Chapter 2.2
Forest Pests and Other Threats to Ecosystem Health and Community Safety

A healthy forest landscape has the capacity for renewal and for recovery from a wide range of disturbances, while continuing to provide public benefits and ecosystem services. Threats to forest health include insects, disease, invasive plant and animal species, air pollution and climate change. Assessments should identify high value forest landscape areas that are especially vulnerable to existing or potential, forest health risk factors, where forest management practices are most likely to prevent and mitigate impacts. Assessments should also identify areas where management could successfully restore impacted forests (excerpted from the U.S. Forest Service State and Private Forestry Farm Bill Requirement and Redesign Strategies).

KEY FINDINGS

Current Status and Trends

- The term "forest pests," as used in this assessment, refers to both forest insects and diseases.
- Over the past five decades, the number of exotic pests has increased from 10 to 33 percent of pests considered significant in California.
- Native bark beetles and wood borers remain a high priority, however, non-native diseases and insects such as sudden oak death, pitch canker disease, the goldspotted oak borer and the light brown apple moth are currently of major concern to California forest pest management agencies.

- Certain non-native pests may have not impacted large acreages thus far, but have the potential to spread and may already have caused significant local impacts on forest ecosystems.
- Forest pests cause major damage resulting in significant public and private costs and losses. For example, Congress provided over $225 million over three years to address hazards from bark beetle killed trees in Southern California.
- These risks are increasing rapidly and additional resources that work across all lands are needed.
- The goldspotted oak borer (GSOB) is an emerging non-native pest in San Diego County that is of great concern to forest pest management staffs.
- Bark beetles and wood borers (i.e., GSOB) in the South Coast and Sierra bioregions and sudden oak death (SOD) in the San Francisco Bay Area and along the north coast are major issues; Zones of Infestation have been declared to address many of these concerns.

Restoring Forest Pest Impacted Areas to Maintain Ecosystem Health

The priority landscape identified represents forest pest impacted ecosystems where restoration activities are most needed.

- There are over six million acres of priority landscapes that are impacted by forest pests in California, with 31 percent of these ranked as high. Seventy-five percent of priority landscapes are on lands managed by the U.S. Forest Service (USFS) and 18 percent are on privately owned lands.
- Sierran Mixed Conifer (SMC), Eastside Pine (EPN), Red Fir (RFR) and White Fir (WFR) are the habitat types with the most priority acres.
- White Fir had the largest proportion of its habitat identified as a priority landscape (43 percent), and almost 240,000 acres (26 percent) designated as high priority. Twenty-eight percent of RFR was designated as high.

Restoring Forest Pest Impacted Communities for Public Safety

The identified priority landscape represents areas of tree mortality coincident with human infrastructure such as houses, roads and transmission lines, where falling trees are a public safety issue and restoration activities are most needed.

- The South Coast, Bay/Delta and Sierra bioregions comprise 98 percent of high priority areas and 83 percent of priority landscapes.
- San Bernardino, Sonoma, San Diego, Riverside and Placer Counties have over half of the priority landscapes. San Bernardino County alone has almost 60 percent of the highest priority acres.

Preventing Forest Pest Outbreaks to Maintain Ecosystem Health

The priority landscape identified here represents ecosystems most at risk from mortality potentially caused by future outbreaks.

- Almost 95 percent of priority landscape acres are in three bioregions; the Klamath/North Coast (48 percent), Sierra (33 percent) and Modoc (13 percent).
- Two-thirds of areas at risk are U.S. Forest Service lands, one-third are private.
- White Fir (30 percent), RFR (29 percent) and Lodgepole Pine (LPN) (16 percent) are the WHR habitats most at risk (high plus medium priorities) from future tree mortality. These results are partially supported by findings from the previous analysis, which identifies these types as having significant pest activity over the last 15 years.
- Montane Hardwood (MHW), which includes much of the tanoak at risk from SOD, is the habitat with the most total priority landscape acres in the Klamath/North Coast bioregion. RFR, Ponderosa Pine

(PPN), and WFR are the most at risk in the Sierra bioregion.

Preventing Forest Pest Outbreaks for Community Safety

A priority landscape was identified that represents communities most at risk for damage from future outbreaks.

- Over 82,000 acres of community infrastructure are found to be at risk from future forest pest outbreaks.
- Magalia, South Lake Tahoe, Paradise and Truckee are the largest communities identified as priorities for forest pest prevention activities.

Threats from Non-Native Invasive Plant Species

- People are a major conduit for seed movement and the number of non-native weeds found in California has increased with population growth.
- High priority for control or eradication is placed on invasive plants that disrupt ecosystem processes.

Air Pollution Threats to Ecosystems

- The primary air pollutants impacting ecosystems are ozone and airborne fertilizing or acidifying substances.
- These pollutants are generally local in nature and are affecting ecosystems mostly in three bioregions: South Coast, Sierra (southern) and Mojave.
- Trends of these pollutants are decreasing or flat, although many areas still do not meet federal or state air quality standards.

THREATS FROM FOREST PESTS

Current and Historical Trends

The term forest pest, as used in this assessment, refers to both forest insects and diseases. A review of current and historical trends (1949–present) in forest pest outbreaks is helpful in determining priorities for future forest pest management activities.

Native bark beetles, wood borers, defoliators and diseases remain a priority. However, the ratio of exotic (non-native) pests to native pests has been increasing over time (Figure 2.2.1). Currently, up to one-third of the total number of significant pests are now non-native to California. These risks are increasing rapidly and additional resources that can work across all lands are needed.

Movement of both native and non-native pests around the state, and from outside of California into the state, remains a major concern. The unregulated movement of firewood through California, transportation of nursery material, and movement of infested soil on vehicles and hiking boots can transfer forest pests. Damage and mortality caused by forest pests have had significant impacts on ecosystem health, public safety, commercial forests, water, wildlife and wildfire occurrence. Sixty years of data on forest pests in California reveal certain trends among forest pest issues (California Forest Pest Control reports, 1949–2008).

Native Forest Pests

California forests can be affected by many different native forest pests, including the native bark beetles and wood borers, native defoliators and native diseases. For a more complete list of native forest pests in California, see http://frap.fire.ca.gov/assessment2010/2.2_forest_health.html.

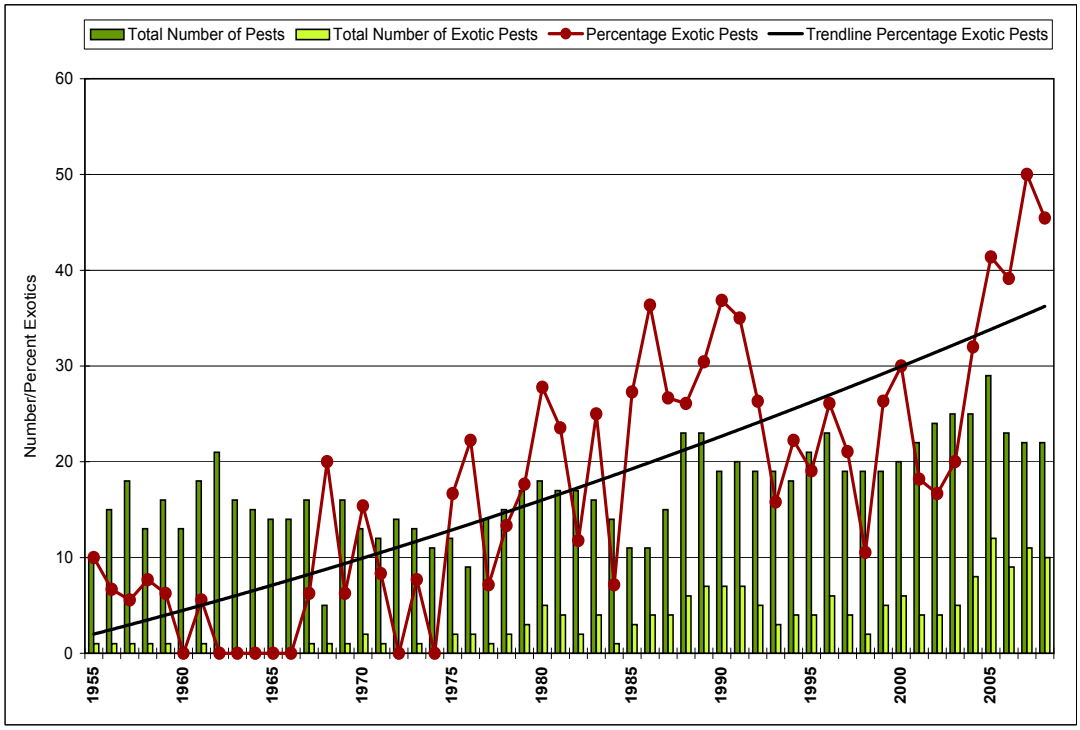


Figure 2.2.1.
Native and exotic pest occurrence in California 1955–2008.
Source: California Forest Pest Conditions Report, California Forest Pest Council, 2009

