The California Oak Disease and Arthropod (CODA) Database[1]

Tedmund J. Swiecki[2] Elizabeth A. Bernhardt[2] Richard A. Arnold[3]

Abstract: *The California Oak Disease and Arthropod (CODA) host index database is a compilation of information on agents that colonize or feed on oaks in California. Agents in the database include plant-feeding insects and mites, nematodes, microorganisms, viruses, and abiotic disease agents. CODA contains summarized information on hosts, agents, information sources, and the details of the host-agent interaction. Most of the 853 insect species in CODA are in the orders* Lepidoptera, Coleoptera, Hymenoptera, *and* Homoptera. *About 40 percent of the 378 species of fungi in CODA are pathogens. Of these, basidiomycete wood decay fungi have the most significant ecological impact.*

Landowners and resource managers need to consider the effects of diseases and arthropod pests on oaks when formulating management plans for oak woodlands or individual oaks. Over the past century, many different researchers have described a wide array of diseases and arthropods that affect oaks in California. However, the reports are found in numerous sources, many of which are not readily available to professionals involved with oak management in California.

As part of a project to study the impacts of diseases and arthropods on California rangeland oaks (Swiecki and others 1990, 1991a, 1991b), we set out to compile the existing information on agents affecting oaks in California. Our goal was to organize this information in a format that was readily accessible and easy to update. We developed a computerized database, the California Oak Disease and Arthropod (CODA) Host Index (Swiecki and others 1996), to store and organize preexisting and new information on arthropods, microorganisms, and abiotic factors that affect oak health in California.

Methods

Review of Literature and Unpublished Data

We obtained records for CODA from both published and unpublished sources. We reviewed numerous synoptic references and review articles and searched several computerized bibliographic databases, including AGRICOLA, BIOSIS, Entomological Abstracts, and CAB Abstracts, to obtain occurrence records. We subsequently checked most records against the original articles to verify each report and obtain additional information on the host-agent interaction.

Although we consulted nearly 2,000 publications during the literature review, our review of the literature was not necessarily complete for all groups of agents, particularly the insects. Because of time and budget constraints, we focused our initial efforts on groups of agents that were likely to cause noticeable damage to oaks. We restricted our initial search for arthropod records to phytophagous insects and mites, concentrating on taxa that are known pests of oaks or other deciduous trees in California and elsewhere. In searching for records on microbial agents, we concentrated our efforts on known or likely pathogens.

We also obtained unpublished records in the form of database files and card files from various sources, including the California Department of Food and Agriculture (CDFA); USDA Forest Service's Pacific Southwest Forest and Range Experiment Station [now Pacific Southwest Research Station]; Jerry Powell,

[1]An abbreviated version of this paper was presented at the Symposium on Oak Woodlands: Ecology, Management, and Urban Interface Issues, March 19-22, 1996, San Luis Obispo, Calif.

[2]Principals, Phytosphere Research, 1027 Davis Street, Vacaville, CA 95687

[3]President, Entomological Consulting Services, Ltd., 104 Mountain View Court, Pleasant Hill, CA 94523

Department of Entomology, University of California at Berkeley; and Isabelle Tavares, University Herbarium, University of California at Berkeley. We have also added records based on our own and others' collections and identifications. To date, we have contacted more than 125 entomologists, acarologists, plant pathologists, mycologists, and other specialists in taxonomy, forestry, and landscape pests, to supplement or confirm information obtained from the literature or other sources.

Database Design

The information in CODA is stored in a relational database composed of multiple DBase III-compatible files. The individual files store information on the host species, agents, specifics of the host-agent interaction, and the references that pertain to each combination. We developed a stand-alone software application for IBM-compatible personal computers that allows users to access the data in the CODA database (Swiecki and others 1990, 1996).

Much of the information in CODA is specific to each reported host-agent interaction, including the fields that describe the following: reported distribution of the host-agent interaction; types of growing situations (e.g., range, urban landscape) under which the interaction has been observed; host life stages attacked; host symptoms and agent signs, including the location and maturity of affected plant parts; whether the agent attacks healthy or compromised tissue; whether symptoms listed are a direct or indirect result of attack; and other notes about the interaction (*fig. 1*). Because of the limitations of available data, many records in CODA do not contain complete information in all of these fields.

