WILDLIFE CONSERVATION SOCIETY

Mapping an Epidemic: Geography of Sudden Oak Death in California

Report to

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Introduction

The quintessential landscape of California and for Californians is oak woodland. Oaks are the central features of the landscape that most Californians identify with; yet, California's oak woodlands are imperiled in many ways. The forces that put California's oaks at risk endanger the birds and other wildlife tied to them. The birds and mammals of California's oak woodlands are connected to this distinctive habitat mainly through acorns, the often-copious fruits of oaks that are eaten and stored by dozens of species. There also is a reciprocal enterprise in the ecology of acorns, as species like Western Scrub Jays, Steller's Jays, and various squirrels often fail to retrieve cached acorns and so act inadvertently to disperse oak seeds across the landscape. Thus, in crucial ways, oaks provide key food for many birds and mammals, and some birds and mammals provide seed dispersal for oaks. Importantly, large oak trees also hold cavities for cavity-nesting birds and mammals, caching sites for acorn woodpeckers, nuthatches, flying squirrels and other species. The ties between oaks, birds and mammals are profound and diverse.

As is true for most all natural landscapes, the loss of oak woodland habitats continues as our ever-growing population converts ranches into suburbia, foothills into vineyard, and forest into prime real estate. Further, the lack of recruitment of new oaks in many species represents a "cryptic" crisis, a crisis a century in the making, but one that is not widely appreciated or conspicuous. Many of our existing oak woodlands are not generating new oaks to replace the old ones. Finally, an odious threat from a new pathogen is killing coastal oaks and tanoaks, dubbed the "Sudden Oak Death Syndrome", represents a very urgent crisis indeed. Lack of regeneration, the new pathogen, or both (Table 1) affect the majority of California's oak tree species.

Table 1. The Oak Trees (and Tanoak) of California and the presence/absence of conservation problems discussed in the text.

Common Name	**Latin Name**	**Group**[1]	**General Distribution in California**[2]	**Recruitment Problems?**[3]	**Infected by SODS?**[4]
Tanoak	*Lithocarpus densiflorus*	--	Coastal forests, spotty Klamaths & Sierras		Yes
Black Oak	*Quercus kelloggii*	Red	Northern foothills	Occasional	Yes
Blue Oak	*Quercus douglasii*	White	Central Valley foothills, dry coastal	Yes	
Canyon Oak	*Quercus chrysolepis*	Interm.	Foothills throughout state		
Coast Live Oak	*Quercus agrifolia*	Red	Central, southern coastal forests	Yes	Yes
Engelmann Oak	*Quercus engelmannii*	White	Extreme southern, coastal CA		
Interior Live Oak	*Quercus wislizenii*	Red	More interior foothills		Yes
Island Oak	*Quercus tomentella*	Interm.	Channel, Guadelupe Islands	Yes	

Common Name	Latin Name	Group[1]	General Distribution in California[2]	Recruitment Problems?[3]	Infected by SODS?[4]
Oregon Oak	*Quercus garryana*	White	N CA (coastal and Klamaths		
Valley Oak	*Quercus lobata*	White	Central Valley, dry coastal	Yes	

Notes:

1. Taxonomic group (from Tucker 1980: Red oaks are those with pointed lobes and densely hairy inner shells of acorns, among other characteristics; White oaks have round lobes and smooth inner shells of acorns, among other characteristics; Intermediate oaks (Interm.) are just that with respect to characters.)
2. The general distribution was described from range maps of *Lithocarpus* from Tappeiner et al., 1990, and of *Quercus* in Pavlik et al., 1991.
3. If recruitment (regeneration) is problematic for oaks, as noted by studies from the literature, a "Yes" or "Occassional" is entered in the column.
4. If oaks have been observed to have symptoms of the new *Phytophthora* infection ("Sudden Oak Death Syndrome", SODS), a "Yes" is entered in the column

Here, I will attempt to bring our understanding of these threats to California's oak woodlands and to discern how these issues are and will affect the birds and mammals that are so connected with them. The primary focus here is on the habitats' problems rather than the immediate problems of the birds and mammals that inhabit them.

The birds and mammals of oak woodlands, in general, are not in decline anywhere near the same degree, for example, as those of riparian habitats. Only two bird species associated with oaks are thought to be in decline, for example. But the conservation concerns outlined here for oak woodlands, particularly the impact of Sudden Oak Death and the consequences of the lack of regeneration of several oak species seem harbingers of problems for all wildlife of California's oak woodlands.

