cover.

34





and wildlife-habitat relationships to serve as a guide for land management activities. The presence and sustainability of specific plant and animal species on hardwood rangeland properties needs to be evaluated with scientific information.

Wildlife Habitat Relationships

Habitats are the specific locations where the factors needed for wildlife survival and reproduction are provided. Successful long-term perpetuation of California's hardwood rangeland wildlife is best achieved by managing habitats because they are the foundation on which wildlife depend. California's five major hardwood rangeland vegetation types (see Chapter 2) and associated riparian types provide habitat for the largest number of vertebrate wildlife species in the state, when compared to habitats dominated by conifers, shrubs, grasses and wetlands. Hardwood rangeland habitats must be able to supply food, water, protection from weather and predators, and locations to reproduce in order to support viable wildlife populations.

In eastern Tehama County, deer use of the lower elevation blue oak and blue oak-foothill pine woodlands are an example of wildlife habitat relationships. These areas are important winter habitat with food and cover for deer that have migrated from higher elevation conifer and meadow habitats around Mount Lassen where they spend the spring and summer to produce fawns. Their autumn migrations take them through montane hardwood habitats where they feed on acorns and browse to gain weight for the strenuous rutting period where bucks (male deer) compete for breeding opportunities. Breeding takes place during the fall and early winter on the lower elevation oak woodlands. Does (female deer) feed on acorns and herbaceous vegetation of oak woodland wintering habitats to provide energy for fawning. These activities are critical and their populations would be dramatically reduced if hardwood habitats failed to provide these key breeding, food, and cover resources.

Habitat Scale Concepts

One way to understand the management complexities of hardwood rangelands is to look at the relationships among its component parts. Wildlife biologists typically evaluate woodland habitats on five levels, providing a convenient system for explaining woodland ecology. Although each level has its applications, it is critical for you to select the management level that is appropriate for your goals. From smallest to largest, these levels are:

1. *Individual*: The interactions of individual plants or animals with their surroundings is the most tangible level of woodland ecology. Survival and reproduction are results that you can observe from the interactions of individual plants or animals.
2. *Population*: The interactions among individuals of the same species and the interactions with their woodland environment form the population level of organization. A population is typically described by the shared characteristics of its individuals, including where they occur, the range of things they eat, when and how they produce young, and how they disperse or migrate. We use this composite picture to define the wildlife habitat relationships between a species and the areas where it occurs. Although this composite picture is somewhat abstract, population data allows biologists to predict the consequences of management activities in woodlands.
3. *Community*: The interactions among species that occur together in a community form the next step in the hierarchy. Species interactions define this level; some species prey on others, some compete with each other for resources, some share resources or recycle nutrients for one another, and some interact in hundreds of other ways. Examples include a deer browsing on oak seedlings, bees pollinating wildflowers, or jays planting acorns. Community interactions are often difficult to detect, and may occur over long time periods.
4. *Ecosystem*: The physical processes and structure that link living things to each other and their ecosystem is the next level of organization. Ecosystems are often defined by their resident or dominant species, such as the hardwood rangeland vegetation types discussed previously. This level of management is somewhat abstract, with boundaries that often blend into adjacent ecosystems.
5. *Landscape*: The geographic patterns of all the other levels creates the landscape level of organization. Some aspects of landscapes are quite tangible, such as the boundaries of a watershed. Others are abstract, such as the patterns of gene flow across the oaks in the coast ranges.

If you protect a 400-year-old oak in your backyard, then you are operating at the individual level of conservation. However, it is often impractical for landowners to manage their woodlands tree by tree. If your goal is to



maintain a specific density or age distribution of oak trees on your property, then you're working at the population level. If you control exotic plants to reduce their effect on oak seedling survival, then you're altering community level interactions among your understory plants. Altering fire frequency to re-establish oak understory would be an ecosystem level of action. Finally, fires burn many different patterns across a landscape, from small patches to catastrophic sweeps of multiple watersheds. Using prescribed burning to create a mosaic of burned and unburned habitats would be a landscape management action.

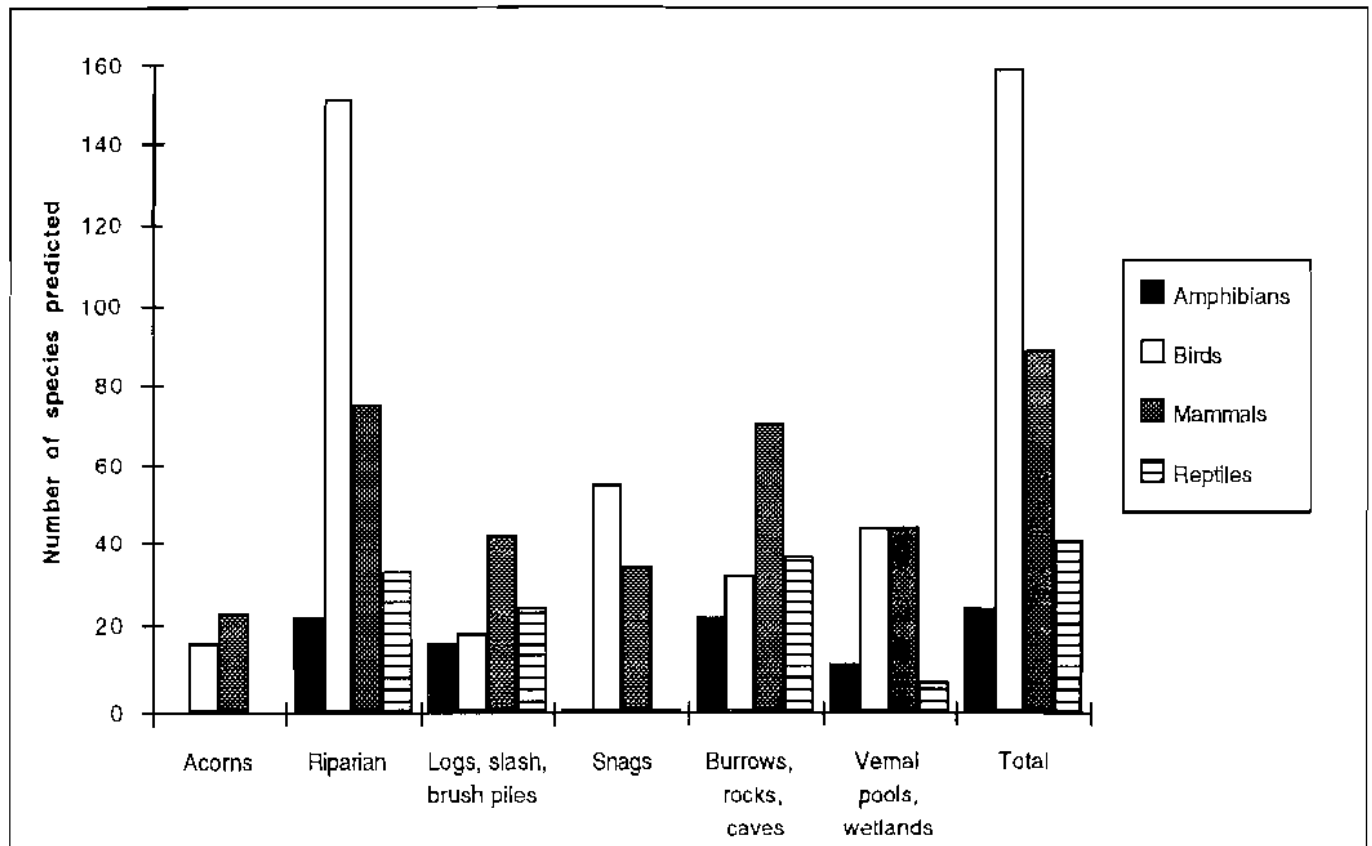
Habitat Structure

Favorable hardwood rangeland habitats supply food, water, and cover to sustain wildlife species. Each habitat element provides unique niches, favoring particular wildlife species. Conversely, the absence of a particular element in a habitat may limit species diversity.

Examples of elements of a hardwood rangeland habitat that are important to consider include riparian zones, vernal pools, wetlands, dead and downed logs and other woody debris, brush piles, snags, rock outcroppings, and cliffs. Figure 4-2 gives the relative number of wildlife species that are predicted to use various elements found on hardwood rangelands. The complete species list in Appendix A shows the specific species that are predicted to use these elements on hardwood rangeland habitats.

Riparian areas are those habitats influenced by the presence of adjacent seasonal or yearlong watercourses. They tend to have a higher biomass level of vegetation due to better water availability throughout the growing season. In general, they have higher tree crown cover, a more diverse assortment of vegetation species, and herbaceous material that stays green later into the summer. As shown, riparian habitat elements are used by almost 90 percent of all hardwood rangeland wildlife species, illustrating the importance of conserving this habitat element where present.

Figure 4-2. Number of amphibians, birds, mammals, and reptiles predicted to use several important habitat elements of California hardwood rangeland habitats by Version 5.0 of the California Wildlife Habitat Relationships System (CWHRS). This list includes those species in the CWHRS System that are predicted to use one or more of these elements for breeding, feeding, and/or cover.





Over one-third of all bird species on hardwood rangelands make use of snags, or standing dead trees in the stand. This suggests that management strategies to maintain an appropriate number of snags will result in greater wildlife species diversity.

Another important aspect of hardwood rangeland habitat structure is the spatial arrangement of the vegetative cover. The vertical and horizontal distribution of vegetation are both readily visible and easily measured.

