USDA Forest Service

Oregon Department of Forestry

Sudden Oak Death Management in Oregon Forests

Program Report for Oregon State Legislature

Joint Ways and Means Committee

14 March 2023

SUMMARY

This document provides a comprehensive review of the Oregon Sudden Oak Death (SOD) Program as requested by the Oregon Legislature as part of the Oregon Department of Forestry (ODF) General Fund appropriation. This report reviews spending made by ODF and its federal and state partners to slow the spread of SOD in Oregon forests. The report details impediments seen by ODF, its federal and state partners, or contractors in the steps taken to slow or stop the spread of sudden oak death. Based on current funding, the SOD Program presents an implementation plan for slowing disease spread and a review of the effectiveness of disease management activities. Program alternatives to the Sudden Oak Death program for all forest lands in Oregon for the next four years are also presented. State and federal management teams responsible for the SOD program reviewed these options.

ISSUE

The slow-the-spread program uses early detection, monitoring, and local eradication treatments to reduce the rate of disease spread and slow disease intensification. The SOD technical team designed the program to treat infested sites outside of the generally-infested area (GIA) where the disease is commonly found. Treatment priorities are based on multiple factors, including:

- Pathogen variant
- The number of infested trees
- Location relative to quarantine boundaries
- Available funds

Eradication treatments on non-federal lands range from cutting and burning an infected tree and its nearest neighbors (within 1/10 acre) to cutting and burning all host plants within a 300-foot treatment buffer (up to a maximum of a 600-foot buffer). Expanding the GIA frees non-federal and federal landowners from the high financial burden of having to treat infested sites.

At the current pattern and rate of spread, the program does not have enough funds to treat all high-priority sites (all sites outside of the GIA with a 300-foot treatment buffer) for disease spread, as proposed in the slow-the-spread program. As the disease progresses, the slow-the-spread program will become more costly. Furthermore, the inability to apply local eradication treatments to infested sites on all land ownerships will intensify disease and spread and ultimately require expansion of the GIA. This will also increase the probability SOD will spread into surrounding counties (beginning with Coos, Douglas, and Josephine).

BACKGROUND

In 2001, *Phytophthora ramorum*, the invasive non-native pathogen that causes sudden oak death (SOD) disease in tanoak, was discovered in Oregon. *P. ramorum* spreads mostly by air when rain splashes the spores into the wind, carrying them to another host species, most likely the upper canopy of tanoak. People can also spread the disease by transporting infected plant material to uninfected areas. Besides tanoak, *P. ramorum* can infect over 200 other plant species, including Oregon native trees and shrubs. In Oregon, *P. ramorum* usually doesn't kill these other hosts.

Since its initial emergence in Oregon in 2001, four distinct clonal variants of *P. ramorum* have been recognized worldwide (LeBoldus et al., 2022). In the late 1990s, the first variant was discovered in California. It was eventually named NA1 (North American variant 1), while the second, NA2 (North American variant 2), was discovered in ornamental plant nurseries in Washington in 2004. A third variant, EU1 (European variant 1), was first described in European ornamental plant nurseries. EU1 has since spread into Japanese larch plantations in the United Kingdom. The fourth variant, EU2 (European variant 2), was first described in 2012 and is only present in the United Kingdom. Based on genetic analysis, it was hypothesized that the EU1 variant was introduced from Europe to the Pacific Northwest, first appearing in Oregon nurseries in 2003 and then in forests in 2015. In hindsight, it is apparent that NA1 was the first variant to invade forests in California. The variants differ in mating type: NA1 and NA2 are the same mating type, whereas EU1 is a different mating type. Thus, the emergence of both mating types in close proximity is of great concern in terms of creating the potential for sexual reproduction and increased variability within the *P. ramorum* population in Oregon forests. This could result in a more aggressive pathogen population with the potential for further natural spread, intensification of infested areas, or new host species being affected.

When SOD was first discovered, the objective of Oregon's SOD program for forestland was the complete elimination of the pathogen through eradication. Eradication treatment of an infested site consists of cutting, piling, and burning all infected plant material and exposed host plant material within a specified radius (aka treatment buffer) surrounding infected plants. The species of exposed host plants that are treated varies from site to site based on infestation levels. The list could include Oregon myrtle, evergreen huckleberry, and rhododendron. The size of the treatment buffer varies depending on the level of infestation and funds available to conduct treatment, but efforts have shown that treatment within a 300-foot buffer conducted promptly following detection can eliminate the pathogen from the site and slow spread. Eradication treatment can also include applying herbicides to prevent sprouting of tanoak from stumps.

Treatment is followed by reforestation with conifer or other non-host species that reduce the risk of disease recurrence or spread. Sites are monitored for the persistence or recurrence of the pathogen, with follow-up treatment to destroy residual or recurring infections.

The spread of *P. ramorum* is managed by designating a SOD quarantine area under the authorities of the Oregon Department of Agriculture (ORS 603-052-1230) and the U.S. Department of Agriculture Animal Plant Health Inspection Service (7 CFR 301-92) (Figure 1). The state and federal quarantines regulate the intrastate and interstate movement of host plant material outside of the quarantine area. Oregon regulations require infested sites on state and private lands to undergo eradication treatment and set forth requirements for disease-free certification when moving uninfected host material to areas outside the quarantine. While federal land management agencies (U.S. Department of Interior Bureau of Land Management (BLM) and U.S. Department of Agriculture Forest Service (USFS)) are not required by federal regulations to eradicate *P. ramorum* from infested sites, federal land managers have conducted eradication treatments on all known infested sites on federal lands in Oregon through 2022.

By 2010, the quarantine area had expanded from its original 2001 size of nine square miles to 154 square miles. That's when Oregon's SOD program on forestland transitioned from eradication to slowing the spread of *P. ramorum*. The 2010 SOD Quarantine also designated a Generally Infested Area (GIA) within the quarantine area where eradication treatment of infested sites was no longer required. While the USFS has no land within the current GIA, the BLM continues to conduct eradication treatments on infested sites within the area. In contrast, the treatment of non-federal sites within the GIA has mostly stopped. The quarantine area expanded to 202, 264, and 512 square miles in 2012, 2013, and 2015, respectively.

In 2020, the GIA was expanded from 89 to 123 square miles. If SOD expands beyond the 2015 quarantine boundary, the next quarantine area could expand to encompass all of Curry County.