Native Bark Beetles and Wood Borers

- Bark beetles and wood boring insects have undergone periodic outbreaks nearly every decade, often related to several years of drought (California Forest Pest Conditions Reports 1949–2008).
- Currently there are elevated levels of activity of fir engraver, western pine, Ips and red turpentine beetles throughout the South Coast and Sierra bioregions, and other areas of the state.
- In 2003, Congress provided over $225 million over three years to address hazards from bark beetle killed trees in Southern California, allowing agencies to remove over 1.5 million dead trees.
- Areas of attack tend to be in stands under extreme stress due to root disease, other insect and disease impacts, or severe local soil moisture stress and dense overstocked stands.
- Alterations in forest stand structure and composition away from pine and towards younger true firs, in some areas, have increased the spread of forest pests (Parker et al., 2006).
- Lack of sawmills in some areas and historically low wood prices have left many spot infestations untreated and growing rapidly.

Native Defoliator Insects

- Most outbreaks of defoliators are localized and cyclical in nature and do not occur on a statewide basis.
- Periodic outbreaks have occurred of the Douglas-fir tussock moth, the fruit tree leaf roller, the California oak worm, fall webworms and tent caterpillars.
- Some outbreaks have been nearly continual, such as the ongoing outbreak of the lodgepole needleminer in the Yosemite National Park area and the Modoc budworm in the Modoc bioregion.
- Douglas-fir tussock moth outbreaks recently occurred in the northern end of the state, defoliating true firs in the Mount Shasta area
- A severe outbreak of fruit tree leaf roller recently defoliated thousands of acres of oaks in the San Bernardino Mountains.

Native Diseases

- Root diseases and dwarf mistletoes are found throughout the state's coniferous forests.
- The outbreak of bark beetles in Southern California from 2001 through 2004 has led to an increasing concern about the potential lack of consistent borax stump treatment, which may lead to future root disease pockets in the South Coast bioregion.
- Damage from diseases often leads to attacks by other forest pests that can kill the affected trees more quickly.
- Cytospora canker regularly impacts fir trees infected with dwarf mistletoe but is often not seen until periods of drought stress.
- Needle casts and elytroderma needle blight outbreaks have often been associated with periods of high moisture.

Non-Native Forest Pests

Exotics have killed millions of trees in California, causing significant commercial, aesthetic, economic and environmental impacts. Unlike native pests, non-native insects and diseases have no natural enemies that help control outbreaks, and local host species often have not evolved built-in defenses to repel them. The growing number of non-native introductions of both insects and diseases remains a great concern to ecosystem health in the state. Certain exotic pests may not have impacted large acreages so far but have the potential to spread and may already have significant local impacts on forest ecosystems. Rapid recognition and quick control efforts are key strategies to reduce the impacts from non-native forest pests.

Pitch canker disease, sudden oak death, white pine blister rust and Port-Orford-cedar root disease are examples of non-native diseases currently of major concern in California. The potential for spread and impact of the gypsy moth, the light brown apple moth, the goldspotted oak borer and exotic bark beetles is also a major concern.

Sudden Oak Death

- Sudden oak death has killed millions of tanoak and live oak trees throughout the Zone of Infestation (ZOI) along the coast of California.
- The pathogen that causes SOD can also infect the foliage and twigs of over a hundred other species, which does not kill these species, but can lead to increased spread.
- Sudden oak death continues to slowly spread northward through previously uninfected stands within its potential host range.
- Many species are stressed by the disease, opening up the potential for attack by other pests and building up fuel loads for potential wildfires.

Pitch Canker

- Pitch canker remains an ongoing pest problem in California.
- The disease has killed thousands of Monterey pines as well as bishop pine and knobcone pine along the central coast of California, with isolated infestations in Southern California. Most commonly, however, the disease just kills the terminal leaders of the infected trees.
- The disease continues to spread to stands that were not previously infected with the pathogen.

Light Brown Apple Moth

- This non-native defoliator insect from Australia and New Zealand poses the potential for significant damage, since it has a host range of over a thousand known species that includes most commercial timber species, as well as the majority of commercial crops grown in California.

Other Non-Native Insects and Diseases

- Bark beetles, such as the banded elm bark beetle, the Mediterranean pine engraver beetle and redhaired pine bark beetle, all have potential for spread and impact on California's native and urban forest landscapes.
- The goldspotted oak borer (GSOB) cover an area of about thirty square miles in the interior of San Diego County and has killed over three

quarters of the mature black oak and coast live oak in the impacted area.

- White pine blister rust is thought to be gradually moving south through the range of sugar pine and into higher elevation five needle pine species.
- Port-Orford-cedar root disease has largely filled in its potential range in California, making it an ongoing management challenge.

California Forest Pest Regulations

Regulations governing forest pest management can be found in Sections 4712–4718 of the Public Resources Code (PRC) of California.

- These sections declare that "bark beetles, other insect pests or plant diseases which are harmful, detrimental and injurious to timber or forest growth are a public nuisance."
- In California, non-native forest pests are regulated by the USDA and California Department of Food and Agriculture, who work to keep non-native pests out of the state and attempt to control or eradicate them.
- When exotic forest pests become established or are declared to be not actionable, responsibility for their control often falls to the California Department of Forestry and Fire Protection (CAL FIRE) on state and privately owned lands and the U.S. Forest Service on federal lands.
- Forest Pest Management rules allow or require:
  - emergency harvesting of infected, infested or damaged timber;
  - sanitation removal of insect or disease attacked trees to maintain or improve the health of a stand;
  - salvage removal of trees killed by pests or other causes;
  - timber operations are to be conducted in a manner that minimizes the build-up of destructive insect populations or the spread of forest diseases;
  - forest plans include mitigation for pests for properties in a Zone of Infestation.

CAL FIRE, with the approval of the California Board of Forestry and Fire Protection (BOF) can declare a Zone of Infestation for native and exotic insect and disease pests. Within a Zone of Infestation CAL FIRE employees may go on private lands to attempt eradication or control in a manner approved by the BOF. At present, there are Zones of Infestation for bark beetles in the Lake Tahoe basin and the Southern California mountains. Zones of Infestation also exist for the impacted counties in the state where sudden oak death and pitch canker are found (Figure 2.2.2).