Background

Oak Woodland Habitats in California

Oaks appeared in southwestern North America, including California, beginning in the Eocene (ca. 50+ million years before present) (Axelrod 1988). The history of oaks and oak woodlands in geologic time in California is a complicated one of community assembly and disassembly with the vicissitudes of climate change. In general, oaks increase in prominence in warmer, drier conditions, and decline in cooler, wetter conditions (Axelrod 1988). By the Miocene (ca. 24 million years before present), many of California's present oak species were evident (e.g., tanoak, coast live oak, interior live oak, blue oak, and valley oak).

Finer-scale fluctuations in oak abundance and distribution are evident in the Holocene (from 10,000 years ago to the present), as shown in pollen studies (Byrne et. al., 1991). Oaks began to reestablish themselves following the last glacial period in California. Oaks were more abundant than at present during the mid-Holocene (ca. 6,000 years ago). With the cessation of fires generated by Native Americans and the onset of European-style grazing of domestic animals, oak density changed from an open, park like appearance to a more cluttered appearance evidenced today in intact oak woodlands.

Oaks are in the plant family Fagaceae. The members of this family include *Lithocarpus* (tanoaks, the majority of species (ca. 300) are in Asia), *Catanopsis* (now more frequently referred to as *Chrysolepis*) (the chinquapins), *Castanea* (chestnuts), and *Quercus* (oaks). All produce hardened fruits. Hardened fruit evolution in the Fagaceae and related families, the associated dispersal of such fruits by vertebrates, and a great explosion of plant diversity among such families all occurred in the Eocene (Tiffney 1986). *Lithocarpus* is considered the most plesiomorphic ("primitive") while *Quercus* is considered the most apomorphic ("advanced") members of their family, as evidenced from floral morphology (Kaul 1986).

There is a long history of classification of present vegetation in California (see review in Sawyer and Keeler-Wolf 1995). Holland (1986) identified 18 natural communities dominated by oaks in California. Six are forest communities (e.g., coast live oak riparian forest), four are chaparral communities (e.g., scrub oak chaparral), and eight are woodland and savanna communities (e.g., blue oak woodland and Oregon oak woodland).

In their own treatment of California vegetation, Sawyer and Keeler-Wolf (1995) note no fewer than 15 series of oak-dominated by shrubs and 14 series of oak (and tanoak)-dominated by trees; a total of 81 tree series are described in total. Among the tree series, the Black Oak, Blue Oak, Coast Live Oak, Mixed Oak, Oregon White Oak, Tanoak, and Valley Oak series occur over significantly large areas of California.

Griffin (1988) noted that oak woodlands have "little floristic unity", but nonetheless partitioned oak woodlands broadly into "Foothill Woodland", "Southern Oak Woodland", "Northern Oak Woodland", and "Riparian Forest" region, with each category having several subcategories, or phases. In the Foothill type, valley oak, blue oak, and interior live oak dominate. It is in the Southern oak woodland type that we find coast live oak. Griffin's main emphasis, however, is that oak woodland represents an "ill-defined zone of oak-dominated communities growing between open grassland and montane forest."

Thus, for our purposes, we define oak woodlands as simply those forests or woodlands where oaks (or tanoaks) are common or predominate. We wish to emphasize that for wildlife, including the bird and mammal communites, the key issue of oak woodlands is not so much in the detail of which oak species are present, but rather that all oaks (and tanoaks) produce acorns. Acorns are perhaps the most important food product for wildlife produced in California's many diverse habitats.

Conservation in Oak Habitat

Oak woodlands are thought to have the richest wildlife species abundance of any habitat in California as some 331 species depend on this habitat to varying degrees (Verner 1980; Barrett 1980; see also Block and Morrison 1998). The key connection between much of the wildlife and oak woodlands is through the oak's production of acorns. Acorn production varies in time and space between and among species (Sork et al 1993; Healy et al., 1999), including species in California (Koenig et al., 1994). So-called "mast" years in oaks, when acorn production is copious in an area, are critical to triggering pulses in vertebrate populations and reproduction (see Koenig 1990; Ostfield et al., 1996; McShea and Schwede 1993; and McShea 2000). The inclusion of at least some oaks in forests mean higher vertebrate diversity than similar forests without oaks (see Rosenstock 1998). That difference is due both to acorn production, and the increased cavity-nesting sites afforded by large oak trees in the landscape.

Large oak trees in oak woodland habitats are important for cover, nesting sites for cup nesting species and cavity nesting species, as well as caching sites for birds and mammals storing acorns. In oak woodlands with large oaks, the abundance of cavity nests is important to many species of wildlife (Watters 1988; Purcell 1995). Old, large oak trees are mosaics of living and dead branches, providing ample sites for woodpecker to excavate cavities and for insect-eaters to forage for larvae and adults. Dead branches and trunks in both living and dead large oaks are critically important for storage sites of acorns by Acorn Woodpeckers (Gutierrez and Koenig 1978).