DISEASE SPREAD

From the original infestations in 2001, SOD has naturally spread 30 miles to the north, 10 miles to the east, and 8 miles to the south (Figure 1b). The farthest of the infestations have received eradication treatments consisting of cutting, piling, and burning of all host material within a 300-foot treatment buffer surrounding infected trees. Many factors can affect the rate of disease spread. These include climate, forest structure, host distribution, and disease abundance. The maximum distance of natural spread (no evidence of human assistance) in any given year appears to be 3 to 4 miles. From 2001 to 2022, the disease spread northward 30 miles (average of 1.4 miles/year) from the original 2001 infestations. Over the same period, the spread to the northeast up the Chetco River was 10 miles (average 0.5 miles/year) from the original infestations.

Human-assisted spread by moving infected plant material, usually nursery stock, can transmit the disease over long distances and is a wildcard in terms of predicting disease spread. Although *P. ramorum* was first detected in 2001, it was likely introduced into Oregon forests in the late 1990s through infected nursery stock from California. Following this initial introduction, the SOD Program staff, along with researchers at Oregon State University, have identified three other introductions likely from infected nursery stock.

In 2010, a new infestation near Cape Sebastian State Park was detected 12 miles from any known infestation. Genetic analysis identified infected nursery stock from California as the source. The infestation was aggressively treated with a 900-foot treatment buffer across state and privately owned lands. Subsequent monitoring of the area from 2010 to 2017 resulted in no further detections of *P. ramorum,* demonstrating successful local eradication.

In early 2015, the EU1 variant of *P. ramorum* was detected along the Pistol River on non-federal land. This is the first report of the EU1 variant in US forests. Prior to 2015, the NA1 variant accounted for all other forest infestations. Genetic analysis suggests a nearby private nursery (now closed) as the probable source. This finding is of particular concern because in Europe the EU1 variant kills or damages several conifer tree species, including Douglas-fir and western hemlock, and is considered more aggressive than NA1.

Recent Trends in Disease Intensification and Spread

Due to funding limits on the current slow-the-spread effort on non-federal lands and the establishment and expansion of the GIA (where there is no eradication effort on non-federal land), the amount of disease is increasing. This, along with favorable wet weather conditions for disease spread, has increased the number of new infestations at dispersal distances greater than 2.5 miles. In 2021, the Oregon SOD Program found two new infestations of *P. ramorum* outside the state SOD quarantine area (Figure 2). The first, detected in March, was on the Rogue River Siskiyou National Forest along the north bank of the Rogue River, six miles north of any previously known infestation. Infected trees were identified by interpretation of high-resolution aerial imagery as a part of the annual aerial survey. The second infestation, just outside Port Orford, 21 miles northwest of the Rogue River and 13 miles south of Coos County, was detected on April 27, 2021, along Highway 101 by a passing Oregon State University (OSU) researcher. Collected samples tested positive for the NA2 variant of *P. ramorum*; however, two of the confirmed positive samples, one tanoak and one rhododendron, were found to be the NA1 variant. Previously found only in nurseries, this is the first time the NA2 variant has been found in Oregon wildlands. Since 2021, this infestation has been the program’s top priority, with ODF, USFS, and OSU surveying over 600 acres of ground transects and collecting over 470 samples, resulting in 206 positive detections.

CURRENT SOD SLOW-THE-SPREAD PROGRAM

The current slow-the-spread program uses early detection, monitoring, and eradication treatment in areas outside the GIA to reduce the rate of disease spread and slow disease intensification. Survey, detection, and monitoring efforts are composed of ground, aerial and stream bait surveys. Ground-based detection and delimitation surveys around infested sites are done year-round. Aerial surveys, conducted from fixed-winged aircraft and a helicopter, take place four times per year, with the main surveys occurring in July and October when current-year tanoak mortality is most visible. Aerial surveys cover at least 700,000 acres of forest; ground surveys cover 600 acres. The current program uses high-resolution digital aerial imagery to augment aerial surveys. Stream baiting, the practice of periodically submerging host plant materials in streams and then testing the material for the presence of *P. ramorum,* is done in high-risk streams within and outside of the SOD quarantine area. Additional streams near infested nurseries or other infested non-forest sites may also be baited. Stream baits are deployed and collected at two-week to one-month intervals for a minimum of 8-10 months, beginning in late April.

Once an infestation is detected by survey, eradication treatments are conducted on all infested sites outside the GIA to the desired 300-foot treatment buffer. Eradication treatment on non-federal land still complies with quarantine regulations for conducting treatment, but the level of treatment varies from site to site due to limits on available funds. Federal land managers conduct eradication treatments to the desired 300-foot treatment buffer outside of the GIA, and in the case of BLM, also within the GIA.

Eradication treatments are most effective when carried out promptly and with the largest treatment buffer possible. However, if funds are not sufficient, minimal treatment is better than no treatment but increases the likelihood of the disease showing up nearby in subsequent years.

- Minimal Treatment -- Cut and burn all host material within a **20 to 50’** radius of an infected tree (0.03 to 0.18 acres) and fell and lop the remaining tanoak within a 300’ radius of the infected tree. Cost $1,650 per site.

- Desired Treatment – Hack and squirt all tanoak, then cut and burn all tanoak within a **300’** radius of an infected tree (6.5 acres). The cost would amount to $35,750 per site ($5,500 per acre). Sites that have a cluster of infected trees would be disproportionately higher in cost as the 300’ radius for the buffer treatment is from the farthest tree from the center.

- Ideal Treatment – Hack and squirt all tanoak, then cut and burn all tanoak within a **600’** radius of an infected tree (26 acres). The cost would be $143,000 per site ($5,500 per acre). Sites that have a cluster of infected trees would be disproportionately higher in cost as the 600’ radius for the buffer treatment is from the farthest tree from the center.

Program Structure

Essential program functions are shared among the following:

Oregon Department of Forestry (ODF) – Survey, detection, and monitoring; planning and administration of eradication treatments on non-federal land; landowner education and assistance. Operations are managed from Salem by the statewide forest pathologist in the Forest Resources Division and two Coos Bay District SOD foresters, and one seasonal forestry technician based in Brookings.

Oregon Department of Agriculture (ODA) – Authority and administration of the SOD Quarantine. Authority and administration of the nursery SOD program. Coordinates with USDA Animal and Plant Health Inspection Service (APHIS). Operations are managed out of Salem.

USDA Forest Service (USFS) – Planning and administration of eradication treatments on Rogue River-Siskiyou National Forest lands; assists ODF with aerial survey, conducts ground survey, detection and monitoring and technical assistance to federal land managers. Ground survey and treatment operations are managed by the Regional Sudden Oak Death Pathologist in Portland and a SOD Forester in Gold Beach in conjunction with the Rogue River-Siskiyou National Forest. Aerial survey assistance is provided by the Pacific Northwest Region Forest Health Protection aerial survey program. Through grants provided to ODF and BLM and contracts with OSU, the USFS provides program funding, technical support and assistance to entities engaged in SOD work.