CODA also contains information specific to each disease agent, host, and reference. Disease agents and arthropods are identified with hierarchical taxonomic and non-taxonomic codes. True taxonomic synonyms as well as other scientific names that have been encountered in the literature are listed in a synonym field for each agent. CODA also contains descriptions of the included oak host species, and full literature citations and descriptive notes for references (*fig. 1*).

Because of software limitations at the time that the program was developed, much of the host-agent interaction data is abbreviated or coded. All codes are described in the software documentation, and functions in the access program allow the user to translate all displayed codes on screen and in printed reports (*fig. 1*). These codes can be used in various combinations to filter records from the database.

We used Paradox® 5.0 for Windows database software (Borland International, Inc., Scotts Valley, Calif.) to tabulate statistics on the CODA database contents. Statistics are based on queries of the January 1996 version of the CODA database files.

Results and Discussion

The CODA Software

We released and distributed the first version of the CODA software in 1990. Since that time, we have edited and updated the information extensively and have released several different versions of the data and access program. As of February 1996, we had distributed more than 150 copies of the software.

The categories and format of the information stored in the CODA databases are shown in a sample report for one occurrence record (*fig. 1*). The information for a given record can be displayed on screen, sent to a printer, or saved to a text file.

Figure 1—Full-length report for the record of *Inonotus andersonii* on *Q. douglasii* printed from the CODA software.

```
Quercus douglasii                          Agent:  B P F BAS POL
Common: Blue oak                           Genus:  Inonotus
                                         Species:  andersonii
Distribution: BA,NV,CI,SV,CC               Subsp:
  Situation:  RL                          Common:  Canker-rot
     Stages:  3D                         Synonym:  Chromosporium pactolinum

                 Maturity   Site    Symptoms/Sign                                Status
-------------------------------------------------------------------------------------
    Flowers:
     Acorns:
     Leaves:
   Branches:        M        HW     WROT,PCANK,FAIL,TCANK,BRES                    1d
      Trunk:        M        HW     WROT,PCANK,FAIL,TCANK,BRES                    1d
      Roots:
-------------------------------------------------------------------------------------
  CODE DESCRIPTIONS:

Agent Codes:
  B      Biotic (Organisms, viruses, and genetic factors)
  P      Pathogens (disease-causing agents)
  F      Fungi
  BAS    Basidiomycetes
  POL    Polyporales (Polypores)

Distribution codes:
  BA     Bay area:  Alam,CCosta,Marin,Napa,SMateo,SFran,SClara,Solano,Sonoma
  NV     North Valley:  Butte,Colusa,Glenn,Lake,Sacto,Sutter,Tehama,Yolo,Yuba
  CI     Central Interior:  Alpne,Amadr,Calavrs,EDorad,Marip,Nev,Placer,Tuolum
  SV     South Valley:  Fresno,Kern,Kings,Madera,Merced,SJoaquin,Stanisls,Tulare
  CC     Central Coast:  Monterey,SBenito,SLuisObispo,SBarbara,SCruz,Ventura

Situation code:
  R      Range
  L      Landscape

Stage codes:
  3      Mature
  D      Dead

Maturity Codes:
  M      Mature tissues

Site Codes:
  H      Heartwood (older wood near center of stem)
  W      Wounds, includes fire scars, branch stubs, leaf scars, pruning wounds

Symptoms/Sign Codes:
  WROT   White rot (light-colored decay; spongy, stringy, crumbly, or brittle)
  PCANK  Perennial canker (discrete lesion that persists 2 or more years)
  FAIL   Failure (breakage or collapse of limbs, trunk or roots)
  TCANK  Target canker (regular, concentrically zonate perennial canker)
  BRES   Basidiocarp-resupinate (a sheet-like fruiting body)

Status Codes:
  1      Primary - agent attacks healthy tissue
  D      Direct symptom
-------------------------------------------------------------------------------------
  GENERAL NOTES:

-Observations suggest that various types of target cankers, especially those
associated with old branch stubs, may be caused by the interaction between
this fungus and certain trees.
-Probably one of the most significant causes of decay and mortality in blue
oak over much of its range. In the field, distribution of affected trees is
variable, and “hot spots” or disease foci may occur.
-------------------------------------------------------------------------------------
```