There are a few studies of bird and mammal communities in California's oak woodlands (Block 1989; Block et al., 1990; Tietje et al., 1997; Verner et al., 1997; Sisk et al., 1997). These studies indicate many of the ecological connections between oak woodlands and wildlife. They make clear the strong link between wildlife communities and the production of oaks, the importance of cavity nests in large trees, and the often complex interactions and connections between habitat features and wildlife species (Table 2).

Fragmentation studies, efforts to identify minimal size and shape requirements of oak woodland habitat, are few but important (see, for example Aigner et al., 1998 and Merenlender et al., 1998). Land managers need to know tradeoffs in habitat size and the consequences for wildlife. Restoration efforts, too, can be guided by knowing how many species might be present with what effort of scale.

Problems affecting oak woodland wildlife:
Habitat Loss

More than a third of all oak woodlands have been lost since the settlement of Europeans to California; of an estimated 10-12 million acres, only some seven million remain, and of those, only some 4% are formally protected (Thomas 1997). Most of the loss of oak woodlands has been due to the ever-increasing urban and suburban growth of California. The city of Oakland, the town of Thousand Oaks, and many other town names recall the former prevalence of oak woodlands, and their importance to earlier communities. The clearing of oaks has also been done on ranches to "improve" forage quantity (Bolsinger 1988), and for firewood (Bolsinger 1988; Griffin and Muick 1990; Aigner et al., 1998).

A comparatively new habitat loss challenge to oak woodlands is loss to expanding wineries. A recent example in Santa Barbara county where a prominent winery removed a small grove of oaks, causing a great backlash among citizens (Van de Kamp 1996, 1997; Burns 1998a,b; Sage 1998a,b) provides evidence for the value that Californian's place on remaining woodlands and large oak trees. The wine industry is attempting to come to grips with this conflict of economic growth and aesthetic decline of oaks (Tobin 1998; Larson 1999). Adina Merenlender and others from the Integrated Hardwood Range Management Program are seeking to educate vineyard owners and identify ways to manage oaks in and around vineyards (Merenlender et al, 1998).

Table 2. Birds associated with oak woodlands in California, with information on their use of acorns, nesting substrate, general foraging habitat in oak woodlands, and whether the species is endemic to California.

Species	Consumes Acorns?	Caches Acorns?	Nest[1]	Foraging Habitat	California Endemic?
Wood Duck	**Yes**		**2º Cavity**	Wooded Streams	
Red-shouldered Hawk			Cup	Woodlands	**?**
Wild Turkey (I[3])	**Yes**		Ground	Woodlands	
Band-tailed Pigeon	**Yes**		Cup	Woodlands	
California Quail	**Yes**		Ground	Woodland-shrub	
N. Pygmy Owl			**2º Cavity**	Woodlands	
Acorn Woodpecker	**Yes**	Tree, many	**1º Cavity**	Woodlands	
Lewis Woodpecker	**Yes**		**1º Cavity**	Woodlands	
Nuttall's Woodpecker	**Yes**		**1º Cavity**	Woodlands	**YES**
Ash-throated Flycatcher			**2º Cavity**	Open Woodlands	
Western Scrub Jay	**Yes**	**Ground, many**	Cup	Woodland-Scrub	
Yellow-billed Magpie	**Yes**	**Ground, few**	Cup	Woodlands	**YES**
Oak Titmouse	**Yes**	Tree, few	**2º Cavity**	Woodlands	**YES**
White-breasted Nuthatch	**Yes**	Tree, few	**2º Cavity**	Woodlands	
Bewick's Wren			**2º Cavity**	Woodland-Scrub	
Blue-gray Gnatcatcher			Cup	Woodlands	
Western Bluebird			**2º Cavity**	Open Woodlands	
California Thrasher			Cup	Woodland-Scrub	**YES**
European Starling (I)			**2º Cavity**	Agriculture edge	
Hutton's Vireo			Cup	Woodlands	
California Towhee			Cup	Woodland-Scrub	**YES**
Lark Sparrow			Ground	Grass - Woodland	

Notes: 1. Cavity nesting species differ as to whether they excavate their own cavities (1º cavity nester) or they take over nests (2º cavity nester). 2. (I) denotes an introduced, nonnative.