USDI Bureau of Land Management (BLM) – Planning and administration of eradication treatments on Coos Bay District lands; conducts ground surveys and monitoring. Operations are managed by BLM foresters in the Coos Bay District Office with program coordination by Oregon State Office in Portland.

Oregon State University (OSU) College of Forestry – Testing of sampled plant material for *P. ramorum,* related diagnostics, and research. Jared LeBoldus' Forest Pathology Lab in Corvallis.

Oregon State University College of Agricultural Sciences/USDA Agricultural Research Service (ARS) Horticultural Crops Research Unit -- Genotyping of *P. ramorum* species and clonal lineages from sampled plant material. Nik Grünwald's Lab in Corvallis.

Oregon State University Forestry and Natural Resource Extension Service – Outreach, education, and assistance. Operations are conducted by the Forest Health Extension Specialist in Corvallis and the Coos and Curry Extension Forester in Myrtle Poin

Coordination of operations is conducted by the SOD Science Team: Sarah Navarro (Forest Pathologist, USDA Forest Service), Jared LeBoldus (Forest Pathologist, OSU), Gabriela

Ritokova (Forest Pathologist, ODF), and Chris Benemann (Interim Plant Program Director, ODA). Communication among landowners, nurseries, other organizations, and other interested parties is conducted through monthly SOD Core Group conference calls hosted by Sarah Navarro, USFS.

Program Expenditures

The survey, detection, and treatment for the SOD Program are labor and time intensive and have increased in cost over the last 20 years. From the first discovery in 2001 to 2022, management of the SOD epidemic in Oregon has cost upwards of $35 million (Table X). Federal agencies (USFS, USDA APHIS, and BLM) have borne most of the program costs, including a large influx of funds provided by the American Recovery and Reinvestment Act of 2009. Since 2017, state funding increased from previous levels through House Bills and through additions to the ODF biennial appropriations. Recently, the SOD Program has used new agreement authorities passed by Congress, such as the Good Neighbor Authority, to find creative ways to manage the disease. This enables the program to continue and strengthens the all-lands philosophy of disease management.

Federal Funding Sources

USFS funds a pathologist who provides program oversight and expertise and a Gold Beach RD SOD forester position focused on detection and treatment on National Forest lands ($228,000). The USFS also provides $200,000 per year for SOD diagnostics via a participating agreement with the LeBoldus Forest Pathology Lab at OSU. USFS treatments on the Rogue River Siskiyou National Forest are funded internally through the USFS budget on an annual basis and vary based on the detection of new infested sites.

USFS provides funding to ODF annually through cooperative agreements. These agreements support SOD surveys, monitoring, outreach and education, and treatments on privately owned lands. ODF receives between $375,000 and $500,000 per year from these agreements (this includes $35,000 from the forest health monitoring grant for stream baiting). Funding through the USFS requires 1:1 matching funds from receiving cooperators, which is met using personnel time, contractual treatment work, and in-kind contributions.

BLM funds eradication on their lands and related work through their internal budgeting process (between $60,000-$305,000) and through interagency grant programs, which are about $250,000 per year from USFS. Starting in 2020, ODF entered into a Good Neighbor Authority with BLM for ODF staff and contractors to conduct surveys, detection, and treatment on BLM lands. This agreement is in place until 2025.

USDA APHIS and NRCS provide funding when available within their agency budgets to assist with SOD Program needs. The Grunwald Lab receives $45,000 per year from USDA

APHIS for genetic variant analysis on all samples collected from Oregon forests. SOD treatments are prioritized by sample variant results, with NA2 infestations the highest priority for treatment under the SOD Program objectives. From 2019 to 2020, USDA NRCS paid out around $373,000 over 10 contracts with local landowners for SOD treatment on their properties through the Department's Environmental Quality Incentives Program (EQIP). The funds provided a 30-40% cost share depending on the activity, with ODF using state funding to fund the remainder of the treatment work; thus allowing state funds to complete treatments on more acres per year.

State Funding Sources

ODF funds a statewide forest pathologist out of the Salem Headquarters, two SOD foresters, and a seasonal technician in Brookings, plus office space, vehicles, and field equipment for staff. Over the last two biennia (2019-2021 and 2021-2023), ODF received $1.7 million in SOD Program funding through the Oregon State Legislature. In 2019, the funding was part of HB5050 and in 2021, it was added to the agency's biennial appropriation. This funding also included a provision to provide $50,000 as a block grant to the Association of Oregon Counties to convene and facilitate the SOD Task Force.

Estimated Annual Program Expenditures- (funding source)

ODF-Brookings Field Office ($146,000 US Forest Service, $123,000 State General Fund)	$269,000
ODF-Salem Staff (State General Fund)	$92,000
ODF-Aerial Surveys (includes digital imaging) (US Forest Service)	$55,000
OSU-LeBoldus Lab (US Forest Service)	$200,000
OSU/USDA ARS-Grunwald lab (USDA APHIS)	$45,000
USDA Forest Service	$228,000
BLM-Coos Bay staff	$145,000
Subtotal	**$1,034,000**

Estimated Annual Eradication Treatment Expenditures

ODF ($850,000 State General Fund; $250,000 US Forest Service)	$1,100,000
USDA Forest Service	$250,000
BLM ($305,000 BLM and $250,000 US Forest Service)	$555,000
Subtotal	**$1,905,000**
TOTAL	**$2,939,000**

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Table 1. Funding sources and total costs for management of the Oregon SOD Program