continued

Figure 1 continued

```
REFERENCES:

AUTHOR:   Swiecki, T. J.; Bernhardt, E. A.
 TITLE:   Field notes, observations, and collections
          1988-1992
SOURCE:
  DATE:   1988-92
NOTES:
These records are based on field observations and material collected from
various oak hosts by T. J. Swiecki and E. A. Bernhardt. Records of these
observations are on file at Phytosphere Research, 1027 Davis Street,
Vacaville, CA 95687-5495. Phone 707-452-8735. Some of the collected materials
were deposited at the UC Berkeley Herbarium.

AUTHOR:   Gilbertson, R. L.; Ryvarden, L.
 TITLE:   North American Polypores
SOURCE:   Fungiflora A/S, Oslo, Norway
  DATE:   1986
NOTES:
A two-volume monograph on the fungi in the Polyporales that occur in North
America. Contains keys to species, descriptions, notes on distribution,
cultural characteristics, type of rot caused, hosts, and other data.

AUTHOR:   Sinclair, W.A.; Lyon, H.H.; Johnson, W.T.
 TITLE:   Diseases of trees and shrubs.
SOURCE:   Cornell University Press, Ithaca, NY
  DATE:   1987
NOTES:
A general reference to diseases of trees and woody shrubs. Includes color
photographs of symptoms, descriptions of causal agents, disease cycles,
distribution, host range, and other information.
```

```
 AGENT NOTES:

-Widely distributed in U.S., to PA, WI, TX, AZ, CA and OR on Quercus,
Populus, Salix, and Carya.
-Causes a white rot of the heartwood of living oaks. Bark cankers are formed
where the fungus invades and kills the sapwood and cambium. Cankers are a
common site of branch or trunk failure. Infection typically occurs at wounds,
especially branch stubs.
-Basidiocarps are annual, sheetlike, often large (to over 50 cm long), and
develop under outer layers of sapwood or bark. The bark and/or sapwood is
ruptured by the basidiocarp as it matures. Spore deposits are bright golden
yellow.
```

```
 HOST NOTES:

-Subgenus Quercus (Lepidobalanus): White oaks
-Also called mountain white oak, iron oak, post oak
-Deciduous tree with rounded crown, 6-20 m high.
-Endemic to California, blue oak grows on dry rocky slopes of foothills of
Sierra Nevada and Coast Ranges from Shasta Co to Los Angeles Co. Also extends
well out onto valley floors in areas, such as near Burch Creek and the
Sacramento River (Tehama Co) and near Thornton (San Joaquin Co).
-Bark checked, light gray to almost white.
-Leaves 3-6(-8) cm long with petiole 3-9 mm, shallowly and irregularly lobed
or entire, minutely pubescent, dull bluish green above, paler below.
-Acorns maturing the first year, variable in shape, commonly ovoid, nut 2-3
cm long, cap 12-20 mm wide, 6-10 mm deep cup to bowl shaped, scales slightly
tubercled.
-Hybridizes with Q. garryana, Q. john-tuckeri, Q. lobata.
```

Organizing the information found in CODA as a computer database application provides several advantages over presenting the same information in the form of a publication. Many of the records in CODA describe one-to-many relationships, such as an agent which occurs on many oak species. These relationships are easily organized and displayed with relational database software, but are difficult to present as printed material. By using functions built into the CODA software, the CODA databases can be filtered or queried easily to produce subsets of data. This allows the database to be used as a simple expert

system for diagnosing pest and disease problems. To remain current, the information in CODA needs to be updated periodically to account for taxonomic changes and add new records and additional details. Compared with a lengthy publication, a database can be updated and distributed to users more quickly, easily, and at a lower cost.