Vertical Distribution

Vegetation often occurs in layers from grasses, to shrubs, to trees. This vertical layering affects the duration and intensity of light reaching the ground, which in turn, affects the insects, plants and subsequently those vertebrates dependent on them. Multi-layered habitats provide a diversity of elements offering more niches for wildlife. Most hardwood rangeland species, including California quail, western fence lizards, rufous-sided towhee and acorn woodpeckers, depend on multi-layered vegetation structure. Land managers should consider the consequences of activities that tend to simplify or eliminate vegetation layers.

Horizontal Distribution.

The distribution of different types of habitat or successional stages across a landscape creates diversity in all habitat elements needed for breeding, food and cover. Considering horizontal distribution is important for species that rely on large blocks of land, such as black-tailed deer, mountain lions, and red-tailed hawks.

Alteration of the horizontal distribution of habitats across large landscapes from fire, weather, residential development, rangeland conversion, or oak harvesting, can result in smaller, fragmented habitat patches. Small, isolated patches can eventually become *islands* of habitat that have a similar biological function to oceanic islands. The movement of populations of species isolated on these islands are restricted, so these populations are more susceptible to local extinction than populations which have free access to larger habitat patches. Less mobile species, such as many amphibians, have greater risks of local extinctions than those with greater mobility, such as bird species.

Maintenance of free interaction between reproducing adults is key to the survival of any wildlife species. Connecting patches of habitat through habitat *linkages* or *corridors* improves the interaction of breeding individuals between otherwise isolated populations. These linkages reduce predation and minimize impacts of harsh environmental conditions. Riparian areas often serve as linkages to hardwood rangeland habitats.

Resources Change Through Time

Important wildlife habitat attributes from oaks such as acorn-producing trees, snags, logs, and large and/or dead branches require considerable amounts of time to develop, even though they may persist for decades once they develop these characteristics. Land use practices that remove these attributes without allowing replacement will negatively alter the wildlife community. For example, it may take almost a century for most oaks to grow from acorn-produced seedlings to mature trees capable of producing abundant acorn crops. Oaks must be mature and several centuries old before they are large enough to have large diameter branches. Also, dead branches often result from heart rot which typically affects older, less healthy trees that are more susceptible to decay agents. An oak tree typically must live its entire life of several centuries before it dies and becomes a snag. Once developed, snags persist for many decades before they fall down and become logs. Logs will persist for many decades until they decay and become part of the soil. Furthermore, individual trees may produce more acorns, have more large branches, and make larger snags and logs than other trees. Therefore, trees with these desirable characteristics should be identified and retained so that wildlife communities will benefit. For example, observing acorn production of individual trees for two or three years over several weather cycles should allow most landowners to identify trees that produce large acorn crops relative to other trees on their lands (see chapter 9).

Habitat Use

The functional relationships among plants, animals and their physical environments are the foundation of ecosystems. Most wildlife species can use a variety of habitat types. The deer mouse is an example of a habitat generalist. It is thought to be the most widely distributed and abundant mammal in North America, and occurs in virtually every terrestrial vegetation type. Deer mice feed on a wide variety of plant and animal materials. They store food for use during periods of shortages, and build nests in almost any form of confined cover, such as rocks, leaves, or logs. The deer mouse can get its water from free water sources, dew, or from its food.

However, some wildlife species are so specialized that they occur in a relatively small number of habitats. The acorn woodpecker is an example of a habitat specialist. Although it has a widespread distribution, its habitat use



patterns are relatively restricted, coinciding with acorn-producing tree and shrub oaks in oak and oak-pine forests and woodlands.

Every wildlife community consists of both habitat generalists and specialists. Habitat generalists are more tolerant of a variety of land use practices than the habitat specialists. The challenge to any manager or landowner is to ensure that habitat needs are provided for all members of the wildlife community. This can be achieved by designing land use activities that ensure the continued presence of habitats and habitat elements needed by all members of the wildlife community.

For example, consider a large tract with a mosaic of oak woodlands, brush patches, riparian areas, savannas, pastures and grasslands. Cyclic, seasonal vegetation changes provide a diversity of food resources, including forbs, insects, fruits, and seeds, including acorns, that allow species with differing foraging strategies to co-exist. Birds that frequent oak woodlands throughout the year, both resident and migratory species, will partition these resources to minimize competition for them. If the necessary habitat elements are present, herbivores (plant eaters), insectivores (insect eaters), carnivores (meat eaters), omnivores (plant and meat eaters) and even highly specialized piscivores (fish eaters) can co-exist on this tract because of the way each group selects its food.

Species grouped according to a particular habit are referred to as a *guild*. (see Figure 4-3). For example, herbivorous species that eat seeds and are restricted to habitat edges are in a single guild. This includes song sparrows, California towhees, and rufous-crowned sparrows. If the necessary food and habitat elements are removed from an area, all species associated with this guild will also be removed. Similarly, insectivorous species that forage on wood would be negatively impacted if all standing and dead trees were removed from the site. Pileated woodpeckers, white-breasted nuthatches, and hairy woodpeckers are examples of species in this guild.

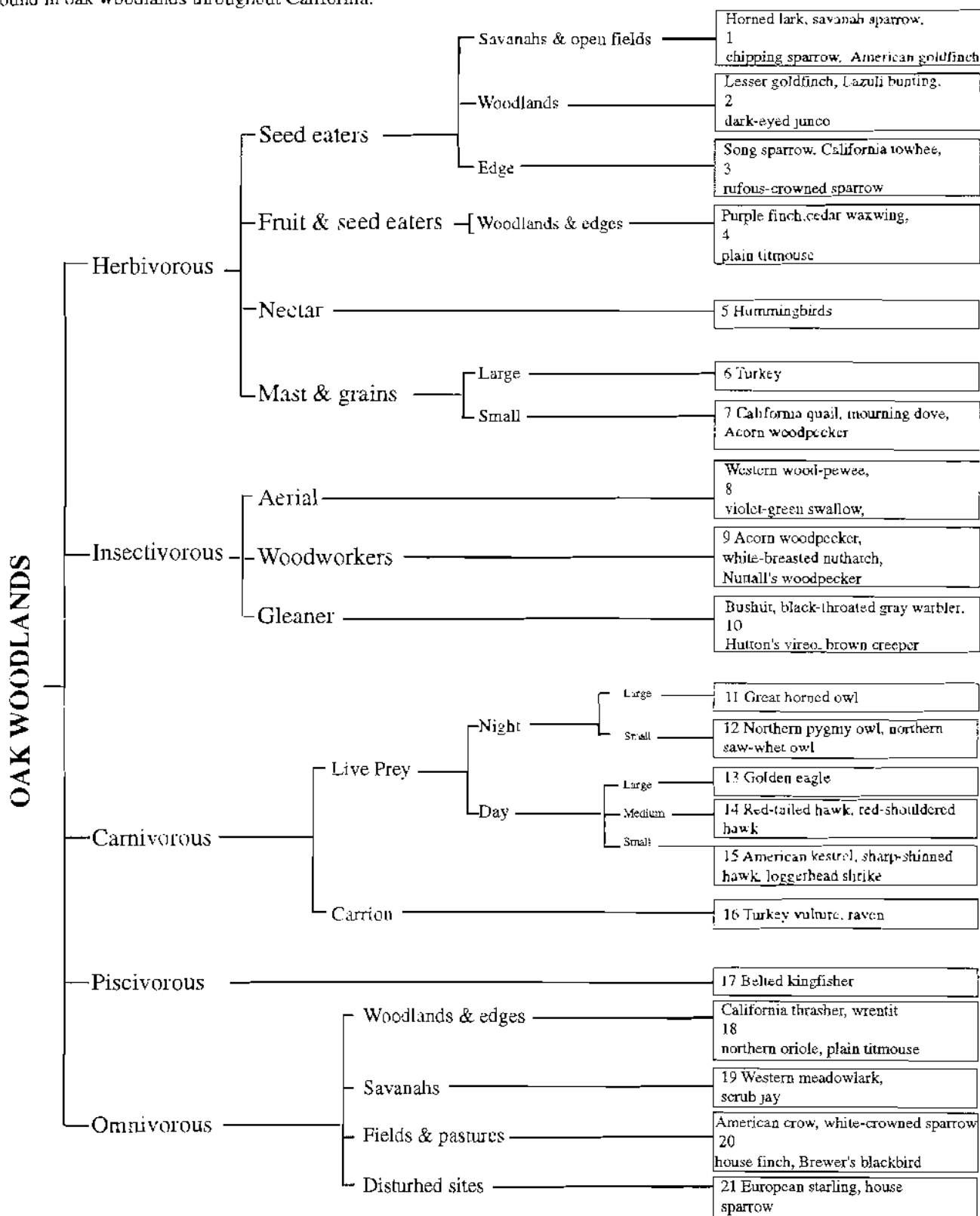
Wildlife use habitats at two broad levels usually defined as *macro* and *micro* levels. Management activities must consider both levels to sustain the biological integrity of hardwood rangeland habitats. The *macro*-level consists of all the habitats and their inter-relationships. *Macro*-level characteristics include habitat patch size and shape, edges with other habitats, and adjacent habitats. *Macro*-level features are used over a wide area during a time period that ranges from several weeks to several years.

Micro-level habitat characteristics are more focused on the individual features of the plants and the physical environment within an individual stand of trees. These features include species of plants, snags, rocks, water, acorns and other food items, tree size, and amount of vegetation cover. *Micro*-level elements are items an individual wildlife species uses throughout their daily and yearly cycles for breeding, feeding, and cover.





Fig. 4-3. An example of resource partitioning based on food habits of some land-dwelling birds that are commonly found in oak woodlands throughout California.