Year	USDA Forest Service (Federal)	OR Department of Forestry (State)	Bureau of Lant Management (Federal)	Landowners (Private)	Other OR State Agencies (State)	USDA APHIS/NRCS (Federal)	USFS ARRA (Federal)	Total Program Funding
2001	$96,100	$25,000	-	-	-	-	-	$121,100
2002	$258,400	$50,000	-	-	-	-	-	$308,400
2003	$222,000	$70,000	-	$10,000	-	-	-	$302,000
2004	$404,700	$70,000	-	$10,000	-	-	-	$484,700
2005	$130,000	$70,000	-	$10,000	-	-	-	$210,000
2006	$424,000	$436,000	-	$10,000	-	$70,000	-	$940,000
2007	$530,000	$814,000	$25,000	$10,000	-	$75,000	-	$1,454,000
2008	$838,000	$252,000	$445,000	$10,000	-	$325,000	-	$1,870,000
2009	$359,200	$150,000	$700,000	$10,000	-	-	-	$1,219,200
2010	$569,000	$95,000	$531,000	$10,000	-	-	$2,692,000	$3,897,000
2011	$735,000	$175,000	$507,000	$207,000	$86,500	-	-	$1,710,500
2012	$805,000	$260,000	$447,000	-	-	-	-	$1,512,000
2013	$577,300	$395,000	$239,000	$10,000	-	-	$10,000	$1,231,300
2014	$640,000	$290,000	$557,000	$10,000	$10,000	-	-	$1,507,000
2015	$915,000	$290,000	$450,000	$15,000	-	$20,000	-	$1,690,000
2016	$842,000	$490,000	$467,000	$10,000	-	$20,000	-	$1,829,000
2017	$913,500	$942,000	$489,000	$10,000	$81,000	-	-	$2,435,500
2018	$1,188,997	$1,215,000	$328,784	$10,000	$334,687	-	-	$3,077,468
2019	$870,000	$1,915,000	$458,749	$10,000	-	$397,490	-	$3,651,239
2020	$1,138,000	$365,000	$737,000	$10,000	$15,774	$116,711	-	$2,382,485
2021	$875,000	$1,915,000	$279,091	$10,000	-	-	-	$3,079,091
2022	$629,127	$269,000	$296,395	$10,000	-	-	-	$1,204,522
TOTAL	**$13,331,197**	**$10,284,000**	**$6,660,624**	**$382,000**	**$527,961**	**$1,024,201**	**$2,702,000**	**$36,116,505**

PROGRAM SUCCESSES AND CHALLENGES

Successes

Over the last 20 years with intensive surveys, detections, and treatments, the Oregon SOD Program has slowed the spread of the disease in southwest Oregon forests and delayed large-scale economic and ecological effects. SOD is much more widely established in Californian forests than in Oregon, with 16 counties from the Oregon border to the central coast region under federal quarantine. Since the beginning of the program, state and federal agencies have worked collaboratively together for an "all lands" approach to the program, making it currently one of the only landscape-level forest disease management programs in the US. While funding has remained at relatively stable levels throughout the years, the amount of disease on the landscape has always outpaced the available funding for treatments on private lands. Program managers with ODF, USFS, and BLM have utilized new has new agreement authorities passed by Congress, such as the Good Neighbor Authority, to find creative ways to manage the disease and continue to strengthen the all-lands philosophy.

In 2016, the Association of Oregon Counties formed a SOD Task Force, which convened local, state and federal government agencies, tribes, industry, and local residents and environmental groups. After two decades of SOD management in Oregon's forests, the SOD Task Force serves to reengage fatigued stakeholders who previously saw no end in sight and brought new participants to the table. Originally co-led by State Senator Brock Smith and US Senator Jeff Merkley, the mission of the Task Force was to develop a collaborative-based strategic action plan, including securing more resources to contain the NA1 lineage of *P. ramorum* and eradicate the EU1 lineage in Curry County using the best available science. Following the strategic action plan, ODF commissioned an economic impact assessment of SOD, completed in 2019.

The assessment concluded that there would be a 19:1 cost benefit to the southern Oregon economy to continue to slow the spread of SOD under the current management strategy. These savings are largely due to delaying the effects of potential timber export sanctions and the loss of associated jobs, which include:

- Sanctions on southwest Oregon timber exports by China, Japan, and/or Korea
- Loss of 1,200 jobs related to timber export; $57.9 million in annual wages
- Reduction of timber harvest by 15%, with proportional loss of forest products harvest tax revenue, and forest sector jobs and wages
- Collapse of rural residential property value; loss of real estate transaction revenues

- Decline in recreation and tourism income if an unfavorable public perception of the region takes hold due to SOD infestation

Potential impacts of SOD strike at core values that elude economic quantification, particularly tribal cultural values and the merits of tanoak-dominated forests. Cultural practices with great historic and traditional meaning—acorn gathering, materials for basket weaving, hunting—are already compromised by SOD but lack a consensus value in market terms. SOD may be an existential threat to tanoak and species that depend on tanoaks; these forests have inherent non-monetary value and may contribute to unrecognized ecosystem or biodiversity values.

Challenges

Despite disease management efforts, SOD has invaded southwestern Oregon forests at least four times. In hindsight, the establishment of larger buffers around infested sites (initially set at 100-m radii) would have slowed down or halted the epidemic; but pathogen biology research was still being conducted when treatment buffer size was established. By about 2010, it became apparent that SOD could only be slowed. Attempts to eradicate the subsequent EU1 invasion also failed and it is likely that eradication of the newly detected NA2 variant will also fail. ODF does not have the treatment budget or staff time to complete treatments within the SOD Quarantine at this point given the priority placed on the Port Orford treatment area. Although the SOD Program shifted from the original objective of complete eradication, treatments have been shown to reduce pathogen load, slow the spread of the pathogen, and delay potential limits on the export of Douglas-fir logs.

Funding levels and, in some years, lack of funding influenced the program's switch to slowing the spread of SOD in Oregon. Disease spread potential is highest during late spring and early fall, when temperatures are mild and moisture levels are high. The program tries to time treatment work during these times as well to reduce pathogen loads on the landscape. However, these periods coincide with the end of the state and federal budget cycles, where funding may not be available to rapidly respond to infested sites. Given state funding deadlines and federal agreement life span, the SOD Program has no mechanism of "banking" treatment funds across multiple years to use in years with high-priority infestations are present. Although program managers across federal and state agencies work collaboratively to stretch funding across all lands where allowed, it can only go so far and many private landowners are left without treatment for SOD infestations.

Early detection/rapid response is key to any invasive species management program. The Spread of SOD on the landscape continues due to the challenges of early detection of newly infested sites, as the pathogen may be present and spreading for up to two years before whole tree symptoms are visible to SOD foresters. While the program has employed a multitude of detection techniques, including newer technologies such as remote sensing and now drones, early detection of SOD has been difficult. Without reliable tools to detect new infestations right away before the pathogen can intensify at a site and spread, the program will continue to be behind the actual leading edge of the disease for treatments.

Obtaining landowner permission for treatments and monitoring, working in populated areas with heavily fragmented ownerships with multiple management objectives, and working around utilities and other infrastructure are challenges facing state agency personnel trying to manage SOD. As a last resort, on five occasions, ODF staff have had to obtain administrative warrants to complete surveys and treatments. Another challenge has been finding enough contractors to treat multiple infestations simultaneously before the rainy (spread) period sets in. Even when contractors are under contract, limited labor force availability has made it difficult to get the treatment work completed in a timely manner. Likewise, seasonal fire restrictions limit treatment progress during the dry season, which would be advantageous from a disease-spread standpoint.