We designed the database to easily handle simple changes in agent names. However, more complex changes, such as those that involve the lumping or splitting of taxa, require careful examination of existing records to avoid introducing inaccuracies into the database. For example, agents originally described as occurring on *Q. dumosa* Nutt. needed to be reassigned to either *Q. dumosa* (strict sense) or *Q. berberidifolia* Liebm. after the taxonomic status of this species was revised (Hickman 1993). Some records contained enough detail to be reassigned definitively, but many records could not be reassigned and have been retained provisionally under a separate host entry for the wide sense of *Q. dumosa*.

In addition to updating the data in CODA, it will also be necessary to periodically revise the user interface. The current interface software runs readily on most platforms that can run DOS applications, and 87 percent of the respondents to our 1993 user survey (Swiecki 1993) rated the program as easy or very easy to use.

CODA Host Index Statistics

The databases that comprise CODA contain information on 45 native and cultivated oak species in California, 1,259 agents that affect these oaks, and 320 references that describe these interactions. CODA contains information on 2,619 individual interactions between oaks and biotic or abiotic agents.

Native Host Oak Species

Of the oaks listed in CODA, 20 species, along with eight varieties and hybrids, are native to California. The oak species with the greatest numbers of associated agent records are listed in *table 1*. The number of agents listed for each oak species in CODA is a function of the total amount of arthropod and microbial biodiversity associated with each host species and the degree to which each host has been studied by researchers. For example, many of the arthropod records reported for *Q. agrifolia* are lepidoptera that have been collected or reared from this oak by Jerry Powell and his students over a 30-year period. If complete surveys of each oak species were conducted, it is likely that the number of agents associated with most of the native oak species would increase substantially.

Table 1—Counts of agents associated with the certain California tree oak species listed in the CODA database as of January 1996

Oak species	Arthropod species and subspecies	Diseases and microbial agents	Total number of agents
Q. agrifolia	299	148	447
Q. chrysolepis	111	58	169
Q. douglasii	141	50	191
Q. garryana	94	14	108
Q. kelloggii	150	85	235
Q. lobata	155	54	209
Q. wislizenii	132	33	165
Not specified	357	208	565

Arthropods

CODA currently contains records for 1,788 insect-oak interactions and an additional 52 interactions between plant-feeding mites and oaks. These interactions involve 853 species of insects and mites, representing 14 orders and more than 120 families (*table 2*). Although most of the conspicuous oak-feeding arthropods are included in CODA, further searching of host records for certain insect taxa would probably yield some additional records. However, some likely occurrences have not been added to CODA because the reports do not specifically indicate that the interaction has been observed in California. Many reports in the entomological literature provide only general locality information, such as western United States or Pacific Coast, and general host information, such as *Quercus* sp., and we have not included these general listings in CODA. Therefore, the total number of arthropod species that feed on oaks in California is probably much higher than the current total contained in CODA.

Table 2—Counts of families, genera, and species of mites and insects known to feed on* Quercus *in California, listed in the CODA database as of January 1996[1]

Order	Common name	Families	Genera	Species
Acarina	Mites	4	18	32
Microcoryphia	Bristletails	1	1	1
Embioptera	Webspinners	1	1	1
Phasmatodea	Walkingsticks	1	1	1
Orthoptera	Grasshoppers, crickets, katydids	1	3	3
Isoptera	Termites	2	3	3
Psocoptera	Booklice, barklice	6	8	8
Hemiptera	True bugs	6	9	12
Homoptera	Cicadas, leafhoppers, aphids, scales	16	69	137
Thysanoptera	Thrips	3	20	21
Coleoptera	Beetles	24	105	194
Hymenoptera	Bees, ants, wasps	13	52	172
Lepidoptera	Butterflies, moths	36	122	290
Diptera	Flies	7	11	11
Totals		121	423	853

[1]Ordinal arrangement follows Arnett 1985.

Within the CODA database, the orders Hymenoptera, Lepidoptera, Coleoptera, and Homoptera are represented by the greatest number of species. The most taxonomically diverse collection of oak-feeders is found within the Lepidoptera, which has representatives from 36 families. Most of these are leaf-mining and external foliar-feeding moths. The arthropod family represented by the greatest number of species (126) is the Cynipidae. These are highly specialized gall-forming wasps.