Lack of oak regeneration.
A major threat to the oak woodlands of California is that several species have experienced very little regeneration this past century (White 1966; 1971, 1976;). This general problem is not unique to California (e.g., see Watt (1919) for problems in Britain's oak woodlands). The causes and influences of this issue are many and interconnected. It is a "cryptic" conservation crisis because it is not clearly evident as one looks across the oak woodland landscapes that surround so many of California's population centers. The classic park-like appearance of many oak woodlands seems intact – large trees spreading over grassy hillsides. But, upon closer inspection, little to no young trees are growing. In fact, in many areas, small trees are old trees of suppressed growth, not recent recruits (). The consequence for several species of oaks is that existing trees with senesce and die, and not be replaced unless we actively manage a different outcome.

There are several factors that contribute to this problem, and each interacts with others in ways that are often not fully understood. The factors include fire suppression, cattle grazing, invasion of European weedy annual grasses that have largely replaced native perennial grasses, and herbivory of oak shoots by cattle and native mammals.

Fire and oak woodlands are profoundly tied together in evolutionary and ecological ways (Reich et al., 1990; Abrams 1992; Stephens 1997). Frequent, low intensity fires gave oak woodlands in and around the Central Valley their open, park-like appearance. Frequent fires acted to thin out the understory of shrubs and small trees, and thus provide less competition for soil nutrients and water among larger, established oaks. Fire suppression arrived with the European settlement. Prior to the European settlement, native Indians of California had augmented natural fire regimes by setting fires, often on an annual basis, to facilitate an increased acorn harvest (see Biswell 1989; McCarthy 1993). Fire suppression began in earnest in California early in the 20th century (Biswell 1989). Although California has devastating fires annually, the overall effect of fire suppression has led to widespread changes in forest and woodland structure and function (Biswell 1989, Bonnicksen 2000).

Cattle grazing has been shown to have multiple and strong detrimental effects to ecosystems in the West (see reviews by Fleischner 1994; Belsky et al., 1999). Cattle grazing has severely disrupted ecosystem structure and functioning (Fleischner 1994) generally, and in California oak woodlands as well (Stromberg and Griffin 1996; Jackson et al., 1998; Swiecki and Bernhardt 1998). Cattle grazing has directly and indirectly facilitated the invasion of weedy (European) annual grasses and the associated decline (and often loss) of native perennial grasses (Hamilton 1997). The weedy annual grasses compete for soil moisture with oak seedlings. Cattle also consume young oak shoots, as do feral pigs and native wildlife like pocket gophers and deer.

Another effect of fire suppression on oaks is the change in vegetation structure that arises as a result. For example, fire suppression has led to the increase in incense-cedar (*Calocedrus decurrens*) and white fir (*Abies concolor*) in Yosemite National Park, which in turn has reduced the density of black oaks there (Phillips et al., 1997). In northern California, fire suppression has led to increased densities and a lower elevation occurrence of Douglas-fir (*Pseudotsuga menziesii*) at the expense of white oak, which has declined in number (Barnhart et al., 1996) (this scenario is also true in the Willamette Valley of Oregon (Johannessen et al., 1971)).

The tree oaks known to have serious problems with the lack of regeneration include valley oak (Thompson 1961), blue oak (Swiecki and Berhhardt 1998), coast live oak (Parihk and Gale

1998), and island oak (Pavlik et al., 1995). Valley oak and blue oak occur where grazing pressure is the greatest. Some regeneration problems have been observed in some regions for black oak (The problem is not in acorn production or acorn viability, rather it is in the inability of seedling to survive to become young trees (Borchert 1990)). There has been intensive research and some multiple management solutions to the recruitment problem. There is a large and diverse literature available on facilitating regeneration in oak trees, through such diverse means as seedling shelters from grazing, prescribed fire, progressive cattle management and other techniques that vary in management intensity (Adams et al., 1997; Alpert et al., 1997; Bernhardt and Swiecki 1997; Borchert 1990; Callaway 1992a,b; Gordon and Rice 1993; Griggs and Peterson 1997; Tyson 1996a,b; Janzen et al., 1997; Larsen and Johnson 1998; McCarthy 1993; McCreary and Tecklin 1997; Momen et al., 1994; Muick 1990, 1997; Parikh and Gale 1998; Phillips et al., 1997; Plumb and De Lasaux 1997; Rogers and Johnson 1998; Schwan et al., 1997; Standiford et al., 1997; Strong and George 1990; Swiecki et al., 1997a, b; Swiecki and Bernhardt 1998; Techlin et al., 1997.)

The key issue of the regeneration problem is that many diverse solutions have been identified and implemented (citations above). Management of oak recruitment can and has been successful; the challenge is in facilitating large-scale implementation, particularly in collaborating with private landowners that collectively hold the vast majority of oak woodland habitat.