PROGRAM EFFICACY

Disease Modeling

Over the last 6 years, researchers at North Carolina State University collaborated with ODF, USFS, and the Oregon SOD Task Force to model SOD spread and control (Gaydos et al., 2021). The resulting model is an extension of the Pest or Pathogen Spread (PoPS) model, an interactive geospatial simulation that was originally developed to model SOD in California (Jones et al., 2021). The updated model reflects the unique host and weather conditions in Oregon and has calibrated the spread parameters with over 20 years of detection data provided by ODF. Because different pathogen strains exhibit different epidemiology, the model was calibrated separately for the EU1 and NA1 strains. Not enough data was available to accurately calibrate the NA2 strain (at least 3 years are needed), but based on local observations, EU1 parameters were believed to be an appropriate surrogate.

The model can simulate treatments (e.g., removal of infected hosts) and can therefore be used to evaluate treatment efficacy. For example, the model can be used to test the efficacy of removing and burning infected tanoaks in limiting disease spread, with treatment parameters defined based on input from ODF and USFS experts. Stakeholders tested and refined this treatment during two modeling workshops (Gaydos et al., 2019; Gaydos et al., 2021). The current model reflects our understanding of SOD spread and control in Oregon based on the data and local stakeholder observations.

Using the model, simulations were made to test the efficacy of standard disease treatments in limiting the spread of NA1 and EU1 in Oregon; modeled results were compared results with actual disease occurrence data generated by ODF. For each variant, model simulations projected the initial conditions in the year of first detection to 2022 (NA1: 2001-2022; EU1: 2015-2022). The model is stochastic (i.e., each iteration will be slightly different), so each simulation was performed 1,000 times to generate the expected variation in the results. In the Simulated Treatment (ST) scenarios, the model used treatment location data provided by the SOD Program to remove tanoak in areas that had been treated by ODF, USFS, and BLM, simulating actual treatments that have been made. In the Simulated No Treatment (SNT) scenario, the model did not remove tanoak from the data, representing a hypothetical situation where no treatments were conducted. Actual detection and treatment data from the SOD Program were plotted for comparison.

The model-simulated area of infection at the end of the projections was similar to actual current conditions, indicating that the model worked as intended and that the ST scenario is a decent approximation of reality (Figures 3 and 4). We see a greater divergence between the observation and simulation with the NA1 variant because of the compounding of errors over a greater projection length (Figure 5). The divergence is predicted to occur around the time the generally infested area (GIA) was established, but whether this is a contributory factor is unknown. The difference between the actual treatment and ST scenarios for the NA1 variant was not small, but the actual or predicted acreage, respectively, was a fraction of the infected acreage predicted for the SNT scenario (Figure 4). This was true for both variants and was expected because, without treatment, inoculum can build up, intensify locally, and increase disease spread. These model results suggest that Oregon's control strategy to date may have prevented 180,647 ∓ 7,448 acres of NA1 infection from 2001-2022 and 1,178 ∓ 235 acres of EU1 infection from 2015-2022.

The model was also used to conduct a forward-looking analysis to determine how continued treatments or lack of treatments might impact disease spread over the next 4 years, starting with 2022 infections. In the previous scenarios, treatments were applied in the exact locations treated by ODF and cooperators. For these forward-looking scenarios, the treatment areas for the projections were based on modeled infections and parameters determined by ODF and USFS. For example, pixels treated in 2024 were based on model-predicted disease spread from 2023. The simulation treated approximately 173 acres each year (the average acreage treated from 2020-2022), although the acreage varied slightly if treatments overlapped. All variants were modeled concurrently, and treatment locations were prioritized, starting with the northernmost EU1 and NA2 infections and moving south until 173 acres were treated. NA1 infections were only treated if all EU1 and NA2 locations had already been treated. The model results suggest that continuing the current treatment strategy could prevent 31,850 ∓ 18,256 acres of NA1 infection, 8,127 ∓ 5,125 acres of EU1 infection, and 457 ∓ 321 acres of NA2 infection over the next 4 years (Figures 6-8).

The model does not account for all possibilities, and the future of SOD spread in Oregon is uncertain. Importantly, the model does not consider the potential for new introductions through the human-mediated movement of infected plants or materials. As observed with the relatively recent EU1 and NA2 outbreaks, a new introduction can quickly change the trajectory of disease spread and management. Additionally, the model does not consider the possibility of completely new variants or sexual recombination between existing variants. However, these events are rare and highly uncertain, and the model is a reasonable approximation based on the current situation. Model results indicate that treatments conducted by ODF and cooperators have substantially reduced SOD spread and impacts over the last 20 years, and that continued treatments are likely to reduce spread over the next 4 years.

ALTERNATIVES AND THEIR CONSEQUENCES

Alternative 1: Transition To Living With The Disease

Sudden oak death is here to stay and will be a forest health issue in the future. Under this alternative, the slow-the-spread program (survey, detection, and eradication) would be halted. Federal funding for SOD would likely decrease and agencies would conduct SOD detection and monitoring surveys during their normal course of business. Through annual aerial surveys and imaging, small-scale ground surveys, and possible citizen science programs, the disease spread could be monitored and provide data to researchers and graduate students. ODF could continue to provide technical assistance to landowners who want to know why their tanoaks are dying and what they can do about it, give advice on how to reduce hazards from fire and tree fall, assist in enforcing quarantine regulations, and promote best management practices for this forest health issue. In short, we would rely on educating people to mitigate the effects of the disease and prevent its spread to other susceptible forests in adjacent counties. This scenario would be similar to what is happening in much of California.

Without treatment, the disease intensifies and the rate of spread increases. Tanoak is rapidly dying out in infested areas in California and in the Oregon GIA. Oregon will lose tanoak in at least the western portion of its range. Birds, mammals, insects and fungi dependent on tanoak will adjust, migrate or die. Loss of tanoak will impact traditional Native American culture; they have traditionally relied on tanoak acorns as a food source. Assuming no human spread, starting at the farthest north infestation (Hunter Creek), the disease spreads northward at 3.5 miles per year. At this rate, the disease could reach the Coos County line in 10-12 years.

The quarantine regulations could change soon to encompass all of Curry County and eventually Coos and Douglas counties, potentially raising export and trade issues with species on the *P. ramorum* host list, including Douglas-fir, western hemlock, grand fir, and others. Forest, nursery, Christmas tree and other forest product operations that intend to ship material will need inspections and disease-free certifications, probably on a fee-for-service basis.