Wildlife respond to many different environmental characteristics when they select habitats to use. The three primary characteristics known to be important to many wildlife are: 1) habitat structure (e.g., size, height, amount of vegetation cover); 2) vegetation species composition; and 3) presence of *micro*-habitat elements.

Acorn woodpeckers are a good example illustrating the selection for the three broad habitat characteristics: structure, composition, and elements. They are found almost exclusively in open canopied, tree-sized habitats with substantial numbers of oaks, demonstrating selectivity in the structure and composition of their habitat. Their selection of habitats dominated by tree-sized oaks to provide live trees and snags large enough for granaries and nest cavities, demonstrates habitat selection on the basis of micro-habitat element characteristics. All three characteristics are inter-related to varying degrees, and the overall importance of a particular characteristic varies by season and geographic location.

Studies have also demonstrated the importance of habitat characteristics in California's hardwood habitats to other species. The importance of blue oak woodlands to wintering deer in Tehama County were discussed earlier in this chapter. Black bears showed greater use of habitats dominated by canyon live oak in the San Bernardino Mountains in spring, summer, and fall because these habitats provide cool environments, sufficient water, and low levels of human activity.

Wildlife habitat use changes over time and across landscapes. The migratory and wintering habitat use patterns of deer previously discussed is a good example. Black-tailed deer along the Coast Ranges are year-round residents and do not have pronounced migratory patterns. Yet, these resident deer use many habitats throughout the year, relying on oak-dominated habitats when acorns are available.

Golden eagles display fairly pronounced locational habitat use patterns. In hardwood rangelands, their nesting habitat includes area with large diameter, tall foothill pines with large branches, or tall cliffs with ledges for nests. Therefore, their nesting habitats are typically blue oak woodlands, blue oak-foothill pine woodlands, shrublands, or other habitats located in canyons or along cliffs. However, they feed in grasslands and open oak-dominated woodlands with sufficient populations of prey such as California ground squirrels, black-tailed hares, other medium-sized mammals, and ground-dwelling birds. These different nesting and feeding habitats must occur together over a large area in order to support a pair of nesting golden eagles.

Native Plants within Oak Woodlands

Oak woodlands are a diverse and dynamic ecosystem in California. In fact, for many people, oaks are a symbol of this State. Within oak woodlands, the several species of oak are the most striking plants present. But they represent only a small portion of the plant diversity which occurs in oak woodlands. As stated above, over 2,000 species of California native plants occur in oak woodlands. The scope of this book does not allow for detailed description of the many native plants of oak woodlands. For the more common plants associated with oak woodlands, refer to Appendix C. This section provides information on fundamental habitat relationships of plants that are considered to be sensitive to land use practices in oak woodlands. These species are a small, but special portion of those 2,000+ plant species that coexist with oaks.

Sensitive Plants

There are 130 known sensitive plant species that occur in oak woodlands. Sensitive is defined as plant species that are considered rare, threatened, or endangered within California, whether or not they are state or federally listed. Many of these plants are naturally rare because unique biological needs limit their distribution. Others may have been affected by human activities such that they have become rare, threatened, or endangered within California. Appendix B lists 130 sensitive plant species and their known oak habitat relationships. If a particular oak habitat exists on your property, you may have a particular sensitive plant species depending on the plants' distribution and special habitat relationships (see *Investigating the Occurrence of Sensitive Plants*)

Different Designations of Sensitive Plants

Appendix B designates sensitive species in three categories: federally listed, state listed, and California Native Plant Society (CNPS) categories 1B and 2. Eight oak woodland plant species are federally listed as threatened or endangered, while the State of California has listed 42 as rare, threatened, or endangered. The federal Endangered Species Act establishes protection for federally listed species. Plants state-listed as rare, threatened, or endangered are protected under the Native Plant Protection Act or the California Endangered Species Act. CNPS maintains an inventory that evaluates native plants on their rarity, endangerment, and distribution. This chapter lists only two of their five categories: 1B and 2. Category '1B' is defined as *rare or endangered in California and elsewhere*, while



category '2' is defined as *rare and endangered in California; more common elsewhere*. For a more thorough list of sensitive plant species and a detailed explanation of CNPS's inventory system, you may refer to the electronic or printed California Native Plant Society's INVENTORY of Rare and Endangered Vascular Plants of California (5th Edition). You may also wish to attain a copy the California Department of Fish and Game's (CDFG) *Special Plants List*.

Investigating the Occurrence of Sensitive Plants

As stated above, the list of plants in Appendix B does not reveal whether a particular plant species does occur on your land. The table does inform you if a particular plant has been found in a particular oak habitat(s). Additionally, the table lists unique ecological characteristics of each plant species. This information is a starting point for you to determine the possibility of one or more rare plants being found on your land. In many cases, the type, periodicity, and intensity of the land use determines whether rare, native plants exist, just as is the case for wildlife.

When determining what plants occur on your land, surveying your land for all plants (*floristic survey*) allows you gain detailed knowledge about the occurrence, distribution, and abundance of all plants, whether they be oaks, common trees, shrubs, grasses, and herbs, or sensitive species. In some cases, plant survey information may already exist for your property. In addition, there are other sources of useful information. These sources would be the local university or college, the regional resource conservation district, individuals or firms involved in biological consulting, your regional CDFG Plant Ecologist or District Biologist, and CDFG's Natural Diversity Database (NDDDB). NDDDB maintains location information for sensitive plants, animals, and natural communities for all of California. Regional CDFG staff have access to NDDDB information, and you may contact NDDDB directly if you wish to investigate what is already known about sensitive plants in your area. However, if the NDDDB does not include any known records of sensitive plants on your property, this is no guarantee that sensitive plants do or do not occur there. Only plant surveys can determine that.

Management of Lands for Sensitive Native Plants

In a nutshell, there is no recipe for maintaining an area's native flora. For certain species with certain needs, avoidance or minimum activity for a period of time may be crucial (i.e., removing cattle while plants are flowering and setting seed). On the other hand, management for native plants might involve a certain activity for a particular period of time (i.e., prescribed burning to allow seeds to sprout; maintaining grazing so to reduce exotic grasses which in turn allows native species to exist, etc.). Each sensitive plant has specific needs, and it is best to consult with your local botanists, field biologists, and other plant and vegetation experts when deciding on land management activities to meet your needs and the needs of the sensitive plants that may exist on your land.

41

A Worksheet for Evaluating Woodland Habitat Impacts

There are many ways landowners can manage their oak woodlands for wildlife or to maintain native plants. One can choose to manage on the basis of vegetation composition, percent canopy cover, or even a single wildlife species such as deer. Yet, when assessing various management enterprises, land managers should consider a broad scale approach to management. This *system-wide* management approach considers both ecological and economic effects prior to implementing a management plan. This is really just a new way of saying "don't put all of your eggs in one basket".

When evaluating the impacts of various management actions, there are often unforeseen consequences. It is easy to recognize the consequences of harvesting individual oaks (e.g., they become firewood), but more difficult to recognize the potential consequences at the population (e.g. loss of acorn producers), community (loss of bird nesting locations), ecosystem (increased light to forage plants), and landscape (increased edge with grasslands or loss of habitat linkages) levels. Worksheet 4-1 is provided to help assess these broader effects by examining the resources present in the area proposed for management and the anticipated changes of the proposed enterprise to the woodland ecosystem. It is suggested that you work through this process for any enterprise you are considering, to allow you to assess the concepts presented in this chapter.

This worksheet is designed to help assess the impact of the proposed hardwood rangeland enterprise on a particular habitat element. In column one of the worksheet, you should assess the particular habitat element in the area proposed for a particular enterprise. Column two is used to describe how significant that element in the enterprise area is in relationship to the broad region or landscape surrounding the enterprise area. Column three



is used to describe anticipated changes that are expected to occur as a result of the particular enterprise. Column four is used to list the anticipated regional impacts expected as a result of undertaking a specific enterprises. In order to undertake this exercise, you will need a map of your property and basic knowledge of its resources. It is best to have an aerial photograph of your land and the surrounding landscape, but you may use other estimates if a photograph is unavailable. The material you have developed from chapter 3 will help you get started. Instructions on the use of the worksheet and definitions of terms used will follow.



The Potential Impacts of Development on Wildlands in El Dorado County, California¹

Shawn C. Saving² and Gregory B. Greenwood³

Abstract

We modeled future development in rapidly urbanizing El Dorado County, California, to assess ecological impacts of expanding urbanization and effectiveness of standard policy mitigation efforts. Using raster land cover data and county parcel data, we constructed a footprint of current development and simulated future development using a modified stochastic flood-fill algorithm. We modeled combinations of constraints from the 1996 County General Plan and parcel data—slope, stream buffers, oak canopy retention, existing development, public ownership, regional clustering, and acquisition programs—and overlaid development outcomes onto the land cover data. We then calculated metrics of habitat loss and fragmentation for natural land cover types. Rural residential development erodes habitat quality much more than habitat extent. Policy alternatives ranging from existing prescriptions to very restrictive regulations had marginal impact on mitigating habitat loss and fragmentation. Historic land parcelization limits mitigation of impacts by the current General Plan prescriptions that only apply when a parcel requires subdivision before development. County-wide ordinances were somewhat more effective in preserving habitat and connectivity. These solutions may not offer enough extra protection of natural resources to justify the expenditures of “political capital” required for implementation. Custom, parcel based acquisition scenarios minimized habitat loss and maximized connectivity. Better analysis of public policy and planning design may be a more effective “smart growth” tool than generic policy prescriptions.