Sudden Oak Death.

The newest challenge to our California oaks has emerged very dramatically. Tanoaks in Marin County were found to be dying in 1985 (Svihra 1999a,b,c). In 2000, pathologists. Dave Rizzo (UC Davis) and Matteo Garbelotto (UC Berkeley), isolated the pathogen and discovered it to be a previously undescribed species of *Phytophthora* (Standiford 2000). Species of *Phytophthora* caused the potato famine, have been attacking Port-Orford-cedar (*Cupressus lawsoniana*) to the risk of extinction (Hansen et al., 2000), have attacked Mediterranean oaks (Brasier 1996), have crippled alders (*Alnus* spp) in Europe (Cech 1998), devastated Eucalyptus forests in Australia (see Hansen 1999), and act as serious pests to innumerable agricultural crops worldwide (Erwin and Ribeiro 1996). Sudden Oak Death is actually a misnomer: the onset of symptoms is not sudden, the disease attacks many species other than oaks and it does not always result in death in these other species. Plant pathologists studying the pathogen have suggested that *Phytophthora canker* is a more accurate and appropriate common name (Rizzo and Garbelotto, pers. com.).

The *Phytophthora* species attacking California's oaks results in a suite of symptoms. The most telling symptom is the appearance of persistent cankers on the trunk and branches with areas of brown or black discolored outer bark, which exude a reddish sap ("sap bleeding"). In oaks, these cankers generally develop before foliate symptoms become evident. In other species, bay laurels, madrones, manzanitas, etc. the primary symptoms are leaf and twig dieback. Secondary infection with the fungus *Hypoxylon* sp., and attacks by bark and ambrosia beetles (Coleoptera: Scolytidae) are also common. On tanoaks, both stem and leaf tissue is infected and on these plants the leaves turn to brown suddenly and spectacularly (Svihra 1999, Standiford 2000).

This particular *Phytophthora*'s DNA did not match any known species, until a newly identified *Phytophthora, P. ramorum*, was described as a pathogen of rhododendrons in Europe (Werres et al. 2001). *Phytophthora ramorum* is closely related to *P. lateralis,* the *Phytophthora* responsible for Port Orford Cedar Dieback in southern Oregon and Northern California (Fimrite 2000).

Although *P. lateralis*, like *P. ramorum,* has been presumed to be an introduced pathogen (Hansen 2000), the propinquity of the two species and the extensive geographic distribution of *P. ramorum* raises some interesting questions. The origin of both species is unknown. *P. lateralis* has been found only in the Pacific Northwest of the United States and once in France (Hansen and Delatour 1999). Similarly, *P. ramorum* is known only from California and Oregon and from several nursery samples in Germany and the Netherlands. It is possible that that *P. ramorum* has been here all along but has suddenly become virulent or pathogenic (Fischer, 2001 Sudden Oak Death Update). Different *Phytophthora* spp. have been isolated from diseased oaks in California before this problem (Raabe 1990), but have not caused anything near the widespread death and infestation that this new pathogen is causing. Brasier (1996) argues that global warming has enhanced the oak decline in southern Europe, caused by *Phytophthora cinnamomi*. To date, adjacent valley oaks, blue oaks, and Oregon oaks show no symptoms of the SODS. Thus, it seems possible that, among oaks, only those oaks in the "Red" group, plus *Lithocarpus* tanoaks, (see Table 1; Tucker 1980) are susceptible, while those of the "White" Group are immune.

Phytophthora species are oomycetes and now placed in their own Kingdom, Chromista, with another genus (see Erwin and Ribeiro 1996), and are no longer considered true fungi because of their distinctive flagella and DNA. Their zoospores are mobile in moist soil and water, which can become resting spores (oospores and chlamydospores) in drier conditions. In the case of *P. lateralis*, the agent killing Port-Orford-cedar, the spores are easily transported by vehicles between watershed on the mud of tires, and by wildlife and cattle, as well as hikers and others in the woods.

Wildlife Conservation Society (WCS) Survey

During 2000 WCS investigated the geography of this new epidemic, called Sudden Oak Death Syndrome, or SODS. We surveyed the range of tanoak for the presence or absence of symptoms. The native range of tanoak runs along coastal forests in southern Oregon, down through coastal California to just north of Santa Barbara, with isolated populations in the Klamath Mountains and in the Sierras (Tappeiner et al., 1990). We combined roadside surveys with plot samples. Our preliminary results indicate that the disease is evident over some 350 miles of California coastal forest (Fig. 1). Presently, the northern boundary is at Humboldt Redwoods State Park, just south of Eureka, and symptomatic trees of all three species were found in regular patches along coastal forests to the Santa Lucia Range north of San Simeon (Fig. 1).