Alternative 2: Continue the current slow-the-spread program (with prioritized treatment sites)

This alternative continues the current slow-the-spread program as funded today. BLM continues to treat all infestations on their managed lands. USFS expects to treat all known sites to some extent; minimal treatment standards may need to be used based on available funds. The number of outlying sites in 2022 exceeded the program's capacity to treat all sites with 300-foot buffers. Thus, the program created treatment priority areas to identify where sites will receive 300-foot buffers while other sites will receive treatment based on available funding. The establishment of the GIA has allowed the program to focus treatment efforts on high-priority sites. However, the current budget does not allow for full treatments of all new infestations outside of the GIA.

The consequences of continuing the slow-the-spread program at current funding levels are becoming clear. In areas where treatments have stopped, disease intensifies dramatically and kills most of the tanoaks in just a few years (Figure 9). As more inoculum is produced in the areas of uncontrolled disease, the leading edge of the main infestation expands northward and eastward, and the probability of human-assisted spread increases. Each year, outlier infestations become more numerous and occur farther from the leading edge. Funding for eradication treatments is not sufficient to treat all outliers effectively and will continue to be increasingly insufficient as the disease continues to intensify. Scaling treatment area size to the importance of site allows the most important infestations to be cut and burned, which slows disease relative to no treatment.

Under this scenario, disease reaches the Coos County line in 15 years. The GIA would continue to expand northward at 2 miles per year (rate of recent GIA expansion), with outliers occurring no more than 12 miles to the north and assuming no human-assisted spread. At current funding levels, there is a risk that the rate of spread and the risk of human spread will increase.

Additionally, Oregon State University would continue to conduct small-scale research studies based on SOD program needs using existing funding from ODF and USFS.

Alternative 3: Continue the current slow-the-spread program, with enhanced funding to fully treat all sites

Assuming at least 717 acres requiring treatment per year on forestlands, implementing the desired treatment level (300-foot buffer) at an average of $5,500 per acre would cost $3,943,500 per year. Expanding this number to $4,500,000 per year would provide an eradication treatment budget that accounts for some sites being larger because they encompass groups of infected trees and/or more costly due to difficult terrain or working in and around homes, power lines, and other structures.

Under this alternative, the slow-the-spread program would need to secure increased funding for conducting eradication treatments on all lands to $4,500,000 per year. Unused funds should be allowed to be banked from year to year so as to take advantage of savings incurred during years with fewer necessary treatments, making it available during years with greater treatment costs. Mechanisms should be developed so funds can also be used on all lands should their managers face the same financial limitation currently being incurred on non-federal lands to treat sites at the desired levels.

Research is needed to improve our ability to combat sudden oak death, especially given the introduction of the EU1 and NA2 lineages in Oregon's forests. A cooperative, competitive research program is proposed to improve early detection and silvicultural control methods, as well as compare aggressiveness and host range for the NA1 lineage versus the EU1 and NA2 lineages. Studies are also needed to describe the ecological impacts of sudden oak death in Oregon.

Alternative 4: Contain To Curry County for as long as possible

Alternative 4 focuses on preventing sudden oak death from entering the adjacent counties (Coos, Douglas, and Josephine) for as long as possible. This alternative increases the chance of protecting important tanoak ecosystems and provides for long-term conservation and adaptation of tanoak genes. Alternative 4 builds on alternatives 2 and 3 because continuing to slow the spread in the southern portion of Curry County is essential for containment farther north.

There is strong interest in avoiding a countywide SOD Quarantine for Curry County as well as slowing the spread of SOD into neighboring counties. A means of ensuring aggressive eradication of human-assisted or other unanticipated infestations would be to establish an Emergency Fund held in reserve and available to rapidly respond to new infestations in an action zone adjacent to neighboring counties or for sites detected in the neighboring counties themselves.

This opportunity also requires an expansion of survey, detection and monitoring capacity due to the need to survey the action zone and the area between the action zone and quarantine area at intensities currently reserved for within the quarantine area and areas proximately surrounding its boundary. Given the cost of an ideal eradication treatment (600-foot radius, 26 acres), this emergency treatment money would be spent in order to cover one infestation. An emergency eradication treatment fund totaling $500,000 would potentially treat five new sites (or 100 acres) at the ideal treatment level; this would relieve the burden of finding continued funding on an annual basis.

Alternative 4 requires increased survey effort in the 6-mile-wide action zone between Curry, Coos and Douglas Counties. The additional survey effort would include 20-30 stream baits and two aerial surveys of 250,000 acres each near the county lines. Intensive delimitation surveys are conducted whenever a new infestation is found. This alternative will likely require an increase in field staff. The cost of this increase in aerial surveys, field technician time, and lab diagnostics is estimated at $100,000 /year.

Additionally, the program must be able to mobilize field support crews quickly and sometimes simultaneously within days or weeks of detection to prevent additional spread, especially in the action zone. Contractor response time has been problematic due to fire danger and contractor availability. We will need to review and secure contracts to ensure acceptable response time or to train a local workforce to conduct eradication work.

Alternative 4 is designed primarily to ensure that SOD does not move into Coos, Douglas, or Josephine counties, and it should succeed at doing that for at least 10 years and perhaps longer. Cutting and burning isolated individual infestations can slow the intensification and spread, provided delimitation and treatments are done properly. Based on current observations, it is unlikely that the disease will naturally spread across the 6-mile-wide action zone without detection and an opportunity for slowing the spread, provided continued diligence of detection surveys. Host removal in disease pathways leading to the action zone should improve the chance of containment in Curry County. The GIA likely will expand slowly, the rate of which will depend in part on our capacity to treat infestations beyond its leading edge to the north but short of the action zone.

Other options can be done simultaneously with alternatives.

Finding and developing disease-resistant tanoaks is a long-term proposition with an unknown probability of success. Preservation of important tanoak ecosystems (refugia) seems possible if located away from the highest disease-risk areas.

- **Tanoak Refugia**: Protection of important tanoak ecosystems (refugia) is possible if located away from the current distribution of SOD as well as away from the highest disease risk areas. Areas of tanoak with high ecological and/or cultural value would be identified. Protection would involve intensive early detection, strict limits on human access and ideally, eradication within 2-3 miles of each identified refuge. These areas likely will be located on federal land and will be selected by land managers and interested parties. These areas also could be part of a larger tanoak gene conservation effort. **Cost: $130,000/year-** $30,000 for additional aerial and ground surveys at 3 areas ($10,000 per area) and $100,000 to expand the scope of the Emergency SOD Treatment Fund to include treatment needs around designated refuges.