Introduction

The California Department of Finance projects the State's population to increase from 34 million to over 45 million by the year 2020 (California Department of Finance 2001). During the past 20 years, the spatial distribution of California's population has also changed as more people moved to the periphery of the dense Los Angeles and San Francisco Bay metropolitan areas and to the historically lower density Central Valley and Sierra Nevada foothills (U.S. Census Bureau 1991, 2001). Since the eastern half of many of these Sierran counties is predominantly national forest above 1,500 meters, the vast majority of this additional population will reside in the lower elevation foothills, a region dominated by oak hardwood savannah. The hardwood rangeland region of the Sierra, extending from 100 to 1,500 meters in elevation, is almost exclusively privately owned and has historically been used for grazing and some dryland farming (Duane 1996, Greenwood and others 1993). The switch from large parcel, low to moderate intensity agriculture to small parcel, high intensity urban and ex-urban land use promises great change to the natural

¹ An abbreviated version of this paper was presented at the Fifth Symposium on Oak Woodlands: Oaks in California's Changing Landscape, October 22-25, 2001, San Diego, California.

² GIS Specialist, Fire and Resource Assessment Program, Department of Forestry and Fire Protection, State of California, 1920 20th St., Sacramento, CA 95814.

³ Science Advisor, Resources Agency, State of California, 1416 9th St., Sacramento, CA 95814.

ecosystems of the foothills region. These 5-acre to 40-acre ranchettes will likely contain the majority of naturally functioning hardwood landscape in the near future.

One such region of rapid change is El Dorado County in the Central Sierra Nevada Mountains. We conducted a policy analysis of the El Dorado County General Plan by modeling development in the western, foothill portion of the county. We were interested in two topics: 1) ecological impacts on wildland habitat resulting from expanding urbanization under the County's General Plan; and 2) the effectiveness of commonly proposed land use policy initiatives to mitigate those impacts. Several models exist for projecting development expansion at the county and regional scale (Landis 1994, 1995, 1998a, 1998b; Johnston 2000, 2001; US Environmental Protection Agency 2000). These models focus on dense urban development (1 - 2 acre parcels or smaller) using economic formulas of land values and empirically derived "attractors" of development such as proximity to existing infrastructure (roads, sewer, water, etc.) to guide development probabilistically and incrementally over time. However, in rural areas (5 - 40 acre parcels), where attractors are less obvious or more difficult to model, or where tractable economic factors are not the primary drivers behind development decisions, these models generally ignore rural development or resort to random allocation (Johnston 2001). In El Dorado County, the General Plan designates 23 percent of the county for development in this rural density range. In order to adequately predict impacts in these regions, we needed to place the existing and potential footprint of development as explicitly as possible. We developed a cell-based, empirical model that characterizes development patterns from existing development and then extends those patterns across the landscape onto vacant lands. Because we were primarily concerned with the relative impacts of the county's General Plan and alternative policy proposals, we chose to extend development to full "buildout" of the General Plan, approximately a 20-year time horizon, rather than incorporating an economic component which might allow the phasing of development over time.

We began by determining where development existed in 1996, the most recent year for which digital parcel data were available. We then predicted where development would be at full buildout of the General Plan under various scenarios (e.g., uncontrolled vs. smart growth, strict vs. loose environmental land use policy, and combinations thereof). For any given scenario, our model can assess the implications for a variety of issues ranging from natural ecosystem functions to local and regional economies to general quality of life. At present, we have analyzed a wide range of land use policies in the County and their relative impacts on two major areas of concern, wildland habitat quality (characterized by extent, fragmentation, and configuration) and economic costs and losses due to wildfire. This paper presents our research on the former.

Study Area

El Dorado County is a predominantly rural county in the Central Sierra region of California stretching from the floor of the Central Valley east of Sacramento to the crest of the Sierras and the southern portion of Lake Tahoe (mean latitude 38.75° N, mean longitude 120.5° W). The county's 463,500 hectares cover a wide diversity of habitats including low elevation annual grasslands and blue oak (*Quercus douglasii*) savannah at the western edge, mid-elevation oak woodlands and mixed oak-conifer-shrub complexes in the central region, and Sierran mixed conifer forest dominated by



Figure 1—Location of study area with major highways and cities.

ponderosa pine (*Pinus ponderosa*), Jeffrey pine (*Pinus jeffreyi*), and lodgepole pine (*Pinus contorta*) in the eastern half. According to the 2000 Census (U.S. Census Bureau 2001), 156,299 people lived in El Dorado County at an overall density of 33.7 persons/km². However, because the eastern half of the county is almost entirely national forest except for settlements on the southern littoral edge of Lake Tahoe, the average density for private lands is 63.3 persons/km². Housing density is 28.9 units/km². Our study area encompasses 220,954 ha and is restricted to the predominantly privately owned western foothills region of the county (*fig. 1*).

From the time Gold Rush pioneers settled in the 1850s, the population of El Dorado County fluctuated between 6,000 and 20,000 people until the 1950s. Since that time the decadal growth rate has ranged from 20 percent to 100 percent, with growth rates of 46.8 percent and 24.0 percent in the 1980s and 1990s, respectively (U.S. Census Bureau 1991, 2001). State Department of Finance projections indicate this magnitude of growth continuing for the next two decades resulting in 252,900 residents by 2020 (California Department of Finance 2001).

Methods

Study Design

The purpose of this study was to evaluate the potential impact of El Dorado County's General Plan on wildland habitat in the county (primarily oak woodland) and how policy alternatives might mitigate these impacts. We modeled several

alternative scenarios, three iterations each, by varying one or more of the General Plan prescriptions, as well as the possible spatial configuration of future development (*table 1*), and overlaying the resulting footprint of development onto the land cover data and measuring the core extent, fragmentation and configuration of wildland. As we intended this work to be directly relevant to issues facing the county, many of these scenarios were devised from suggestions by residents and county officials. Thus, we did not attempt to analyze every possible combination of variables, especially as it became apparent that one of them was not proving to be effective in mitigating the impacts on wildland.

We used three main geographic information system (GIS) datasets as inputs: 1) 1990 Hardwood Rangelands Pixel Data (Pacific Meridian Resources 1994) for land cover and current footprint of development (*fig. 2a*); 2) 1996 County Assessor's parcel data for land tenure information; and 3) 1996 Adopted County General Plan for future potential development densities (*fig. 2b*). We converted the parcel and General Plan data to 25 m raster grids and snapped them to the Hardwoods data. We conducted all spatial modeling with ESRI's ARC/INFO and GRID software (vers. 7.1.1 - 8.1) on UNIX workstations except the fragmentation metrics, which we calculated using APACK v. 2.15 (Mladenoff and DeZonia 2000) on a Windows2000 operating system. An in-depth detail of our methodology has been previously published on the CDF-FRAP website (Greenwood and Saving 1999). Here, we present only a basic overview.

Creating the Footprint of Development

In order to model future development, we first had to construct a pixel-based *footprint of current development* which showed as explicitly as possible where structures and other human disturbances to the natural landscape exist. Remote sensing-based pixel data, such as the Hardwoods data, serve this purpose to some degree, especially in rural areas (Merenlender and others 1998, Ridd and Liu 1998), but provide no context of land use. Such data also miss development obscured by tree canopy and tend to confuse some urban and non-urban land cover types (e.g., rock outcrops and concrete) (Bruzzone and others 1997, Fisher and Pathirana 1990, Quarmby and Cushnie 1989). From the parcel data we determined the land use of each parcel and thus derived two binary layers—development status (*developed* or *vacant*) and intensity of use (*intense* or *not intense*) at the parcel level. For *developed* and *intense* parcels smaller than 1 hectare (2.5 acres), we included the entire parcel in the footprint. However, for larger parcels we turned to the Hardwoods data to identify specific areas of human disturbance within the parcel. We compared the classes Urban and Other (U/O) from the Hardwoods data to the development status of the parcel data. Where a U/O pixel(s) existed inside a *developed* parcel, we included those U/O pixels in the *footprint of current development*. Where a U/O pixel(s) existed in a *vacant* parcel, we considered those pixels "false positives" and did not include them in the *footprint of current development*, although they did remain in the land cover layer as Barren. For *developed* parcels with no U/O pixel(s), we simulated a pattern of development in the parcel using the same technique to project future development patterns (see below). Thus, we created a picture of current development composed of three elements: 1) small, intensely used parcels; 2) scattered pixels of development in larger parcels; and 3) stochastically placed pixels in developed parcels within which we could not determine the explicit location of development (*fig. 2c*).