Few non-phytophagous arthropods are currently represented in CODA. However, only a portion of the arthropods that are associated with oaks would be classified as oak feeders. Many insects are predaceous or parasitic on oak-feeding insects and therefore indirectly depend on oaks for their existence. Also, numerous arthropods that do not feed directly on oaks live in tunnels or galls produced by oak-feeding insects. Additional insects are associated with the fungi that colonize living or dead oaks. Still other insects are detritus feeders that opportunistically feed on decaying wood, but are not necessarily limited to oaks. If these additional species are considered, there may be between 4,000 and 5,000 arthropod species associated with California oaks. This total is more than 10 times the number of terrestrial vertebrates found in oak-dominated hardwood rangeland in California (Guisti and others 1996).

Diseases and Microbial Interactions

CODA contains records of 766 interactions between *Quercus* species and abiotic diseases, and saprophytic, pathogenic, or beneficial microorganisms. Although representatives from almost all of the major groups of plant pathogens are represented in CODA, 97 percent of the microorganisms listed in CODA are fungi. Counts of non-fungal disease agents in the CODA database that are reported to affect California oaks are listed below:

Agent	*Count*
Bacteria	1
Viruses	2
Vascular plants	5
Nematodes	13
Genetic diseases	1
Abiotic agents	6
Total	28

No oak diseases caused by phytoplasmas (plant-infecting spiroplasmas and mycoplasma-like organisms) are currently included in CODA, although such agents have been found in many woody species, including oaks in the eastern United States (Sinclair and others 1994). Undoubtedly, more nonfungal microbial agents are associated with oaks in California than are currently reported. However, detecting and identifying many of these agents, including bacteria, viruses, and phytoplasmas, are difficult and require specialized techniques. Additional diseases involving nonfungal agents are unlikely to be reported in the absence of targeted research in this area.

The fungi are the best characterized group of microoganisms associated with oaks in California, largely because many fungal fruiting bodies are easy to observe and collect. Many of the associations between oaks and fungi included in CODA have not been published and are known only through herbarium records. Primary pathogens, secondary or opportunistic pathogens, saprophytes, and mycorrhizal species are all represented among the fungi in CODA *(table 3)*. Although a few individual oak diseases have been studied in some detail, most interactions between California oaks and fungi remain unexplored, and the oak-associated mycoflora probably includes many more species than are currently reported.

Table 3—Counts of fungal species associated with* Quercus *in California, subtotaled by taxonomic group[1] and ecological niche, listed in the CODA database as of January 1996

Taxonomic group	Pathogenic species	Saprophytic species	Mycorrhizal species	Not specified	Totals
Myxomycota					
Myxomycetes	0	11	0	0	11
Eumycota					
Mastigomycotina					
Oomycetes	6	0	0	0	6
Ascomycotina	52	67	0	1	120
Basidiomycotina	33	102	10	2	147
Deuteromycotina	65	25	1	3	94
Totals	156	205	11	6	378

[1]Taxonomic arrangement follows Farr and others (1989).

Damage to Oaks Caused by Arthropods and Diseases

Arthropods

Insects and mites feed on every part of oak trees and attack all life stages of oaks in California, but arthropod damage records for mature oaks far outnumber those for seedlings and saplings. Part of this difference is almost certainly due to the fact that mature trees have been studied in greater detail. In addition, mature trees provide a greater quantity and wider variety of arthropod feeding sites than do seedlings or saplings. For blue oak (*Q. douglasii* Hook. & Arn.), Swiecki and others (1990) observed fewer insect taxa feeding on small seedlings than on adjacent overstory trees over several seasons.

Most of the arthropods that attack oaks are native species that appear to be in ecological equilibrium with their hosts. Their aggregate impact on oak health and survival appears to be low when trees are growing under favorable conditions. However, the impact of insect and mite damage may be much more significant when oaks are stressed, wounded, or otherwise disturbed. This is especially true for insects such as bark beetles (*Scolytidae*) and wood borers. Furthermore, although much of the damage caused by insects does not significantly affect oak survival, the damage, insects, and/or their by-products (honeydew, fecal pellets, etc.) may not be tolerated in urban situations.