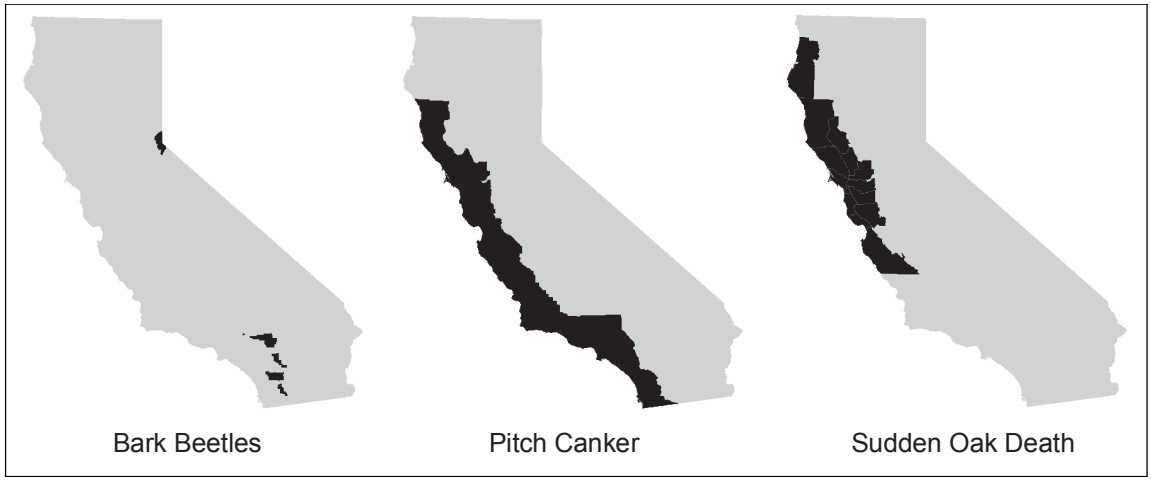


Figure 2.2.2.
State declared zones of infestation.
Data Source: Zones of Infestation, CAL FIRE, 2009

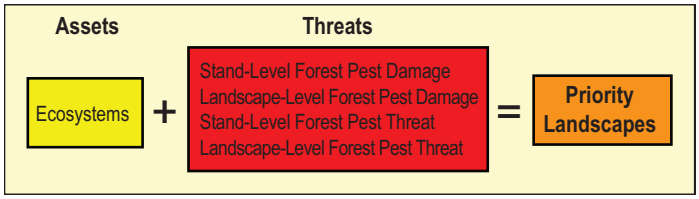
RESTORING FOREST PEST IMPACTED AREAS TO MAINTAIN ECOSYSTEM HEALTH

Prioritizing areas for restoration after major forest pest outbreaks is critical if California is to use scarce resources effectively, given the myriad of forest pests and the large number of host species impacted. This section includes two analyses that identify priority landscapes for restoring forest pest impacted areas. The first is related to ecosystem health, the second to community safety.

The ecosystem health analyses in this document do not differentiate ecosystems based on asset value; the analyses are entirely threat driven. Ideally, each ecosystem could be assigned an asset ranking based on factors such as rarity, sensitivity, habitat value, and level of ecosystem services and public and private benefits provided.

The following analysis identifies a priority landscape that represents areas most in need of treatments to restore ecosystem health.

Analysis



Assets

Ecosystems
The California Department of Fish and Game recognizes the following definition of the term ecosystem:

a natural unit defined by both its living and non-living components; a balanced system for the exchange of nutrients and energy.

To develop a more specific working definition that can be mapped for analysis, ecosystems as defined in this section refer to unique vegetation (WHR) types by tree seed zones (Figure 2.2.3). Tree seed zones help determine the suitability of seed for planting and survival in a particular area and are delineated on the basis of collection criteria adopted by the USDA forest seed policy of 1939 (Fowells, 1946). When combined with vegetation maps, tree seed zones define unique ecosystem assets potentially having unique genetic resources.

Threats

Stand-Level Damage
This threat was mapped and ranked based on current stand-level mortality derived from aerial surveys conducted from 1994–2008 by the U.S. Forest Service Region 5 Forest Health Protection (FHP) staff. The three factors used to rank stand-level damage are severity (the number of dead trees per acre), damage causing agent and time since the outbreak was last observed. Higher ranking is given to more recent and severe outbreaks of pests causing greater than 100,000 acres of damage in the last 15 years.

Landscape-Level Damage
Landscape-level damage captures damage to entire ecosystems, and was derived by calculating the percentage of each ecosystem that has medium or high stand-level damage.

Stand-Level Threat
Forest stands were assigned a threat rank based on expected mortality due to forest pests over the next 15 years, from FHP data.

Landscape-Level Threat
The threat of damage to entire ecosystems at the landscape scale was derived by calculating the percentage of each ecosystem that is expected to have at least 50 percent tree mortality over the next 15 years.

Results

The priority landscape ranks areas impacted by insect and disease outbreaks for restoring ecosystem health (Figure 2.2.4). This involved finding:

1. areas with significant stand-level damage (dead trees),

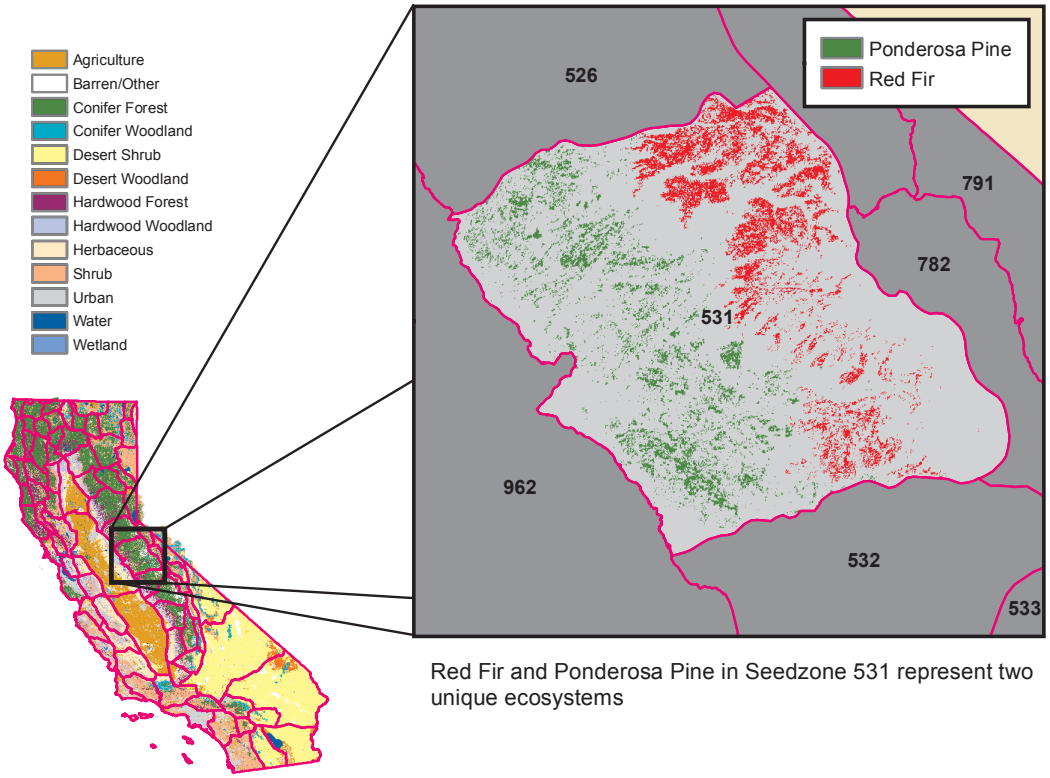


Figure 2.2.3.
Land cover and tree seed zones in California.
Data Sources: California Tree Seed Zones, Buck, et al. (1970); Statewide Land Use / Land Cover Mosaic, FRAP (2006)

2. ecosystems with widespread and significant stand-level damages and
3. potential points of origin for outbreaks in high risk ecosystems (prevent spread).

Priority Landscapes by Owner

There are over six million acres of priority landscapes that are impacted by forest pests in California, with 31 percent of these ranked high. Seventy-five percent of priority landscapes are on lands managed by the U.S. Forest Service (USFS) and 18 percent are on private lands. This ratio is similar when we examine the ownership of the highest priority acres, with 76 percent on USFS lands and 19 percent on private lands.

Priority Landscapes by WHR Type

Sierran Mixed Conifer (SMC) is the most heavily impacted habitat type, with over 1.7 million acres prioritized for restoration, almost 30 percent of all priority landscapes. Over 36 percent of SMC in California is prioritized for restoration.

Eastside Pine (EPN) is second, with just over 600,000 acres in priority landscapes, most of which is in the Modoc bioregion (69 percent). Red Fir (RFR), White Fir (WFR) and Douglas-fir (DFR) were the third, fourth and fifth most heavily impacted habitat types with 501, 404, and 362 thousand acres, respectively.

White Fir had the largest proportion of its habitat identified as a priority landscape (43 percent), and almost 240,000 acres (26 percent) designated as high priority. Twenty-eight percent of Red Fir was designated as high.