Table 1—Descriptions of the combinations of restrictions used for each scenario tested.

| Scenario | Slope/Stream Restrictions | | Canopy Retention ¹ | | Other Restrictions | | Total Area (ha) | |
|----------|-----------------------------------|------------------|-------------------------------|------------------|--------------------------|------------------|-------------------------|-------------------------|
| | Description | Extent Area (ha) | Description | Extent Area (ha) | Description | Extent Area (ha) | Restricted ⁶ | Restricted ⁶ |
| 500 | Present Condition | - | - | - | - | - | - | - |
| 503 | 25 m stream setbacks, < 40% slope | subdiv. 19,567 | as per GP subdiv. | 5,980 | - | - | - | 122,774 |
| 504 | 25 m stream setbacks, < 40% slope | all 26,983 | as per GP subdiv. | 5,980 | - | - | - | 128,389 |
| 505 | 50 m stream setbacks, < 40% slope | subdiv. 23,319 | as per GP subdiv. | 5,980 | - | - | - | 125,988 |
| 506 | 50 m stream setbacks, < 40% slope | all 31,819 | as per GP subdiv. | 5,980 | - | - | - | 132,694 |
| 507 | 25 m stream setbacks, < 40% slope | subdiv. 19,567 | as per GP subdiv. | 5,980 | Clustering ³ | LDR, subdiv. | 12,526 | 122,774 |
| 508 | 25 m stream setbacks, < 40% slope | subdiv. 19,567 | as per GP subdiv. | 5,980 | Clustering ⁴ | LDR, subdiv. | 12,526 | 122,774 |
| 509 | 25 m stream setbacks, < 40% slope | subdiv. 19,567 | Increased ² | 7,096 | - | - | - | 123,920 |
| 513 | 25 m stream setbacks, < 40% slope | subdiv. 19,567 | as per GP all | 6,409 | - | - | - | 123,368 |
| 514 | 25 m stream setbacks, < 40% slope | all 26,983 | as per GP all | 6,409 | - | - | - | 128,944 |
| 515 | 50 m stream setbacks, < 40% slope | subdiv. 23,319 | as per GP all | 6,409 | - | - | - | 126,564 |
| 516 | 50 m stream setbacks, < 40% slope | all 31,819 | as per GP all | 6,409 | - | - | - | 133,217 |
| 520 | 50 m stream setbacks, < 40% slope | all 31,819 | as per GP all | 6,409 | Clustering ⁴ | LDR, subdiv | 12,526 | 133,127 |
| 543 | 25 m stream setbacks, < 40% slope | subdiv. 19,657 | as per GP subdiv. | 5,980 | Acquisition ⁵ | AOC | 2,071 | 124,513 |

¹ Canopy retention restricts development by limiting the amount of development. In most cases, this does not mean complete restriction but rather a reduction in density only (table 2). See Greenwood and Saving, 1999.

² For details, see Greenwood and Saving, 1999.

³ Proportion (B) of developed cells increased from 9% to 14%. Adjacency (C) increased from 55% to 95%.

⁴ Proportion (B) of developed cells increased from 9% to 14%. Adjacency (C) increased from 55% to 98%.

⁵ We manually selected parcels to be restricted from development in Areas of Concern (AOC).

⁶ Includes all restrictions plus existing developed parcels, parcels closed to development, public ownership, and areas designated Open Space (OS) in the General Plan.

Impacts of Development—Saving and Greenwood

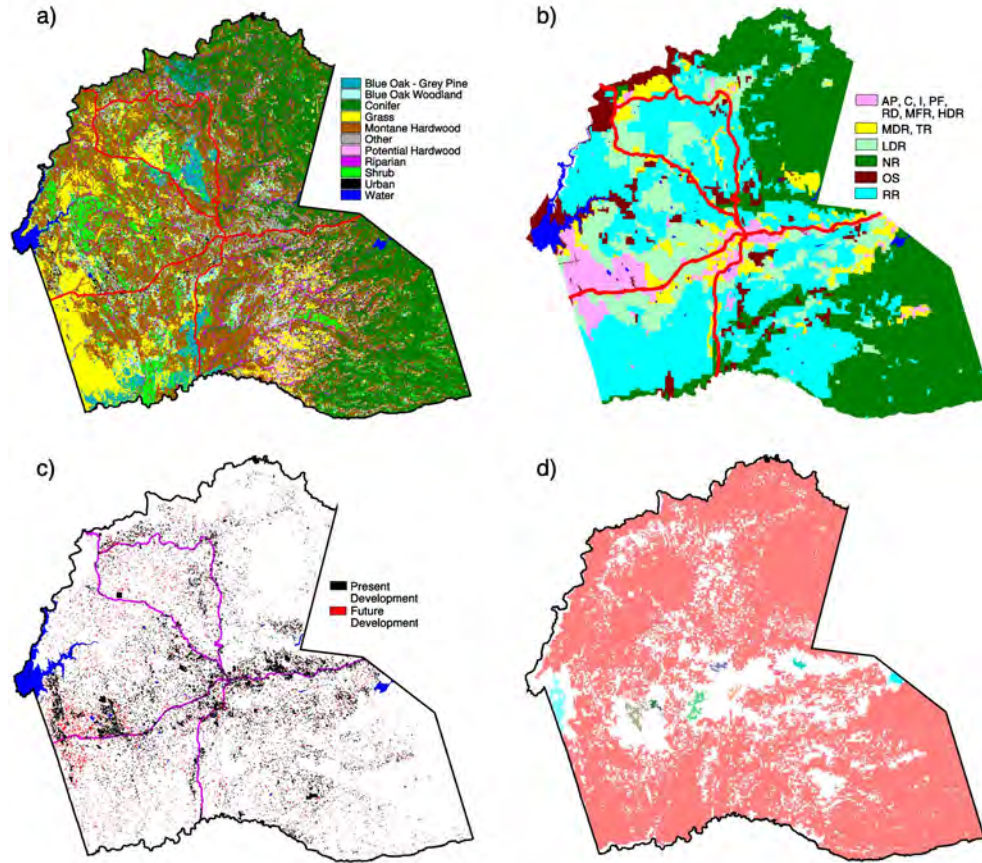


Figure 2—a) Land cover types from 1990 Hardwoods Pixel Data (Pacific Meridian Resources 1994), b) 1996 El Dorado County Adopted General Plan land use classes collapsed to 6 categories (see *table 2* for land use codes), c) footprint of current and future development under General Plan scenario (503), and d) map of current wildland habitat in the study area.

The first step in creating the *footprint of future development* required knowing where development could *not* occur. From the General Plan we derived a restriction status for each parcel. A parcel was *closed to future development* if it were already developed and already at the minimum allowable lot size for that General Plan density class. Alternatively, a parcel was *open to development with restrictions* imposed by the General Plan (i.e., discretionary permit review) if it were *developed* or *vacant* but at least twice as large as the allowable minimum lot size, meaning the lot could be further subdivided. Finally, a parcel was *open to development without restriction* (i.e., ministerial review) if it were *vacant* and already at the minimum allowable lot size for that General Plan density class and therefore could not be subdivided further.

The General Plan contained three major restrictions applying to discretionary permit review that we were able to model spatially – 25 m (1 pixel) stream setbacks,⁴

⁴ The Adopted General Plan calls for 100' stream setbacks. Since our model is raster based, we used a one pixel (25 m) buffer as the closest estimate.

Impacts of Development Saving and Greenwood

Table 2—*Canopy retention guidelines from Adopted General Plan. Values represent percentage of canopy that must be retained for each combination of General Plan Land Use Class and Current Oak Canopy Closure percentage. Where 100 percent of the canopy must be retained, no development can occur on oak pixels.*

| General Plan land use class | Current oak canopy closure (pct) | | | | |
|----------------------------------|----------------------------------|-------|-------|-------|--------|
| | ≤ 19 | 20-39 | 40-59 | 60-79 | 80-100 |
| Multi-family Residential (MFR) | 90 | 85 | 80 | 70 | 60 |
| High Density Residential (HDR) | 100 | 90 | 80 | 70 | 65 |
| Medium Density Residential (MDR) | 100 | 90 | 80 | 70 | 65 |
| Low Density Residential (LDR) | 100 | 100 | 90 | 85 | 80 |
| Rural Residential (RR) | 100 | 100 | 100 | 95 | 90 |

no development on slopes over 40 percent, and an oak canopy retention guideline based on the density class of development and the existing canopy cover (*tables 1, 2*). We created a separate mask for each of these restrictions which could be turned on or off or, in order to simulate an ordinance, be applied to all parcels *open to development* regardless of restriction class. We also created similar masks reflecting 50 m stream buffers and increased canopy retention. Lastly, some areas were off limits to development in every scenario—areas classified as Urban or Other in the Hardwoods data, parcels that were *developed* and *closed to future development*, public lands, private reserves, easements, and open space designated in the General Plan.

Once we determined where development was allowable, we then determined the spatial configuration of development at the 25 m pixel scale. McKelvey and Crocker (1996) developed a stochastic flood-fill algorithm to create theoretical landscapes burned by fire using two aspects of spatial configuration—proportion (B) of landscape burned by fire, and the spatial adjacency (C) of the burned pixels. Adjacency is defined as the probability that if a cell is burned, an adjacent cell is also burned.⁵ We modified their algorithm to create binary neutral landscapes that mimic the development patterns for each housing density class in the General Plan. By overlaying the Urban and Other pixels from the Hardwoods data onto classified 1990 Census block housing density data, we calculated proportion (B) and adjacency (C) for landscapes settled at different densities. The proportion of Urban and Other pixels ranged from 27 percent for housing density classes greater than 1 unit/acre down to 3 percent for density classes less than 1 unit/40 acres (*table 3*). Adjacency values varied to a lesser degree, ranging from 62 percent to 50 percent over the same housing density range (Greenwood and Saving 1999). By masking non-developable areas and inserting portions of these theoretical landscapes into the appropriate General Plan density region, we created potential *footprints of future development* for the study area (*fig. 2c*).

⁵ McKelvey and Crocker refer to the adjacency measure (C) as contagion. To avoid confusion with the contagion indices of O'Neill and others (1988) and Li and Reynolds (1993), we have chosen to use the term adjacency.