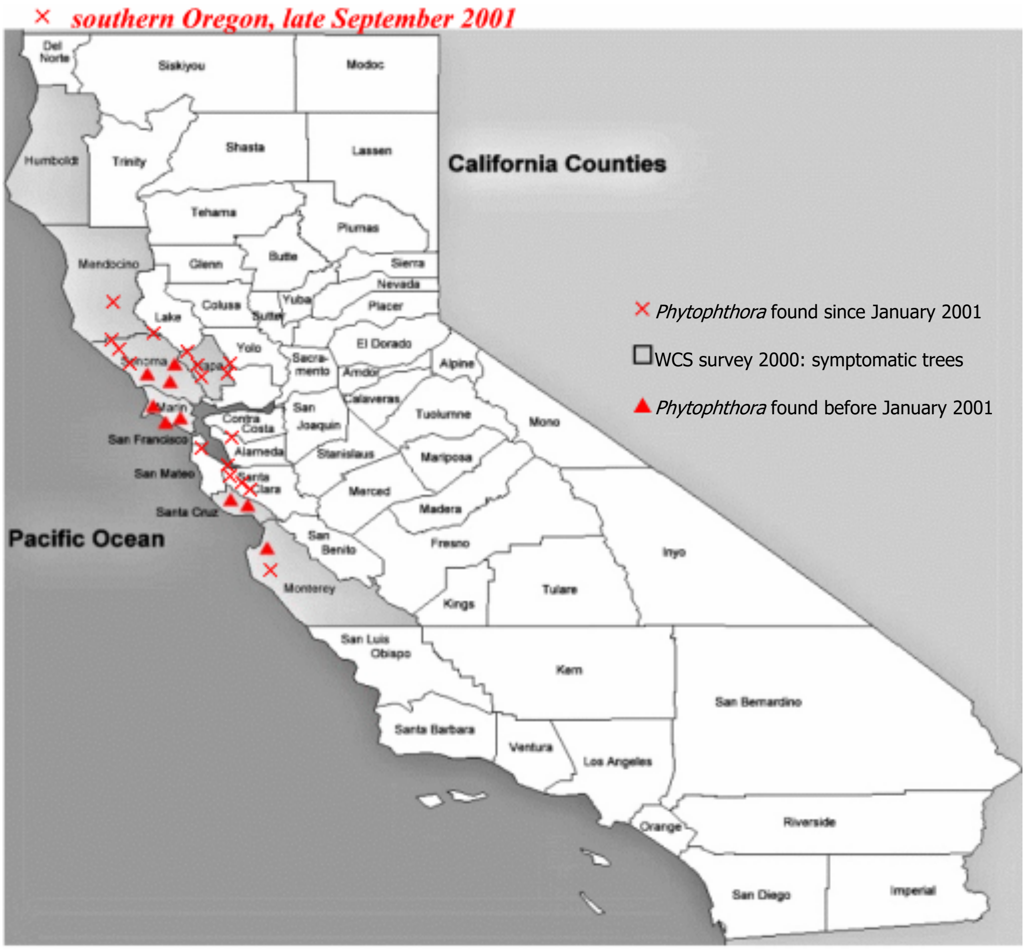

Fig. 1 WCS 2000 survey results

Our preliminary results also reveal considerable regional variation in the extent of the disease (Fig. 2 and Table 3). In northern California, we found that approximately 10 percent of the tanoaks have disease symptoms, whereas in Big Sur (Pfeiffer State Park) nearly 90 percent are dead or diseased. Other areas particularly hard hit (ca. 40-45% of trees are symptomatic or dead) are tanoaks at Muir Woods National Monument, coast live oaks at China Camp State Park (near San Rafael), and tanoaks at Henry Cowell Redwoods State Park (in Felton). It is clear that this pathogen has spread very quickly, in a fashion reminiscent of chestnut blight in North America. It is not all clear if healthy trees in infected have native resistance to the pathogen or have not yet been infected.