- **Resistance Breeding for Tanoak**[1]: Begin a long-term program of locating and developing tanoaks that can grow and reproduce in the presence of *P. ramorum*. Partner with Dorena Genetic Resource Center and OSU. **Cost: $30,000/year.**

- **Tanoak Removal in Strategic Areas:** Identify areas on the landscape that are likely pathways for aerial dispersal of *P. ramorum* into adjacent counties and remove or destroy tanoak in advance of the disease. The location of these areas will be determined by recent dispersal patterns, landforms, the amount and distribution of tanoak, and risk modeling. Private landowners will need incentives to do this. Incentive programs may be available to encourage landowners to remove tanoak and establish conifers or other non-host species. Increase market opportunities to utilize tanoak so as to cover the cost of removal within the quarantine area to encourage projects. **Cost: $650,000/year** to treat 1,000

[1] Finding and developing disease-resistant tanoaks is a long-term proposition with an unknown probability of success.

acres/year; 50% hack and squirt treatment at $300/acre; 50% slash and burn treatment at $1,000/acre. This opportunity is scalable depending on the amount of funding secured.

- **Stakeholder Cooperative:** Coordinate detection and control among all landowners in SW Oregon. If stakeholders, especially private industry, do not want SOD to enter Coos and Douglas Counties, they should begin action and investment now.

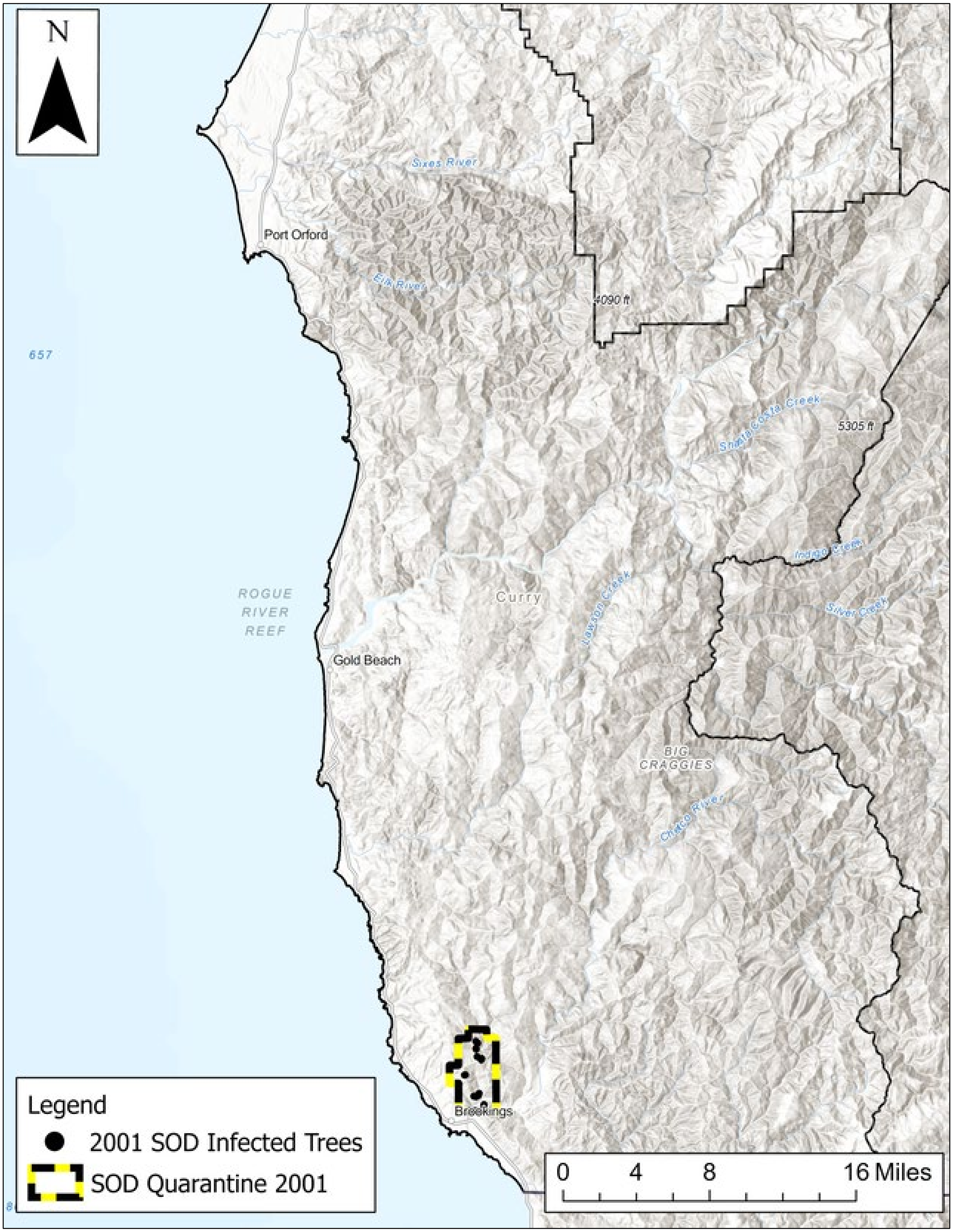


Figure 1a. Initial SOD infestation and establishment of a quarantine area in 2001 denoted with yellow/black.