Discussion

Bioregional Findings

Over 95 percent of the priority landscapes for restoring forest pest impacted areas are in just four bioregions:

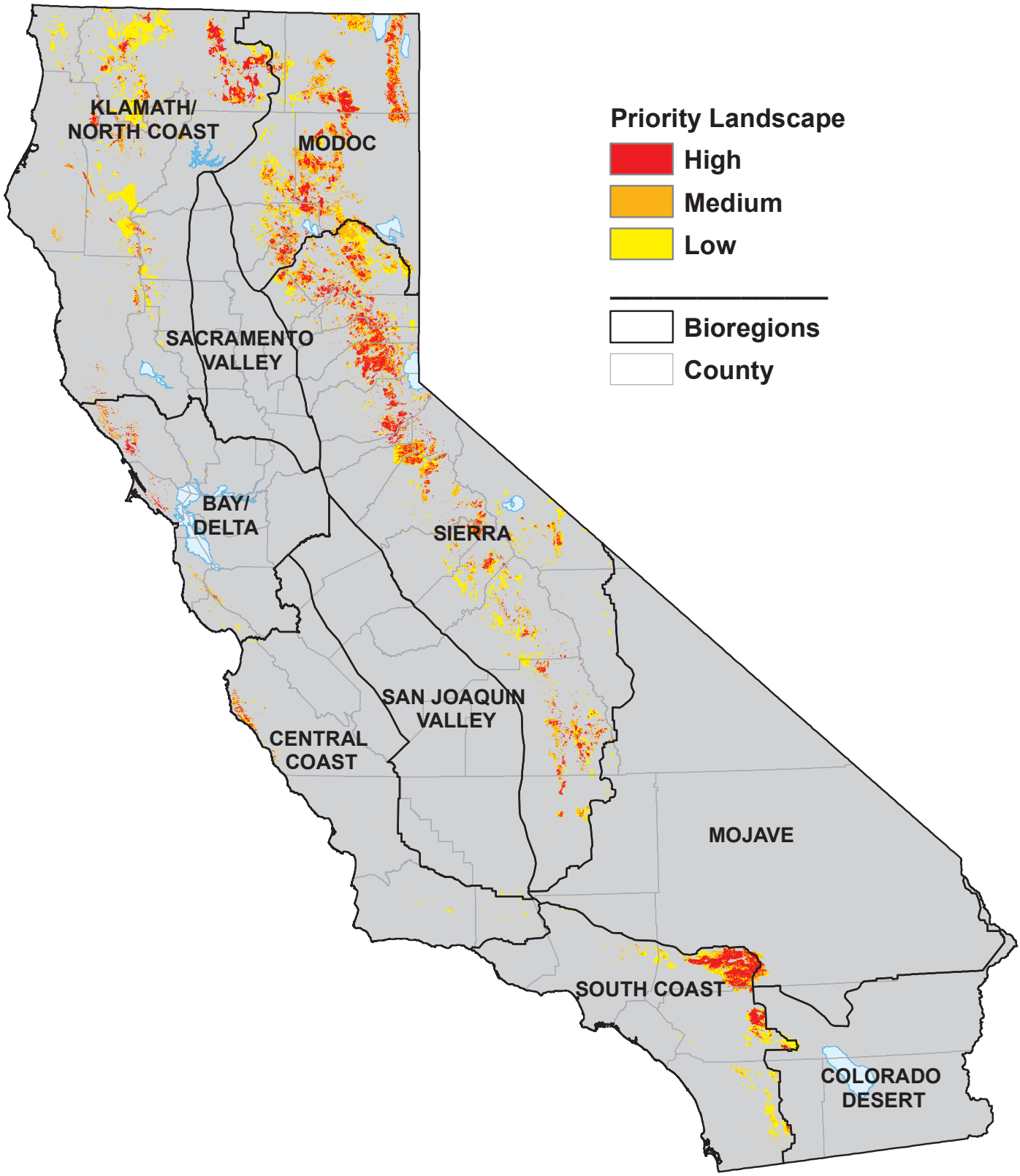


Figure 2.2.4.
Priority landscape for restoring forest pest impacted areas to maintain ecosystem health.
Data Sources: Aerial Detection Surveys, USFS FHP (2008 v1); Statewide Land Use / Land Cover Mosaic, FRAP (2006); California Tree Seed Zones, Buck, et al. (1970)

- Sierra (38 percent),
- Modoc (25 percent),
- Klamath/North Coast (22 percent) and
- South Coast (10 percent).

From a regulatory perspective, declared emergencies in the South Coast bioregion and the sudden oak death Zone of Infestation (ZOI) in the Bay/Delta bioregion already address many of the highest priority habitats identified by this analysis. The goldspotted oak borer is an emerging exotic pest in San Diego County that is of great concern to forest pest management staffs and is not currently addressed by a ZOI. A Zone of Infestation has been declared for the Lake Tahoe basin; however a majority of the Sierra bioregion, with its emerging forest pest related tree mortality is not currently covered under an emergency order or designation. The analysis suggests the need to increase priority for dead tree removal and forest health treatments in this bioregion.

Tools

A variety of forest management tools are available to land managers and public agencies to address forest pest damage to ecosystem health.

- Education and outreach regarding impacts from forest pest killed trees
- Early detection and monitoring of forest conditions and pest activity
- Forestry assistance programs and forest management activities
- State and federal forest policies and declared Zones of Infestation

Within a Zone of Infestation CAL FIRE employees may go on private lands to eradicate or control forest pests. Activities may include:

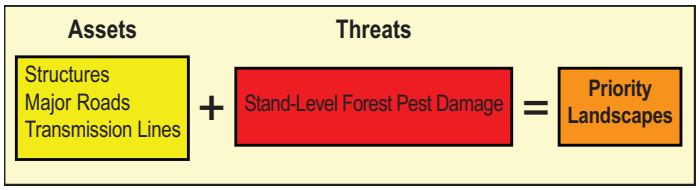
- Removal of dead, dying and diseased trees near community assets,
- Removal of live vegetation directly adjacent to dead or dying trees that is substantially at risk,
- Removal of soil that harbors insects or diseases,
- Eradication or
- Control of forest pest outbreaks that threaten area-wide forest resources.

Enforcement of forest pest regulations often falls under the California Forest Practices Act. The act allows for regulation of commercial timberlands or lands growing commercial timber species around the state. It uses provisions added to timber harvest plans to manage forest pest issues. Management of non-commercial timberlands is more difficult without further action by the state legislature, other state departments or local government regulations. If landowners are not engaged in commercial timber operations, many of the tools available to address forest pest concerns on private lands are limited. Unless a Zone of Infestation or other emergency declaration is made, treatments may only be applied with the consent of private land owners. This can make it difficult for state agencies to react quickly and effectively to prevent and control outbreaks before pests are well established.

RESTORING FOREST PEST IMPACTED COMMUNITIES FOR PUBLIC SAFETY

This analysis identifies priority landscapes in communities already impacted by forest pest outbreaks and most likely to have associated concerns about public safety and human infrastructure. During major outbreaks, large dead trees in populated areas can fall and block major transportation routes, hit power lines (sometimes starting fires) or crush structures. Such events also increase fuel loading, which can create additional fire hazards. Additional threats to public safety outside communities, such as on forest trails and recreation sites are not addressed by this analysis. Although some data on current hazard reduction activities are available for Southern California, these data were not available on a consistent, statewide basis. As a result, ongoing treatment activities to address forest pest threats near communities were not used in this analysis.

Analysis



Assets

High ranking was assigned to dense housing, moderate to major roads and transmission lines. When combining the three assets, housing was weighted three times as much as transmission lines and roads.

Threats

The same stand-level damage threat data based on current tree mortality described in the previous analysis for restoring ecosystem health was used.

Results

The overlay of the threats and assets produces the priority landscape, shown for an example area (Lake Arrowhead) in Figure 2.2.5.

Priority Landscapes by Community

This analysis identified 13 communities with at least 20 percent of their area in priority landscapes (Table 2.2.1). Eight of these are in the South Coast bioregion, which has experienced a high level of tree mortality from drought and subsequent bark beetle (and other forest pests) infestation since 2001. All eight of the South Coast communities are covered by state and county level declared emergencies. Four of the remaining five communities are in the Bay/Delta bioregion and are covered under a Zone of Infestation order, which has been declared by CAL FIRE to address sudden oak death.