TABLE 3

Site	**Tanoak**	**Black Oak**	**Coast Live Oak**	**Interior Live Oak**	**Hybrid**
Humboldt Redwoods	9%	---	----	0%	---
Maillard Redwoods	8%	---	0%	---	---
China Camp	---	50%	30%	---	---

Site	**Tanoak**	**Black Oak**	**Coast Live Oak**	**Interior Live Oak**	**Hybrid**
Marin Watershed	43%	0%	9%	5%	---
Henry Cowell	51%	47%	---	---	---
Pfieffer-Big Sur	88%	---	61%	48%	100%
Los Padres	23%	---	0%	25%	9%

Percent symptomatic trees from 3 half hectare plots at each site

Geography of SODS symptoms, CA 2000

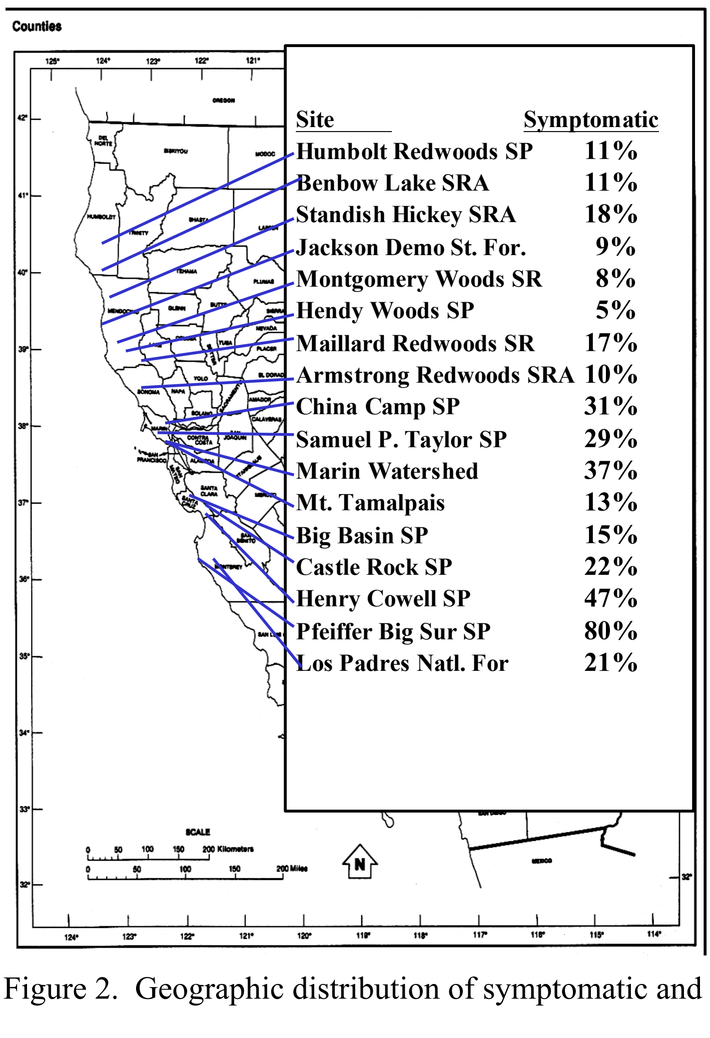

Figure 2. Geographic distribution of symptomatic and dying trees

The effect on wildlife to this dieoff of tanoaks and oaks in coastal California is inestimable. For example, with nearly 90% of tanoaks dead in Pfeiffer State Park in Big Sur, the loss of tanoaks to animals as diverse as black bear, deer, California quail, and

Steller's Jays, plus the several score of other species directly or indirectly dependent on acorns will be dramatic.

The joint concerns of lack of recruitment and the new SODS epidemic dramatically affect most of the nine *Quercus* oak tree species and tanoak in California (Table 1). Of these ten acorn bearing trees, fully seven have one or both of the problems, and black oak and coast live oak are afflicted by both (Table 1).

The striking need for progressive management of California's oak woodlands is challenging for those concerned with oaks and wildlife. Yet, it must be recognized that fully 85% of all oak woodlands are on private lands (Griffin and Muick 1990), and thus the capacity to manage professionally and consistently is challenging, to say the least. Working with private landowners is a significant and necessary challenge for conservationists (e.g., Knight 1999; Dale et al., 2000), but essential to guaranteeing a future of viable oak woodlands and wildlife in the future.

Recent volumes directly concerned with the California landscape have raised concerns of oak woodland viability, particularly the recruitment problem (Barbour et al., 1983; Pavlik et al., 1991; Johnston 1994). The Oaks of California by Pavlik et al. (1991) is a particularly beautiful and well-designed book.

Surprisingly, other recent assessments of biodiversity and environmental problems make no special mention of the major problems facing California's oak woodlands, particularly the recruitment problem (the Sudden Oak Death Syndrome is too new). For example, a major overview of imperiled ecosystems in the United States by Noss et al. (1995) has no significant discussion of California oaks, but cites only a 14% loss of hardwood woodlands (citing Bolsinger 1988), and cites the 99.9% loss of "riparian oak woodland" (those dominated by valley oak, citing Martin 1986). A two volume effort to assess the nation's biological resources by the U.S. Geologic Survey (Mac et al., 1998) makes scarce mention of oak woodlands in it's California section. The recent assessment of habitats and biodiversity by the *Nature Conservancy* (Stein et al., 2000) makes no particular mention of California's oak woodlands. Likewise, a major assessment of North America produced by the *World Wildlife Fund* (Ricketts et al., 1999) emphasizes much of California's distinctive endemic diversity, but again makes no particular mention of California's oak woodlands.