Insects that damage acorns can have a significant impact on this vulnerable oak life stage. CODA includes 14 insect species in seven genera which feed on or form galls in or on acorns. Of these, the filbertworm (*Cydia latiferreana* [Walshingham]) and three species of filbert weevils (*Curculio* spp.) are most destructive and may destroy a large percentage of the mast crop within a location in a given year (Keen 1958; Swiecki and others 1990, 1991a). Thus, even though relatively few species of insects damage acorns, their impact on oak reproduction can be substantial.

In contrast, at least 350 insect species feed on or produce galls on oak leaves, but the aggregate impact of these insects on the long-term health of mature oaks is generally considered to be minor. Only a few species, such as the California oak moth (*Phryganidia californica* Packard) and the fruit tree leaf roller (*Archips argyrospilus* [Wlk.]), are capable of defoliating entire trees or stands of trees. However, these and other moth larvae typically do not cause severe defoliation in successive years, and outbreaks are usually of short duration, so long-term damage to oaks is generally minimal if trees are not also stressed by other agents or factors.

Diseases

The diseases that have the greatest potential to affect the reproduction and survival of California oaks are those caused by acorn pathogens and wood-decay fungi. Both fungi (Swiecki and others 1990, 1991a) and bacteria (Hildebrand and Schroth 1967) cause decay of acorns. These pathogens most frequently gain entry through wounds caused by insects, but acorns are often severely decayed even when insect damage is slight (Swiecki and others 1990, 1991a). As a result of this synergism between microorganisms and insects, damage to the acorn crop may be elevated beyond levels that would exist if these agents acted independently. Acorn-decaying pathogens are one of several groups of acorn-destroying agents that collectively reduce the reproductive potential of California oaks.

Various species of wood-decay fungi, primarily in the Polyporales, constitute the most significant oak pathogens in California. CODA includes more than 40 species of fungi that cause branch or trunk cankers or decay the trunk, root crown, or roots of oaks growing under natural conditions. Canker rot fungi, including several species of *Inonotus*, are important pathogens of blue oak and other oaks in both rangeland (Swiecki and others 1990, 1991b) and urban settings. Canker rot fungi are wood decay fungi that attack living trees and also kill

phloem and vascular cambium, giving rise to perennial cankers (Sinclair and others 1987). Trees colonized by canker rot fungi usually decline slowly and literally fall apart as large branches, and eventually the trunk, fail.

Mature oaks are also killed by root-rotting fungi. Certain fungi, such as *Armillaria mellea* and *Phytophthora* spp., are significant pathogens of urban oaks that are subjected to summer irrigation and stressed by other rootzone disturbances. Other fungi, including species of *Ganoderma* and several other fungi in the Basidiomycotina, kill mature oaks in undisturbed stands as well as those which become incorporated into urban landscapes.

In addition to causing tree mortality, wood-decay fungi also reduce the quantity and quality of wood products that may be harvested from a stand. On the other hand, these fungi play a direct role in improving wildlife habitat value. Decay caused by these fungi aids in the development of cavities in trees, which are utilized by a number of different vertebrate species. Wood-decay fungi affect the amount of dead and downed wood and standing snags in an oak woodland, which in turn contribute to wildlife habitat value (Tietje and others, these proceedings).

At least 40 species of fungi attack the leaves and/or twigs of living oaks in California. The most common and conspicuous of these are the powdery mildews (*Erysiphales*) and the anthracnose fungi. Symptoms caused by these fungi are sometimes severe enough in urban oaks to prompt concern, but these fungi normally have little impact on long-term health or survival of oaks in either urban or rangeland conditions.

Conclusions

Our knowledge and understanding of the interactions between oaks and their associated arthropods and microorganisms will continue to expand only if researchers, resource managers, consultants, and landowners recognize and exchange information on these interactions. CODA provides a means for collecting, organizing, and distributing information on these interactions. However, the CODA software must be distributed, supported, and maintained if it is to remain a useful resource.