Table 3—General Plan land use classes and allowable lot sizes with proportion of cells (B) from the Hardwoods data classified as Urban or Other and likelihood of adjacency (C) of Urban and/or Other cells.

| General Plan land use class | Allowable lot size (ac) | Proportion of urban or other cells (B) | Probability of adjacency (C) |
|---|-------------------------|--|------------------------------|
| Multi-family Residential (MFR), | | | |
| High Density Residential (HDR) ¹ | <= 1 | 0.27 | 0.62 |
| Medium Density Residential (MDR) ² | 1 - 5 | 0.14 | 0.61 |
| Low Density Residential (LDR) | 5 - 10 | 0.09 | 0.55 |
| Rural Residential (RR) | 10 - 40 | 0.06 | 0.55 |
| Natural Resources (NR) | 40 - 160 | 0.03 | 0.50 |

¹ Includes these General Plan Land Use Classes - Adopted Plan (AP), Commercial (C), Industrial (I), Public Facilities (PF), and Research and Development (RD)

² Includes Tourist Recreation (TR)

For most scenarios, we assumed the spatial configuration of development for a given density class would not be significantly different in the future than at present. In other words, the values of B and C for a given density class did not change. However, the model did not limit us to this assumption. The General Plan allows for the doubling of total housing density in the Low Density Residential (LDR) class (5 - 10 acre parcels) if the development is highly “clustered.” Our landscape generator allowed us to easily simulate how this development pattern might appear (scenarios 507 and 508). We created two clustered density patterns for LDR by increasing B from 9 percent to 14 percent to simulate the density bonus, and by increasing C from 55 percent to 95 percent and 98 percent to simulate clustering (*table 1*).

Quantifying Impacts to Wildland Habitat

For this analysis, we defined *habitat* as all land cover types in the 1990 Hardwoods Pixel Data that were not Urban, Other, or Water. We combined Urban and Other pixels, along with developed cells from the *footprint of future development*, into one class called *developed*. Water was masked from the analysis environment. We defined *wildland habitat* as *habitat* more than 50 m (2 pixels) from a *developed* pixel, in patches greater than 100 hectares and containing no constrictions, or narrow necks, of *wildland habitat* narrower than 50 m. *Urban habitat* were those areas of natural vegetation within 50 m of a *developed* pixel. *Marginal habitat* were all areas not defined as *urban* or *wildland habitat* (narrow constrictions or patches less than 100 hectares, and > 50 m from *developed* pixels). This overlay of the footprint of development onto the natural land cover creates a landscape mosaic of *wildland*, *marginal* and *urban habitats*.

A quick review of the landscape ecology literature reveals many highly specialized metrics for capturing specific characteristics of a landscape. Several studies (Hargis and others 1999; McGarigal and McComb 1995, 1999; Ritters and others 1995; Tinker and others 1998) have shown that the simplest, most basic measures are the easiest to understand and serve well to compare and contrast landscapes. We calculated the following fragmentation metrics for wildland habitat for each scenario—total area, number of patches, mean patch size, largest patch size, mean shape index (Frohn 1998, McGarigal and Marks 1995, Ritters 1995), corrected

mean perimeter/area (P/A) ratio (Baker and Cai 1992), and total edge density. Ritters (1995) inverts McGarigal and Marks' (1995) mean shape index for raster data, calling it "average normalized area, square model," to make the values range from 1.0 for a perfectly square patch to 0.0 for patches that are long and narrow. The APACK software calculates Ritters' metric. As this metric measures the same landscape attribute as McGarigal's mean shape index (shape complexity - patch shape relative to a square), we have chosen to use McGarigal's name, mean shape index, when referring to it rather than Ritters' more cumbersome moniker. Although these metrics provide an objective means of comparing landscapes, they do not quantify all aspects of landscape configuration. Therefore, we also assessed model results through visual inspection of the output maps of *wildland habitat* extent.

Results

General Plan

Figure 2d shows the present extent of *wildland habitat* in the study area. The dominant feature of the landscape is a single patch of wildland (mean area of three iterations, 159,535 ha) that extends across the county from north to south and bridges the Highway 50 corridor. The influence of development is substantial yet would appear not to have significantly disrupted the contiguity of wildlands outside of the Highway 50 corridor and the communities of Pilot Hill and Georgetown. *Figure 3a* shows how the county's wildlands might appear if the General Plan were completely built out (scenario 503). The most apparent impact is the increase in number of patches and the cleaving of the wildland into distinctly separate northern and southern regions. Compared to present conditions, mean number of patches per iteration double from 10.0 to 19.67 and mean patch size accordingly drops from 16,182 ha to 6,337 ha (*table 4*). Mean largest patch size similarly declines to 59,603 ha. As patch sizes drop, measures of total edge density and corrected perimeter-to-area (P/A) perforce increase. Mean total edge density rises from 46.6 m/ha to 68.4 m/ha while mean corrected patch P/A ratio increases from 8.97 to 9.76. Mean shape index decreases from 0.070 to 0.043 indicating that not only does wildland shrink and fragment, it also becomes more complex spatially due to low density development perforating the existing wildland matrix. It is important to note, however, that the significant loss of wildland does not mean that large portions of the county have been paved over. While the mean loss of wildland is 23 percent, only 4.5 percent of wildland is actually converted to urban use. For oak woodland land cover types, 40 percent of wildland becomes *marginal* or *urban* woodland but only 4 percent is physically lost to development. In other words, areas that once functioned under a more natural state and presumably provided functional habitat for species are degraded, either due to proximity to urban land uses or by isolation from larger patches of contiguous natural vegetation.

Table 4—Mean values of wildland habitat landscape metrics for three iterations of the Present Condition (500) and General Plan (503) scenarios.

| | Present condition scenario 500 | General Plan scenario 503 |
|---------------------------------|---|--------------------------------------|
| Total area | 161,825 ha | 123,267 ha |
| Number of patches | 10.00 | 19.67 |
| Mean patch size | 16,182 ha | 6,337 ha |
| Largest patch size | 159,535 ha | 59,603 ha |
| Mean shape index | 0.070 | 0.043 |
| Mean patch P/A ratio, corrected | 8.974 | 9.762 |
| Total edge density | 46.57 m/ha | 68.38 m/ha |

General Plan Alternatives Increased Development Restrictions

Figure 3 (b-d and g-k) shows extents of wildlands for the General Plan alternatives meant to mitigate impacts through increased restrictions to development. The most noticeable aspect of the maps is their similarity to the General Plan scenario. The north and south patches remain highly separated in all scenarios except for scenario 543 where a few small patches come close to reconnecting the north and south patches. The differences become more apparent when the metrics are examined. All scenarios maintain a greater area of wildland than the General Plan. Scenarios that increase the areal extent of development restrictions (504, 505, 506, 509, 513, 514, 515, 516) generally indicate a decrease in fragmentation (mean number of patches decreases slightly and mean patch size increases slightly) (fig. 4). However, the range for number of patches and mean patch size for these scenarios is high, indicating site-specific sensitivity to placement of development. Scenarios 506 and 516 show the greatest increase in wildland mean total area (126,716 ha and 126,877 ha, respectively) and mean largest patch size (60,906 ha and 61,105 ha, respectively). Scenarios 506, 509 and 516 have the highest mean patch sizes (6,805 ha, 7,021 ha, and 6,952 ha), although 509 has a large range (1,238 ha). These results are consistent with those expected as the scenarios 506 and 516 restrict the largest amounts of land from development (132,694 ha and 133,217 ha, respectively). Patch shape complexity shows little difference in all scenarios as mean shape index remains virtually unchanged as does the mean corrected patch P/A ratio. Mean total edge density declines slightly with 506 and 516 having the greatest decrease (67.02 m/ha and 67.00 m/ha, respectively).

General Plan Alternatives Development Clustering

For scenarios 507 and 508 we examined the efficacy of clustering development for mitigating wildland habitat loss. For General Plan density classes of Low Density Residential (LDR), we increased adjacency (C) values to 95 percent and 98 percent, respectively. Because the General Plan allowed for a density bonus to the next higher density class, Medium Density Residential (MDR), we also increased the proportion (B) of developed pixels in LDR from 9 to 14 percent for both scenarios. Neither scenario shows a demonstrable increase in wildland habitat retention over the General Plan scenario, while some metrics indicate increased fragmentation. Mean