Conservation Action Recommendations

Specific recommendations for conservation action in the contexts of habitat protection and restoration, land management, research and monitoring, and policy action are offered here. Many of these recommendations follow those made by other organizations, or complement them. The goal of these recommended actions is to facilitate the restoration of oak woodland habitat, including prominently the successful recruitment of new oaks into habitats for future generations of the wildlife that depend on them. Only by restoring the processes involved in oak regeneration can oak woodland birds be secured a future, and thus avoid their listing as threatened or endangered species. It is our hope that these recommendations will help galvanize and guide the programs of conservation organizations, expenditures of government agencies, and the actions of private and public land managers.

Most recommendations are supported by data gathered and by a synthesis of ecological literature on oak woodlands. Some recommendations are, as of yet, poorly supported by research, and so can be tested through the use of research, monitoring, and adaptive management to determine whether new management strategies and restoration efforts indeed result from the suggested conservation recommendations.

As most (85%) of oak woodland habitat is on private land, the major emphasis is on informing land owners of the pervasive issue of oak woodland imminent decline because of lack of regeneration, and engaging in progressive land management activities that support the protection of large trees and the facilitation of regeneration.

Habitat Protection Recommendations

Objective 1: Insure the persistence of native animal species in oak woodlands through management and preservation of protected sites with success in oak regeneration

Recommendation 1-1. Identify oak woodland sites with oak regeneration occurring, particularly for sites with those oak species rarely reproducing (i.e., valley oak, blue oak, coast live oak)

Habitat Restoration Recommendations

Objective 2: Manage oak woodland habitat for successful recruitment of oaks; particularly valley oak, blue oak, tanoak, interior live oak and coast live oak.

Create incentives for private landowners to recruit oaks

Identify sites for the likely success of transplanted oak viability

Replace nonnative annual grasses with native perennial grasses

Discourage use of nest boxes (may encourage European Starling use).

Habitat/Landscape Management Recommendations

Conserve and protect remaining large oak trees

Use prescribed fires to reduce understory (particularly nonnative (annual grasses) and facilitate germination and growth of oak seedlings

Employ progressive grazing regimes to increase the possibility of successful oak tree regeneration

Limit deer populations in areas where natural predators have been extirpated

Prevent transport of infected plant material, soil and tools to uninfected sites

Monitoring/Research Recommendations

Identify minimum size thresholds of connected oak woodlands in urban and vineyard fragments. What densities of oaks are sufficient for occupation by which bird and mammal species?

Test a variety of management methods to facilitate oak regeneration of valley oak, blue oak, interior live oak and coast live oak

Urgent need to compare areas heavily affected by *Phytophthora* and contrast with those not, particularly for how acorn production is affected, and in turn, how that affects the diverse wildlife food chain.

Examine the ability of landscape-scale processes, like fire, to curtail the spread of *Phytophthora* and reduce inoculum levels in already infected environments

Determine levels of plant mortality and rate of spread in selected sites affected by the epidemic

Assess of the role of human activity in dispersing the pathogen.

Provide information to the public on the impact of this epidemic on wildlife

Review proposed management activities to insure that wildlife conservation measures are included.

Policy Recommendations

Enact action for the recently passed Assembly Bill No. 242. This bill enacts the Oak Woodland Conservation Act and provide funds for protection and conservation of oak woodlands throughout the state of California. This program is implemented by the State's Wildlife Conservation Board. It offer financial incentives to private landowners to protect and promote biologically functional oak woodlands over time. Conservation easements, land improvement, and public education and outreach are some of the proposed activities of this bill.

Large scale removal of oaks in intact oak woodlands should now be subject to the California Environmental Quality Act (CEQA) permit process in order to help regulate the accelerated loss of habitat fragments, particularly in the wine growing regions of Northern California.

The most important action with respect to this bill is to encourage and facilitate a broad program of oak regeneration across private lands statewide. Such an effort would be the most important legacy we can leave for future generations of Californians.

Large scale removal of oaks in intact oak woodlands should now be subject to the California Environmental Quality Act (CEQA) permit process in order to help regulate the accelerated loss of habitat fragments, particularly in the wine growing regions of Northern California.

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