Acknowledgments

Development and distribution of CODA through July 1993 was supported by California Department of Forestry and Fire Protection Strategic Planning Program contracts 8CA74545 and 8CA17093. Jim Kellogg, Tierra Data Systems, Reedley, Calif., wrote the CODA database access program. We thank the many researchers and taxonomists who provided information on agents occurring on oaks in California. We are especially grateful to Jerry Powell, Isabelle Tavares, Tim Tidwell, Raymond Gill, Fred Andrews, Alan Hardy, John Stein, and Melvin McKnight, who provided access to unpublished University of California, California Department of Food and Agriculture, and Pacific Southwest Research Station records. We thank Dale Woods and Dave Wood for their helpful comments on earlier drafts of this paper.

References

Arnett, R.H., Jr. 1985. **American insects; a handbook of the insects of America north of Mexico**. New York: Van Nostrand Reinhold Co.; 850 p.

Farr, D.F.; Bills, G.F.; Chamuris, G.P.; Rossman, A.Y. 1989. **Fungi on plants and plant products in the United States**. St. Paul, MN: The American Phytopathological Society; 1252 p.

Guisti, Gregory A.; Scott, Thomas A.; Garrison, Barrett A. 1996. **Oak woodland wildlife ecology and habitat relationships**. In: Standiford, R.B.; Tinnin, P., tech. coord. Guidelines for managing California's hardwood rangelands. Publication 3368. Berkeley, CA: University of California Division of Agriculture and Natural Resources.

Hickman, James C., ed. 1993. **The Jepson manual: higher plants of California**. Berkeley: University of California Press; 1,400 p.

Hildebrand, D.C.; Schroth, M.N. 1967. **A new species of *Erwinia* causing drippy nut of live oaks**. Phytopathology 57: 250-253.

Keen, F.P. 1958. **Cone and seed insects of western forest trees**. Tech. Bull. 1169. Washington, DC: U.S. Department of Agriculture.

Sinclair, Wayne A.; Lyon, Howard H.; Johnson, Warren T. 1987. **Diseases of trees and shrubs**. Ithaca, NY: Cornell University Press; 574 p.

Sinclair, Wayne A.; Griffith, Helen M.; Lee, Ing-Ming. 1994. **Mycoplasma-like organisms as causes of slow growth and decline of trees and shrubs**. Journal of Arboriculture 20(3): 176-189.

Swiecki, Tedmund J. 1993. **Support services to manage distribution of the California Oak Disease and Arthropod (CODA) Host Index Database**. Final Report. Prepared for: California Department of Forestry and Fire Protection, Strategic Planning Program, Sacramento, CA. 6 p.

Swiecki, Tedmund J.; Bernhardt, Elizabeth A.; Arnold, Richard A. 1990. **Impacts of diseases and arthropods on California's rangeland oaks**. Prepared for: California Department of Forestry and Fire Protection, Forest and Rangeland Resources Assessment Program, Sacramento, CA. 94 p. plus appendix.

Swiecki, Tedmund J.; Bernhardt, Elizabeth A.; Arnold, Richard A. 1991a. **Insect and disease impacts on blue oak seedlings and acorns**. In: Standiford, Richard B., tech. coord. Proceedings of the symposium on oak woodlands and hardwood rangeland management; October 31 - November 2, 1990; Davis, CA. Gen. Tech. Rep. PSW-126. Berkeley, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture; 149-155.

Swiecki, Tedmund J.; Bernhardt, Elizabeth A.; Arnold, Richard A. 1991b. **Monitoring insect and disease impacts on rangeland oaks in California**. In: Standiford, Richard B., tech. coord. Proceedings of the symposium on oak woodlands and hardwood rangeland management; October 31 - November 2, 1990; Davis, CA. Gen. Tech. Rep. PSW-126. Berkeley, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture; 208-213.

Swiecki, T.J.; Bernhardt, E.A.; Arnold, R.A.; Kellogg, J. **CODA - California Oak Disease and Arthropod Host Index Database, Version 3.3, Release 1/96** [Computer program]. 1996. Vacaville, CA: Phytosphere Research. DBase III database files and compiled access program, for IBM-compatible personal computers. Available from: Phytosphere Research, 1027 Davis Street, Vacaville, CA 95687.

Tietje, William; Berlund, Tristan; Garcia, Sergio; Halpin, Chris; Jensen, Wayne. 1997. **Contribution of downed woody material by blue, valley, and coast live oaks in coastal California**. [These proceedings].