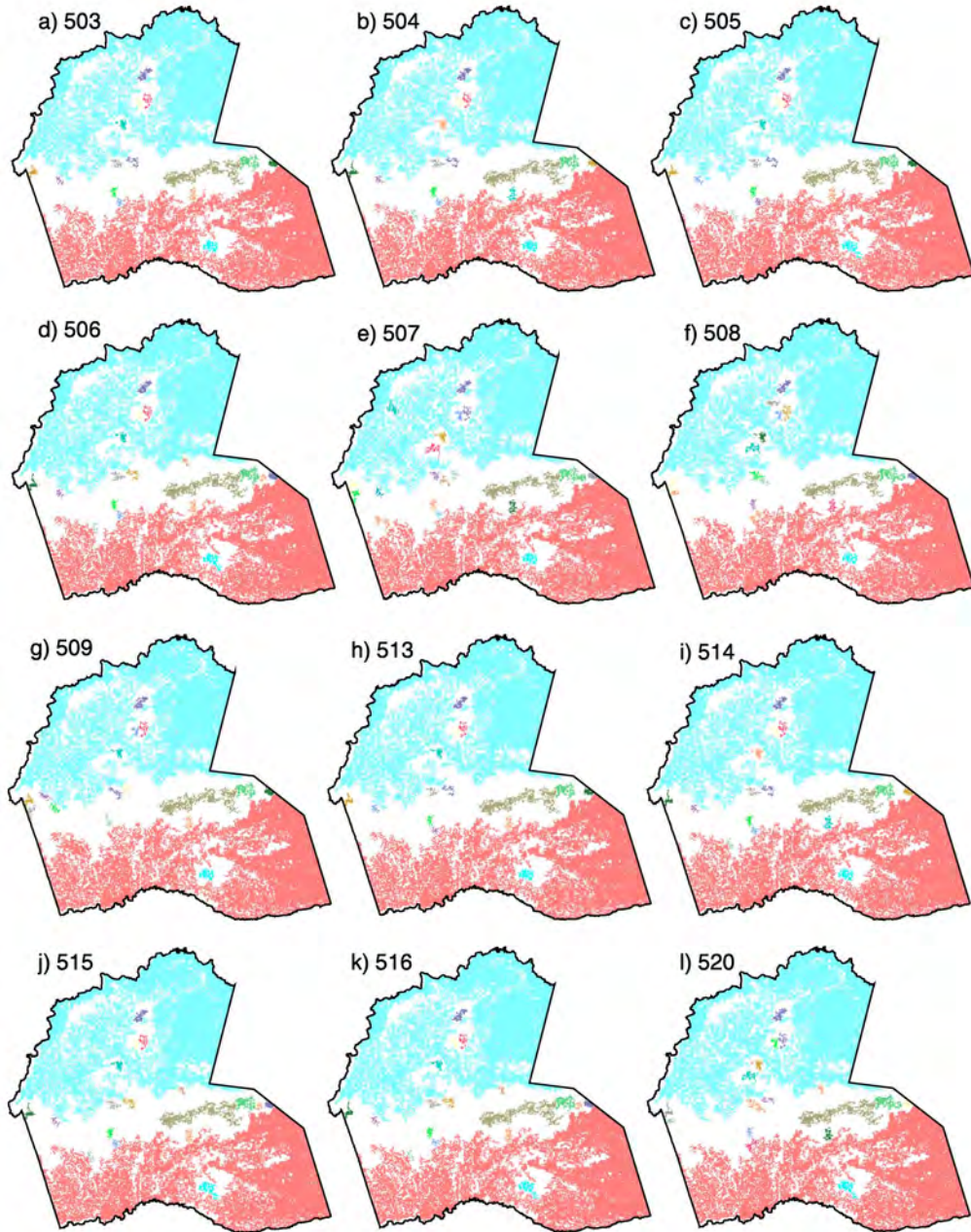


Figure 3—Maps of wildland habitat after full buildout for all scenarios. Areas of the same shade are a contiguous patch.

total area for scenario 507 (123,310 ha) is virtually the same as the General Plan and only slightly higher for scenario 508 (123,831 ha) (*fig. 4*). Mean largest patch size (507 = 59,502 ha, 508 = 59,847 ha) and mean corrected patch P/A ratio (507 = 0.044, 508 = 0.047) show similar behavior while mean total edge density does decrease slightly for 508 (67.39 m/ha). Mean number of patches (507 = 20.67, 508 = 19.0) remains within the range of values of those of the General Plan. Mean patch size actually goes down for 507 (5,979 ha) and remains unchanged for 508 (6,517 ha).

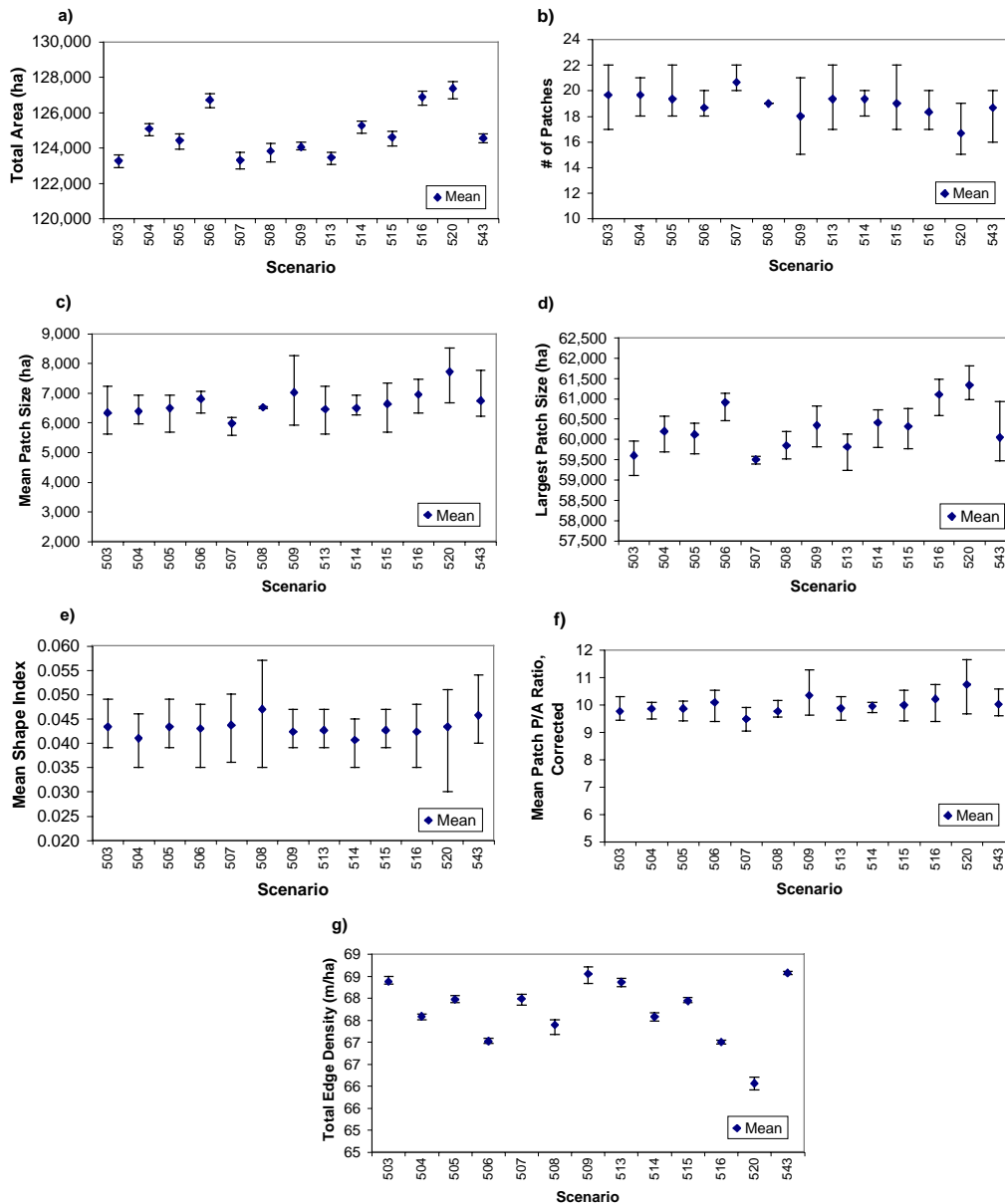


Figure 4—Values of wildland habitat landscape metrics for three iterations of the General Plan scenario (503) and alternatives (504-543). a) total area, b) number of patches, c) mean patch size, d) largest patch size, e) mean shape index, f) mean patch P/A ratio, corrected, and g) total edge density.

One of the iterations for scenario 508 has the highest mean shape index of all scenarios (0.057) but another iteration of 508 has the second lowest (0.035). Neither scenario was effective at maintaining the north-south connection (*figs. 3e, 3f*).

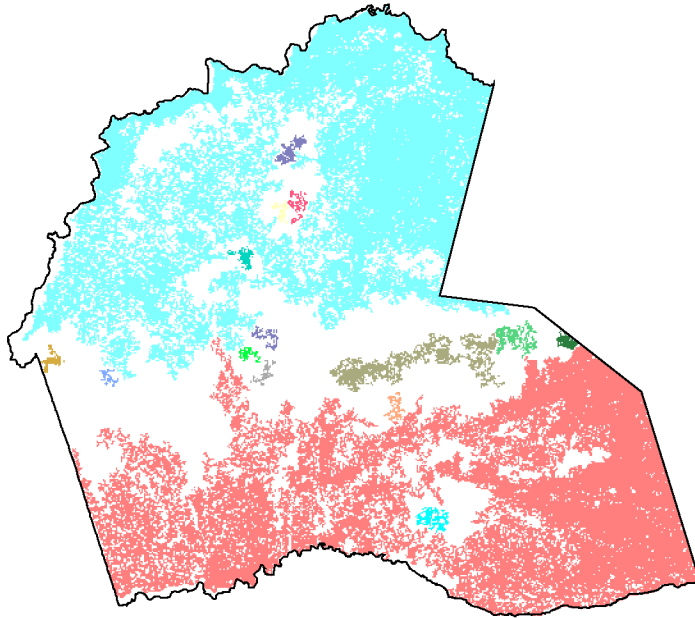


Figure 5—Map of wildland habitat after full buildout for parcel acquisition scenario (543).

General Plan Alternatives "Kitchen Sink" and Planned Acquisition

Given that scenarios 504-516 were ineffective at increasing wildland habitat retention over the General Plan scenario or at maintaining the north-south connection, we tested two additional approaches. Scenario 520, dubbed the “Kitchen Sink” scenario, combined all of the most restrictive policies yet tested – 50 m stream buffers, 40 percent slope restriction, oak canopy retention for all developable land regardless of restriction status, plus clustering as per scenario 508 (B = 14 percent, C = 98 percent) (*table 1*). In contrast, Scenario 543 took a completely different approach leaving all original General Plan restrictions intact but expanding the area of non-developable land by restricting select parcels from development in key areas of concern. This scenario simulates a planned acquisition approach through the use of easements and/or outright purchase of development rights by the county. We selected several vacant parcels in the Indian Creek canyon area where it crosses Highway 50 between Placerville and Shingle Springs in an attempt to reconnect the northern and southern portions of wildland. In those selected parcels, we only restricted development on oak pixels and areas within 50 meters of oak pixels. This left some parcels still potentially developable.