Priority Landscapes by County

Over half of the priority acres are contained in just five counties (Table 2.2.2). San Bernardino has over 20 percent of the priority landscape acres and almost 60 percent of the high priority acres. Sonoma County, which has been hit hard by sudden oak death, has over 10 percent of all priority landscape acres.

Discussion

Bioregional Findings

The South Coast, Bay/Delta and Sierra bioregions comprise 98 percent of high priority areas and 83 percent of priority landscapes.

- Bark beetles and wood borers in the South Coast and Sierra bioregions, and sudden oak death in the Bay/Delta and along the North Coast are major issues. Zones of Infestation have been declared to address these concerns.
- The South Coast bioregion has 37 percent of priority landscapes and 74 percent of high priority acres.
- The Sierra bioregion has 27 percent of priority landscapes and 11 percent of high priority acres.

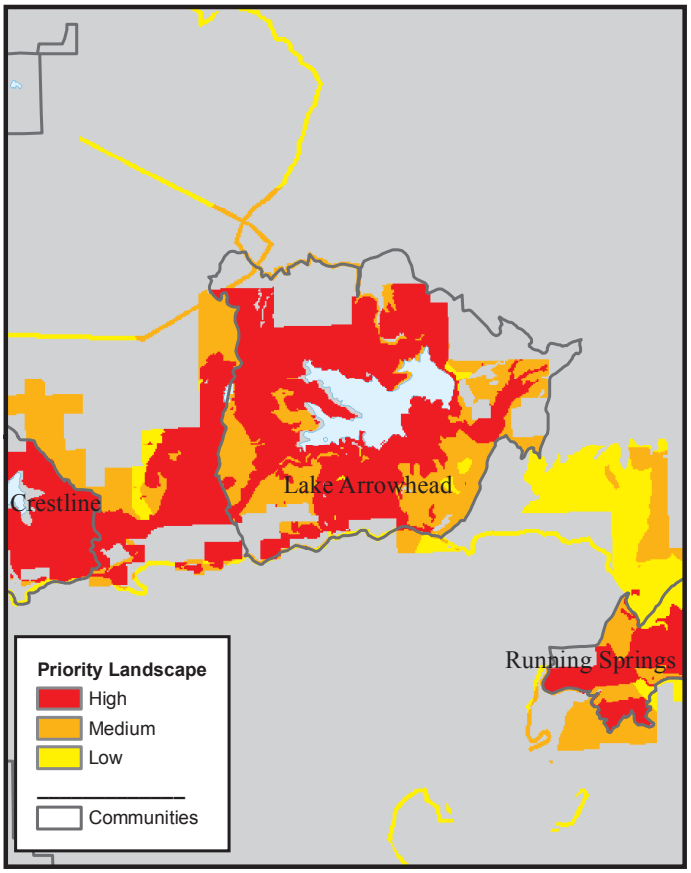


Figure 2.2.5.
Priority landscape (Lake Arrowhead area) for restoring forest pest impacted communities.
Data Sources: Aerial Detection Surveys, USFS FHP (2008 v1); Communities, FRAP (2009 v1); Transmission Lines, California Energy Commission (2007); Major Highways, TIGER (2000); U.S. Census Bureau (2000)

Table 2.2.1. High priority communities for restoring forest pest impacts for public safety (acres rounded to nearest hundred)

Community	Bioregion	Priority Landscape (Acres)	Priority Landscape (Percent of Community)	High Priority Landscape (Percent of Community)	High or Medium Priority Landscape (Percent of Community)
Running Springs	South Coast	2,000	78	55	68
Lake Arrowhead	South Coast	5,400	67	45	66
Wrightwood	South Coast	800	56	46	51
Crestline	South Coast	3,900	55	45	54
Idyllwild–Pine Cove	South Coast	4,700	54	48	54
Big Bear Lake	South Coast	2,400	45	40	45
Monte Rio	Bay/Delta	400	42	42	42
Julian	South Coast	1,800	35	2.5	16
Aromas	Central Coast	900	28	2	28
Big Bear City	South Coast	600	26	26	26
Occidental	Bay/Delta	800	24	5	24
Guerneville	Bay/Delta	500	24	24	24
Inverness	Bay/Delta	800	22	8	22

Table 2.2.2. Priority landscape by county for restoring forest pest impacted communities for public safety

County	Priority Landscape (Acres in Thousands)	Priority Landscape (Percent of County)	Medium Priority Landscape (Acres in Thousands)	High Priority Landscape (Acres in Thousands)
San Bernardino	40	21	16	18
Sonoma	20	10	17	2
San Diego	17	9	2	<1
Riverside	14	7	4	4
Placer	11	6	8	<1

- The Bay/Delta bioregion has 19 percent of priority landscapes and 12 percent of high priority acres.
- The Klamath/North Coast bioregion has seven percent of priority landscapes and one percent of high priority acres.

Declared emergencies in the South Coast bioregion and the declaration of a Zone of Infestation for sudden oak death in the Bay/Delta bioregion already address many of the highest priority communities identified by this analysis, at least from a policy perspective. A Zone of Infestation has been declared for the Lake Tahoe basin, however a majority of the Sierra bioregion, with its emerging forest pest related tree mortality is not currently covered under an emergency order or Zone of Infestation designation and may require additional actions to control the spread early and avoid the most severe consequences to public safety.

Tools

Tools to address forest pest outbreaks near communities are similar to those presented in the previous analysis.

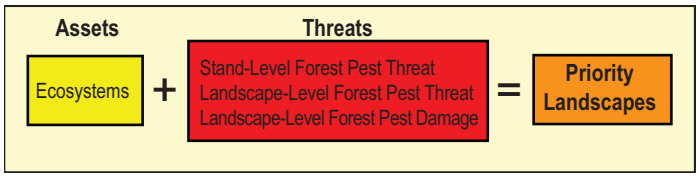
PREVENTING FOREST PEST OUTBREAKS TO MAINTAIN ECOSYSTEM HEALTH

Two analyses were conducted to identify priority landscapes for preventing future damage from forest pest outbreaks. The first was related to ecosystem health, the second to community safety.

The following analysis identified ecosystems at risk from future forest pest outbreaks. The goal is to

prevent outbreaks, especially those with the potential to cause widespread damage to entire ecosystems.

Analysis



Assets

Ecosystem
The ecosystem asset used in this analysis was the same as presented in the previous ecosystem health analysis.

Threats

The threats data used in this analysis were the same as presented in the previous ecosystem health analysis.

Results

Areas at significant risk of future forest pest outbreaks are:

- areas with high expected forest pest related tree mortality,
- ecosystems with a high proportion of areas at risk from forest pests (high landscape-level threat) and
- the undamaged portion of heavily damaged ecosystems.

Using this methodology, over 2.5 million acres have a significant level of threat from future forest pest outbreaks (Figure 2.2.6). Highest priority was given to ecosystems with at least half of its area expected to experience volume loss of greater than 50 percent in the next 15 years. Medium priority was given to areas where at least 10 percent of a given ecosystem has expected stand-level volume loss of greater than 50 percent.

Priority Landscapes by Owner

Over 62 percent of threatened areas are owned by the USFS, 33 percent are on privately owned lands.

Priority Landscapes by WHR Type

Together, Montane Hardwood (MHW), Red Fir (RFR), White Fir (WFR), Ponderosa Pine (PPN) and Sierran Mixed Conifer (SMC) habitat types comprise almost 67 percent of all the priority landscape acres. MHW has the largest total priority acres (424,115 acres, about 17 percent of all priority landscapes), although this is less than 10 percent of the MHW habitat in California. RFR (18 percent), Lodgepole Pine (LPN) (10 percent) and WFR (10 percent) had the highest proportions of their habitats identified as high priority for protection. When high priority and medium priority landscapes were combined, WFR (30 percent), RFR (29 percent) and LPN (16 percent) were again identified.

Discussion

Results pointing to WFR and RFR habitats in trouble are supported by findings from the Restoring Forest Pest Impacted Areas to Maintain Ecosystem Health analysis, which identifies these types as having significant pest activity over the last 15 years. Treatment to stand-level threats in high risk WFR and RFR habitats will yield additional ecosystem health benefits away from treatments by reducing the potential for infestation and spread.

Bioregional Findings

- The Klamath/North Coast (48 percent), Sierra (33 percent) and Modoc (13 percent) bioregions comprise almost 95 percent of priority landscape acres
- Montane Hardwood (MHW), which includes much of the tanoak at risk from SOD, is the habitat type with the most priority landscapes statewide and in the Klamath/North Coast bioregion. RFR, PPN, and WFR are the most at risk WHR types in the Sierra bioregion in terms of total priority acres.

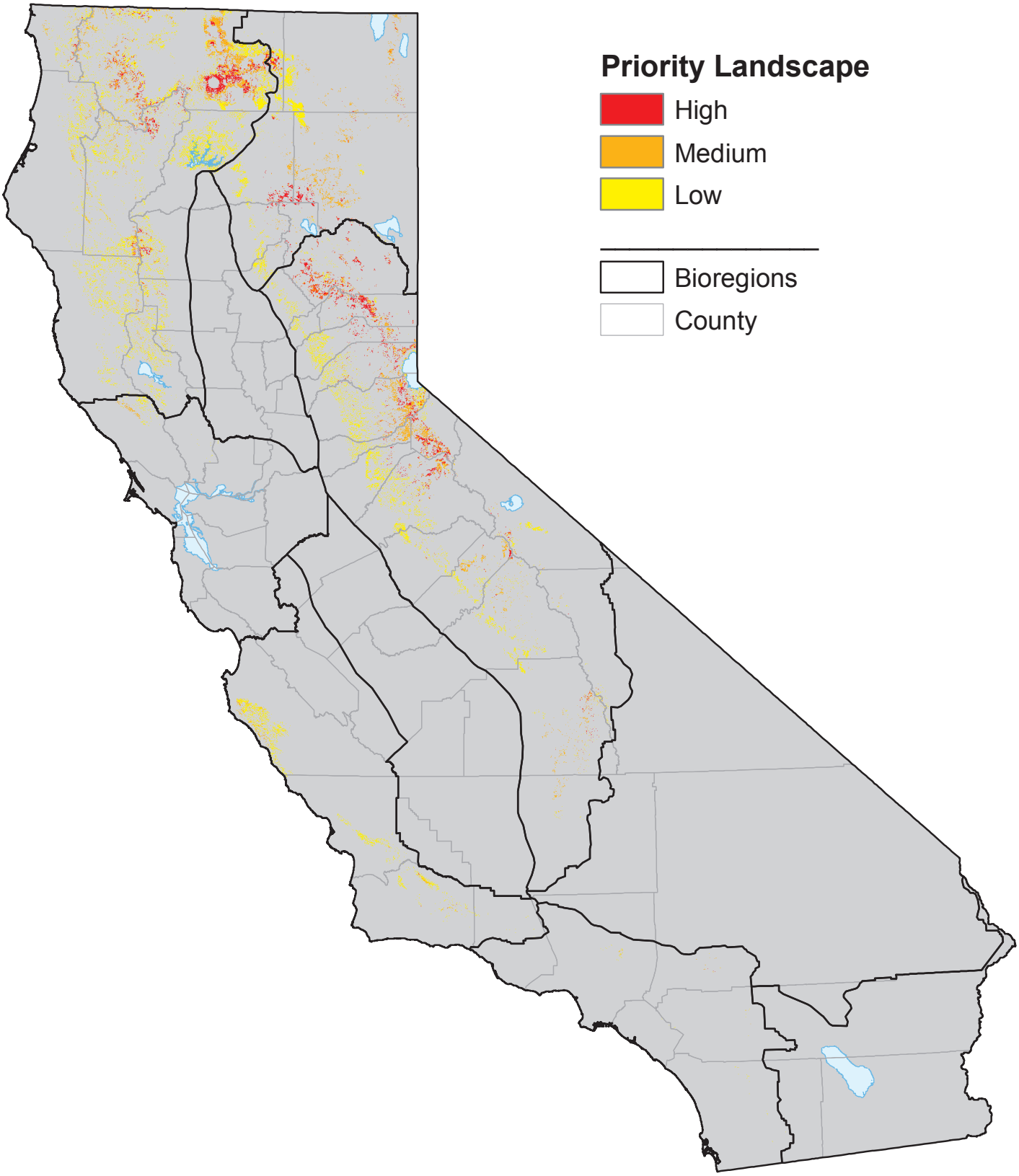


Figure 2.2.6.
Priority landscape for preventing forest pest outbreaks to maintain ecosystem health.
Data Sources: Forest Pest Risk, USFS FHP (2006 v1); Statewide Land Use / Land Cover Mosaic, FRAP (2006); California Tree Seed Zones, Buck, et al. (1970)

These results indicate that the federal government will have a particularly important role to play in protecting ecosystem health from future forest pest outbreaks. Management practices and regulations governing forest policies at the national and regional level will be important in addressing these issues, suggesting that coordination between federal, state and local efforts is critical.

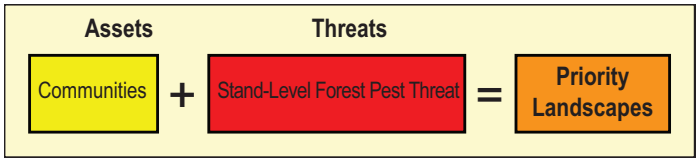
Tools

A variety of forest policy and forest management tools are available to land managers and public agencies to address forest pest risks to ecosystem health. Activities that thin overly dense forests, reduce competition and introduce a mix of tree species that are adapted to the local environment, can help create forests more resilient to disturbances and less susceptible to forest pests. Tools to address forest pest outbreaks are similar to those presented in the previous analysis.

PREVENTING FOREST PEST OUTBREAKS FOR COMMUNITY SAFETY

The priority landscape from this analysis identifies communities potentially impacted by forest pest outbreaks, and that are most likely to have associated concerns for public safety and human infrastructure damage. Additional threats to public safety outside communities, such as on forest trails and recreation sites were not addressed by this analysis.

Analysis



Assets

Communities
The Fire and Resource Assessment Program (FRAP) community data layer identifies incorporated cities and unincorporated Census Designated Places and was used to represent concentrations of people and human infrastructure at risk from forest pests.

Threats

The stand-level forest pest threat data used in this analysis are the same as presented in the previous analysis.

Results

The overlay of the threats and assets produced the priority landscape. Over 82,000 acres of community infrastructure are found to be at risk from future forest pest outbreaks, shown for an example area (Foresthill) in Figure 2.2.7.

Priority Landscapes by Community

Since large communities have very different exposure characteristics than small communities it is useful to discuss these results by community size. There were no communities with populations greater than 50,000 identified by this analysis.

Size Class 4 (Population 10,000–50,000)
Table 2.2.3 lists the five Size Class 4 communities with the most priority acres. Magalia had the most acres with 2,000, which represents 23 percent of the community. This was followed by South Lake Tahoe, with almost 1,600 acres (25 percent) and Paradise, with almost 11 percent.

Size Class 5 (Population < 10,000)
Table 2.2.4 lists the top 20 communities identified by this analysis, in terms of total high plus medium priority landscapes.

Priority Landscapes by County

Table 2.2.5 shows the counties with the most high priority landscape (HPL) and high and medium priority landscape (HMPL) and total priority landscape community acres. Humboldt County had the largest total number of priority landscape acres with almost 20,000 (24 percent of all Size Class 4 community PL acres). Humboldt was followed by Calaveras County, with just over 16,000 acres (20 percent), Tuolumne with over 8,600 acres (10 percent), Shasta County

with 6,200 acres (eight percent), Plumas with almost 5,400 acres (seven percent) and Butte County with about 5,000 acres (six percent). Together, these counties comprise 75 percent of all community priority landscapes identified by this analysis (Table 2.2.5).

Areas in the highest priority category are all inside communities and are at risk of losing greater than 75 percent of tree volume over the next 15 years. See Table 2.2.5 for a complete breakdown of high priority acres by county

High and medium priority landscape areas are inside communities and are at risk of losing greater than 50 percent of tree volume in the next 15 years. See Table 2.2.5 for a complete breakdown of HMPL acres by county.