As expected, scenario 520 retains the highest mean total area (127,376 ha) of wildland because it restricts the greatest area of land from development (133,217 ha) (*table 1*). Mean number of patches (16.67) is the lowest for all scenarios and subsequently mean patch size (7,721 ha) is the highest (*fig. 4*). Mean largest patch size (61,332 ha) is also the highest of all scenarios. Shape complexity does not

decrease, however. Shape index is the same (0.043) as the General Plan scenario and mean corrected patch P/A ratio is the highest of all scenarios (10.74). In contrast, mean total edge density is the lowest of all scenarios (66.1 m/ha). Scenario 520 also does not come close to maintaining the north-south connection (*fig. 3l*).

As we made no attempt to preserve amount, but rather configuration, of wildland, scenario 543 only preserves an average of 1,296 more hectares than the General Plan (mean total area = 124,563 ha) and actually has slightly more average patches (20.0) and a smaller mean patch size (6,229 ha) (*fig. 4*). However, mean shape index is the second highest for all scenarios (0.046) while mean corrected patch P/A ratio is only slightly better than the General Plan (10.013). Mean total edge density is the same as the General Plan (68.57 m/ha). Most importantly, however, scenario 543 comes the closest of all scenarios to maintaining a connection between the northern and southern wildland patches (*fig. 5*).

Discussion

Our study demonstrated that the General Plan for El Dorado County will not allow the county to become one giant suburban subdivision. The General Plan allocates 43.0 percent of private land to development in the 1 unit/5 acre to 1 unit/40 acre density range (LDR and RR). Moreover, only 4 percent of the existing oak canopy will actually be removed by, or converted to, development. However, the configuration of this development is of concern as full buildout could force as much as 40 percent of the County's existing *wildland* oak woodlands into *marginal* or *urban* habitats. When counties are faced with such impacts, a popular mitigation approach is to implement prescriptions in the General Plan that regulate, and/or limit, how and where development can occur (e.g., stream setbacks, slope restrictions, etc.). However, such prescriptions can only apply to development that will undergo discretionary permit review, that is, parcels that have yet to be subdivided to the smallest allowable density in the General Plan. In the case of El Dorado County, 31 percent of *vacant* land that is *open to development* in the county (86 percent of parcels) had been subdivided prior to the adoption of the General Plan and is therefore not subject to these prescriptions. These parcels only require ministerial review (i.e., a building permit) before construction can occur. To impose a restriction that would regulate where development could occur in those parcels would require a county-wide ordinance. Our model allowed us to test both alternative General Plan prescriptions and county-wide ordinances. The former had little effect decreasing wildland habitat loss or fragmentation over existing General Plan policies. We attribute this to the large portion of the county not subject to the prescriptions due to prior subdivision. Ordinances showed greater wildland retention over the General Plan but that increase was still small. Scenario 516, the most restrictive ordinance scenario, only preserved 3,610 hectares more wildland than the General Plan and made little difference to patch configuration, shape complexity or edge density. The political expense in implementing ordinance-type solutions would seem to far outweigh the potential ecological benefits to oak woodlands.

Clustered development is a popular prescription proposed by the smart growth community. By holding overall density constant for an area but decreasing the space between structures, less space is scattered between structures which could otherwise serve as habitat and perform other ecosystem functions. The perceived advantages are so great that in order to promote clustering, El Dorado County offers a density

bonus for clustered development in the Low Density Residential category (5 - 10 acre parcels). We modeled two clustering scenarios allowing densities to increase to the Medium Density Residential level (1 - 5 acre parcels). Neither scenario improved wildland habitat condition over the General Plan and some metrics for scenario 507 (mean number of patches, mean patch size and largest patch size) were actually worse. The increase in density, and therefore the increase in the amount of land developed, offset any benefit that would be gained from clustering. Furthermore, clustering can only occur in *vacant parcels open to development with restriction* in LDR. This occurs only in a few small areas in the northern portion of the county.

Scenario 520, the Kitchen Sink scenario, employed the strictest policy restrictions we tested, plus clustering. Looking solely at the fragmentation metrics (*fig. 4*), this scenario offered the most improvement in wildland habitat condition over the General Plan. Yet when examining the maps, we did not notice any significant difference in wildland amount or configuration (*fig. 3l*). Most notably, the north-south separation was still very pronounced. Implementing county-wide ordinances which mandate 50 m stream buffers, 40 percent slope restrictions and oak canopy retention on all undeveloped parcels, plus requiring clustering in LDR, is highly unrealistic, not to mention, very politically expensive. Again, we contend that the political costs of such a scenario are probably greater than the ecological benefits.

Alternatively, we examined a limited parcel acquisition, or easement, strategy (scenario 543) for areas of concern which removes key parcels from the potential development landscape. One such area is the Indian Creek Canyon region. Here, a stringer of oak woodlands presently connects the northern and southern wildland patches. Although this scenario did not actually maintain the connection, several small patches do extend through the area indicating that the concept has the potential to maintain this critical corridor. This area of the county is highly desirable for development, therefore making this scenario potentially fiscally expensive. However, unlike the ordinance approach, an acquisition approach would encounter fewer stakeholders directly and would offer owners compensation for the loss of development rights on their property. Involving private conservation groups or land trusts could greatly reduce costs to the public sector.

Rural residential development erodes habitat quality much more than habitat extent, requiring a more nuanced approach to assessing impacts than when natural habitats are simply removed or paved over. At these low densities, we were unable to use polygons of housing density to determine the relationship of naturalness to density. At certain scales, the landscape still looks much as it once did. Rather, we modeled the real impacts of site alteration which required an entirely unique set of variables and characteristics such as determining the exact footprint of development (e.g., Do lightly used roads count? Do outbuildings?) and establishing the sphere of influence from a structure (e.g., How far from the structure is natural vegetation disturbed? How far does sound travel? What impact does it have? What influence do pets have and at what distance?). We can easily adjust these variables in our model to examine their sensitivity and ability to assess other issues besides wildland connectivity such as impacts to specific species habitat requirements, watershed degradation from increased sediment generation, and changes in wildfire probability due to vegetative fuel alteration. Most people can agree that high density urban and suburban development do not provide much high quality habitat for most species, but seldom can stakeholders, land managers, public officials, or even scientists agree on the thresholds or the degrees at which rural development begins to impact the

landscape. As more of the landscape of California transitions from large extents of wilderness owned by relatively few private individuals to a landscape divided up amongst thousands of owners regularly dotted with houses every few thousand feet, understanding these impacts and enacting policies that are effective, fair, and feasible become ever more important and challenging.

Future Directions

One aspect of development and conversion of natural land cover that we have not addressed is agricultural expansion. In El Dorado County this primarily involves vineyards. Agricultural expansion has the potential for far greater impact to habitat extent and connectivity than residential development as a greater area of land in larger contiguous patches is generally more greatly disturbed. Agricultural expansion can also be more difficult to predict. Heaton and Merenlender (2000) have developed a model to determine site suitability for vineyard expansion in Sonoma County which could be adapted for use in El Dorado County.

More investigation of the effects of riparian corridors on habitat connectivity is needed, including the effectiveness of stream setbacks and the development of methods to characterize linear features, as opposed to the two dimensional patch features analyzed here.

Better knowledge of the likelihood of development would enhance our ability to tailor solutions to specific areas of concern. The incorporation of economic models of development such as Johnston's UPLAN (2001) and Landis's CURBA (1998a, 1998b) would provide more realistic future scenarios as well as the ability to model development in stages over time rather than only at full buildout as we have done. Implementing other constraining factors to development such as water availability and habitat conservation plans could also improve our predictions of future development.

Conclusion

Fine-grained spatial models with highly detailed datasets are required for evaluating impacts of development on ecological, economic, or social systems at the local level. Such large-scale, high-resolution models also enable stakeholders to more easily relate the data portrayed on maps to their perception of the landscape in which they live. However, most site-specific models of development have been created for dense urban areas, using complex economic formulas of land value and empirically derived patterns of past development trends. These models prove less than reliable at predicting low-density development of the rural ranchette variety which is now so prominent in the Sierra foothills and which has such great impact on habitat quality. We have developed a model that is both fine-grained and capable of predicting potential rural ranchette development and its impacts. Moreover, by having a tool that can operate under various assumptions and constraints, we can actually test a proposed solution's efficacy at achieving a desired goal, which in this case is maintaining wildland connectivity. We have also used our model of predicting footprint of development to assess impacts of wildfire on future structure loss. Our explicit model of development could prove useful for studies of water quality and cumulative impacts for watersheds by incorporating elements such as sediment

generation from road development, nutrient loading from septic systems, and conversion of natural land cover to impervious surfaces.

Existing land tenure (the historic parcelization of land) limits effective control of development by General Plan prescriptions that are only applicable when a parcel requires subdivision before development, thus leaving solutions that require large expenditures of political capital such as ordinances or downzoning. The political expense in implementing such solutions would seem to far outweigh the potential benefits. For El Dorado County, our study concludes that the most effective way to maintain wildland oaks in large contiguous patches would be a land acquisition program focused on those critical areas of connectivity, often referred to as habitat corridors. More importantly, broad-brush, “best management practice” type solutions (i.e., the conventional wisdom) applied evenly across the landscape are not necessarily the most effective approach. Site-specific design may be a more effective tool in minimizing negative impacts of development than generic policy prescriptions. “Good” policy should be a process by which better analysis of the problem leads ultimately to better design of the solution.

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