Discussion

Bioregional Findings

- Almost all of the community areas at risk from future forest pest outbreaks identified by this analysis are contained in three bioregions: Sierra, Klamath/North Coast and Modoc.
- Magalia, South Lake Tahoe, Paradise and Truckee are the largest communities identified as priorities for forest pest prevention activities.

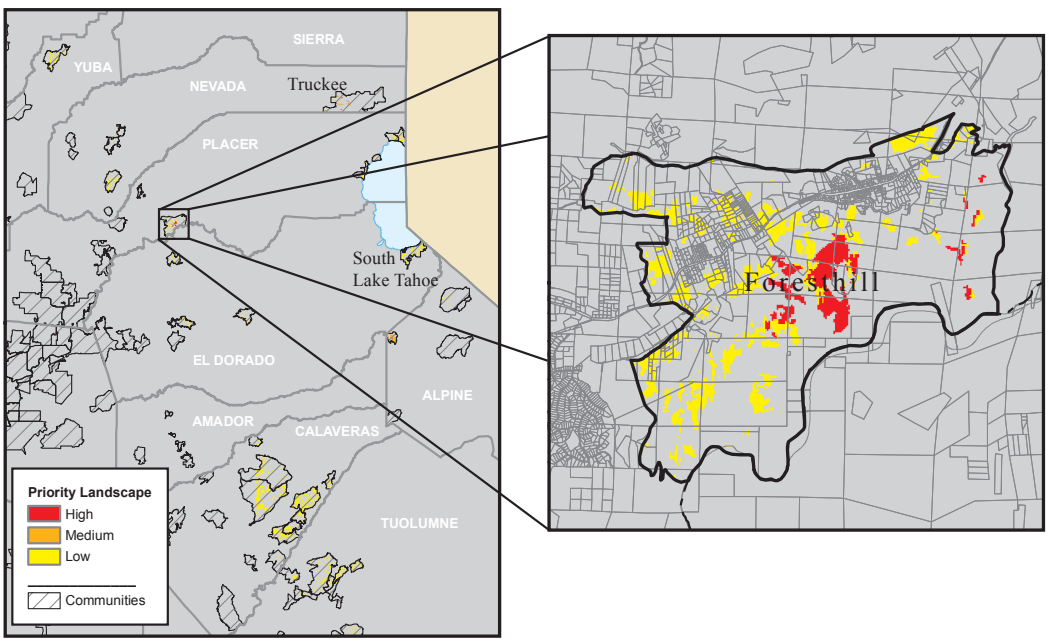


Figure 2.2.7.
Priority landscape for preventing forest pest outbreaks for community safety (Foresthill).
Data Sources: Communities, FRAP (2009 v1); Forest Pest Risk, USFS FHP (2006 v1)

Table 2.2.3. Top five Size Class 4 communities in terms of total priority landscape acres (acres rounded to nearest hundred)

Community	Bioregion	Priority Landscape (Total Acres)	Priority Landscape (Percent of Community)	Medium Priority Landscape (Acres)	High Priority Landscape (Acres)	Percent of Community in HPL or MPL
Magalia	Modoc	2,000	23	0	0	<1
South Lake Tahoe	Sierra	1,600	25	<50	<50	1
Paradise	Sierra	1,200	11	0	0	<1
Truckee	Sierra	700	3	400	100	3
Grass Valley	Sierra	300	8	0	0	<1

Table 2.2.4. Top 20 Size Class 5 cities by HMPL total acres (acres rounded to nearest hundred)

Community Name	Bioregion	Priority Landscape (Acres)	Priority Landscape (Percent of County)	Medium Priority Landscape (Acres)	High Priority Landscape (Acres)	Total HMPL (Acres)
Bucks Lake	Sierra	1,900	28	1,600	<50	1,600
Mineral	Modoc	1,000	4	800	100	800
Kirkwood	Sierra	900	46	600	100	700
Johnsville	Sierra	1,100	12	600	100	700
Mammoth Lakes	Sierra	700	5	400	200	600
Graeagle	Sierra	500	7	300	<50	300
Foresthill	Sierra	1,200	17	0	300	300
La Porte	Sierra	400	14	300	0	300
East Quincy	Sierra	300	4	100	0	100
Meadow Valley	Sierra	300	5	100	0	100
Willow Creek	Klamath/North Coast	20,000	15	<50	10	100
Mount Shasta	Klamath/North Coast	200	9	100	<50	100
Iron Horse	Sierra	100	1	<50	0	100
Weed	Klamath/North Coast	500	17	<50	0	<50
Sunnyside–Tahoe City	Sierra	500	22	<50	0	<50
Lake Arrowhead	South Coast	<50	<1	<50	0	<50
Dollar Point	Sierra	200	16	<50	0	<50
Kings Beach	Sierra	500	21	<50	<50	<50
Mohawk Vista	Sierra	100	2	<50	0	<50
Lakehead–Lakeshore	Klamath/North Coast	2,900	41	0	<50	<50

Table 2.2.5. Top 17 counties by percent of statewide HPL and HMPL and total PL community acres for protection from future forest pest outbreaks (acres rounded to nearest hundred)

County	Priority Landscape (Total Acres)	Priority Landscape (Percent of County)	Medium Priority Landscape (Acres)	High Priority Landscape (Acres)	Percent of HPL in County	Percent of HMPL in County
Placer	2,800	3	100	300	25	5
Mono	700	1	400	200	19	9
Alpine	1,200	1	600	100	14	11
Plumas	5,400	7	3,000	100	13	48
Nevada	2,300	3	400	100	12	9
Humboldt	20,000	24	<50	100	6	2
Tehama	2,400	3	800	100	6	13
El Dorado	2,900	3	<50	<50	2	1
Shasta	6,200	8	<50	<50	1	<1
Siskiyou	1,500	2	100	<50	1	2
Calaveras	16,100	20	0	<50	<1	<1
Trinity	2,100	3	<50	0	<1	<1
Tuolumne	8,600	10	0	0	<1	<1
Butte	5,000	6	0	0	<1	<1
Yuba	1,700	2	0	0	<1	<1
Fresno	1,600	2	0	0	<1	<1
Lake	1,200	1	<50	0	<1	<1

- Sixteen of the top 20 communities with populations below 10,000 are in the Sierra bioregion.
- Humboldt and Calaveras counties have the most community acres identified as a priority; however Plumas has the most acres in high plus medium priority.

These results indicate that a majority of the communities at risk from future forest pest outbreaks are in Northern California counties and have populations of less than 10,000.

Tools

Tools to address forest pest risks near communities are similar to those presented in the previous analysis on preventing forest pest outbreaks to maintain ecosystem health.

THREATS FROM NON-NATIVE INVASIVE PLANT SPECIES

Invasive, non-native plants damage California ecosystems by displacing native species, out-competing native plants, changing plant communities and structure, and reducing the value of habitat for wildlife and stock.

Invasive plants may disrupt physical ecosystem processes such as fire regimes, sedimentation, erosion, light availability, hydrology and nutrient cycling. Some alter soil chemistry, pollute gene pools, suppress native species recruitment and harbor exotic animals. The impact is especially severe in California, with its rich diversity of natural resources. The threat posed by invasive species is second only to habitat loss and is long lasting, difficult to remediate and occurs throughout the state. Many public entities are responsible for the control of invasive plant species in California, and in association with non-governmental organizations (NGOs) and the private sector, a state Noxious and Invasive Weed Action Plan was created (Schoenig, 2005) to coordinate efforts.

Current and Historical Trends of Invasive Plants

Due to geology and climate, California has many different habitats leading to high probability foreign weeds will find a suitable place to become established. People are a prime vector of seeds, as more people came to California, the number of non-native weeds found here has increased (Bossard et al., 2000). As of 2005, approximately 20 million acres of the state were contaminated with noxious or invasive plants (Schoenig, 2005), costing hundreds of millions of dollars. Nearly 30 percent (1,800) of plant species found in the wild are non-native (http://www.cal-ipc.org/ip/inventory/index.php). Approximately 200 are recognized by the California Invasive Plant Council (CAL-IPC) as being invasive.

Many of the 200 invasive plants listed on the CAL-IPC website occur in California's forest and rangeland area. Weed control and restoration are now widely regarded as necessary in many wildlands throughout the state. High priority is placed on invasive plants that disrupt physical ecosystem processes such as fire regimes, sedimentation, erosion, light availability, hydrology and nutrient cycling. Generally these species will act to reduce native species biodiversity and affect wildlife habitat. There are several species or groups of species that may be considered especially troublesome in the forest and rangeland areas of California (Table 2.2.6).

There are unfortunately few statewide comprehensive maps of many of these invasive plant species. However, efforts are underway on several fronts to maintain or develop statewide maps.

Risk of New Non-Native Plant Species Invasions

Human activities, such as urbanization and agriculture, facilitate the initial invasion by non-native plants (Seebloom et al., 2006). People often introduce plants from their homelands when they migrate to new regions, sometimes accidentally. It is generally agreed that areas where the vegetation and soil have been disturbed by humans or domestic animals

Table 2.2.6. Major invasive plant species in California forests and rangelands

Common Name	Scientific Name
Medusahead	*Taeniatherum caput-medusae*
Cheatgrass	*Bromus tectorum*
French Broom	*Genista monspessulana*
Spanish Broom	*Spartium junceum*
Scotch Broom	*Cytissus scoparius*
Portuguese Broom	*Cytissus striatus*
Yellow Starthistle	*Centaurea solstitialis*
Italian Thistle	*Carduus pycnocephalus*
Musk Thistle	*Carduus nutans*
Bull Thistle	*Cirsium vulgare*
Canada Thistle	*Cirsium arvense*
Scotch Thistle	*Onopordum acanthium*
Pampas Grass	*Cortaderia selloana*
Jubata Grass	*Cortaderia jubata*
Giant Reed	*Arundo donax*

are more susceptible to invasion. Grazers introduced by humans often denude large areas of native vegetation, leaving them open to colonization by introduced species adapted to grazing.

Changes in stream flows, the frequency of wildfires or other environmental factors caused by construction, firefighting and other human activities may also hinder survival of native plants and promote invasion by non-natives.

Regulatory Framework for Invasive Plant Species

Many organizations, such as CAL-IPC, publish lists that prioritize which invasive plants need to be addressed. Eleven different federal agencies, ten different state agencies, and as many as four local agencies have invasive, non-native plants as part of their responsibilities. Many of those groups were stakeholders in the 1995 "Strategic Plan for the Coordinated Management of Noxious Weeds in California" which was a broad strategy for cooperation, and increased programs to control noxious weeds. The more action oriented "California Noxious and Invasive Weed: Action Plan" was published with input from many of these same stakeholders. It focused on the overlap of legally defined "noxious" weeds and invasive weeds (recognized by their ability to invade working landscapes or wildlands and to do economic or ecological damage) (Schoenig, 2005). Federal jurisdiction over invasive weeds originates in multiple laws, the most important being the Federal Noxious Weed Act [7 U.S.C. Sections 2801–2813] (Range Management Advisory Committee, 1995). The California Department of Food and Agriculture is the lead agency in noxious weed control in the state and its authority originates in the California Food and Agricultural Code, as does each county Department of Agriculture. These federal, state and local agencies work cooperatively in California's Pest Prevention System to prevent noxious weed and agricultural pest invasions.

AIR POLLUTION THREATS TO ECOSYSTEMS

This section reviews the main effects of lower atmospheric (tropospheric) air pollution on ecosystem health in forests and rangelands in the state. Known or suspected impacts occur from several processes, including ozone (O3) damage to several plant species in areas hard hit by chronic air pollution, and the deposition of fertilizing or acidifying substances in clear mountain waters (e.g., Lake Tahoe) and on mountain and desert soils.

Current and Historical Trends

Air pollution and its gas precursors come from both natural and human-related sources. The single most impacting development in air pollution threats to ecosystems has been the burning of fossil fuels in California, which escalated with industrialization and the invention and use of the automobile in the early 1900s. As such, the most damaging effects to ecosystems typically occur in areas where human activities emit substantial amounts of precursor gases, which contribute to the development of specific damaging air pollutants that impact ecosystem health.

The three bioregions of California that suffer chronically high levels of air pollution affecting ecosystem health are the South Coast, Mojave and southern San Joaquin Valley (and the adjacent Sierra Nevada mountains). These regions all have large urban and

agricultural areas surrounded or confined by high mountains. In other areas of the state, the damage from air pollution has thus far been more limited. Table 2.2.7 provides a brief summary of problem air pollutants and their effects.

Fertilizing and Acidifying Effects on California Ecosystems

Fertilization from airborne pollution is a concern in nitrogen-limited ecosystems such as oligotrophic (nutrient limited) waters and desert soils. Lake Tahoe has recorded increases in nitrogen levels, some of which are due to airborne particulates. This has contributed to the diminishing lake clarity. Research is underway in Joshua Tree National Park on fertilization of the soils and its effects. In the long term, this process has the potential to cause changes in dominant vegetation type and fire regimes. However, major impacts from airborne fertilization and acidification substances on these ecosystems have yet to be demonstrated.

Ozone Effects on Ecosystems

Direct damage from chronically elevated, toxic ozone levels occurs mainly to two dominant tree species and several shrub species.

In particular, ozone affects ponderosa pine and its close relative, Jeffrey pine. The gas damages the needles of these trees, especially when the needle stomates are open. The results are dead or dying needles on affected trees and severely compromised tree health. In severe cases it can lead to plant stress and outright tree mortality. Other forest plant species with measurable adverse impacts from ozone are mugwort (*Artemisia douglasiana*), skunkbrush (*Rhus trilobata*) and blue elderberry (*Sambucus mexicana*).

A 2007 estimate suggests 1.3 million acres of California forestlands are at moderate to high risk of impacts from ozone (Campbell et al., 2007). Three air basins are predominantly affected, corresponding to the southern Sierra, South Coast, and Mojave bioregions. Ozone damage to forests has also been recently detected in areas of the Klamath/North Coast and northern Sierra bioregions, though at a much lower level than to the southern bioregions.

Due in large part to reduced emissions of gas precursors, ozone levels statewide have decreased more than 40 percent since 1988, despite the growth in population by 33 percent over that same period.

According to the California Air Resources Board (ARB), other criteria pollutant trends for the past 30 years and their projections are mixed, with some showing improvement across the state (Cox et al., 2009). Emissions of carbon monoxide (CO), nitrogen dioxide (NO2) and reactive organic gases (ROGs) are predicted to continue their long-term decreasing trends. In contrast, particulate matter (PM) has been relatively constant or shows slight increases. Sulfate (SOs) emissions, greatly diminished since the 1970s, have bottomed out and are forecast to increase slightly into the future, especially due to offshore sources such as ships.

Regulatory Environment

The U.S. Clean Air Act of 1963 requires the U.S. Environmental Protection Agency (EPA) to establish

Table 2.2.7. Air pollutants and their effects and trends

Air Pollutant	Documented Effects on Ecosystems	Main Bioregions Affected	Past and Predicted Trends
Ozone	Damages needles of ponderosa and Jeffrey pine, some shrubs	South Coast, Southern Sierra, Mojave	Strong decrease since 1988
Fertilizing substances	Higher than normal soil nutrients and over abundance of nutrients in lakes leading to oxygen depletion	Potentially South Coast, Sierra, Mojave	Trends in precursors are declining
Acidifying substances	Increased acidity in soils and lakes leading to declines in amphibians and other aquatic organisms	Nowhere acute in California	Trends in precursors are declining

National Ambient Air Quality Standards for air pollutants. The federal standards are two tiered: primary standards, designed to protect public health, and secondary standards, designed to protect the environment, such as visibility, damage to property, soil, vegetation, etc. ARB oversees both state and federal air pollution control programs in California and has divided the state into air basins. Authority for air quality management within each basin has been given to local Air Pollution Control Districts, which regulate stationary source emissions and develop local non-attainment plans within their jurisdiction.

When a region falls outside of attainment, individual air districts or groups of air districts prepare air quality management plans designed to bring an air basin into compliance with relevant ambient air quality standards. Those plans, which are submitted to ARB for approval, usually contain an emission inventory and a list of rules proposed for adoption. The districts regulate emissions from stationary sources while the state regulates emissions from mobile sources such as cars and trucks.