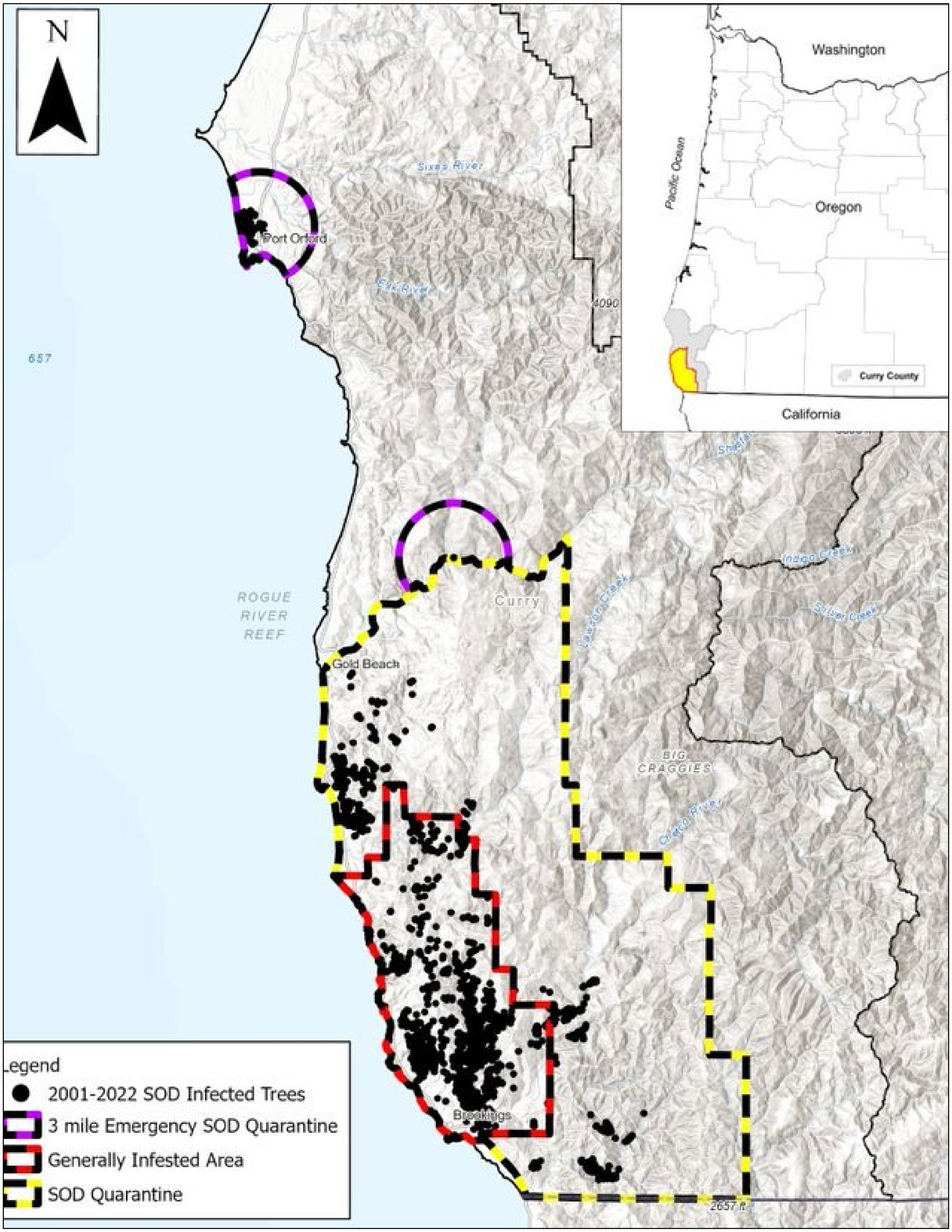


Figure 1b. Oregon SOD infestations from 2001 to 2022. The SOD quarantine area is denoted in yellow/black. The Generally Infested Area (GIA) is denoted with Red/black. An emergency quarantine for NA2 and EU1 detections is denoted with purple/black.

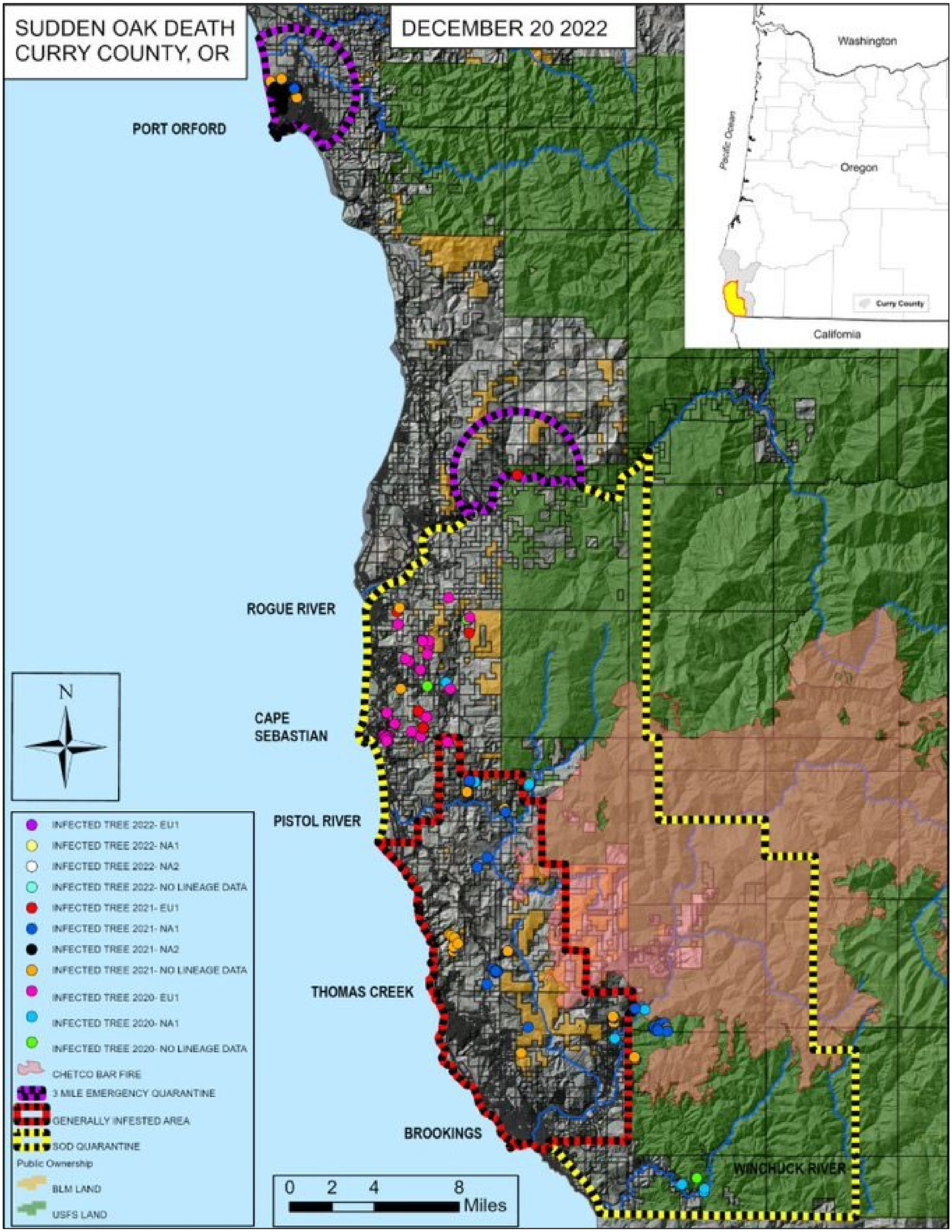


Figure 2. P. ramorum infestations in Oregon from 2020 to 2022. The SOD quarantine area is denoted in yellow/black. An emergency quarantine for NA2 Port Orford and for EU1 detection in 2021 is denoted in purple/black.

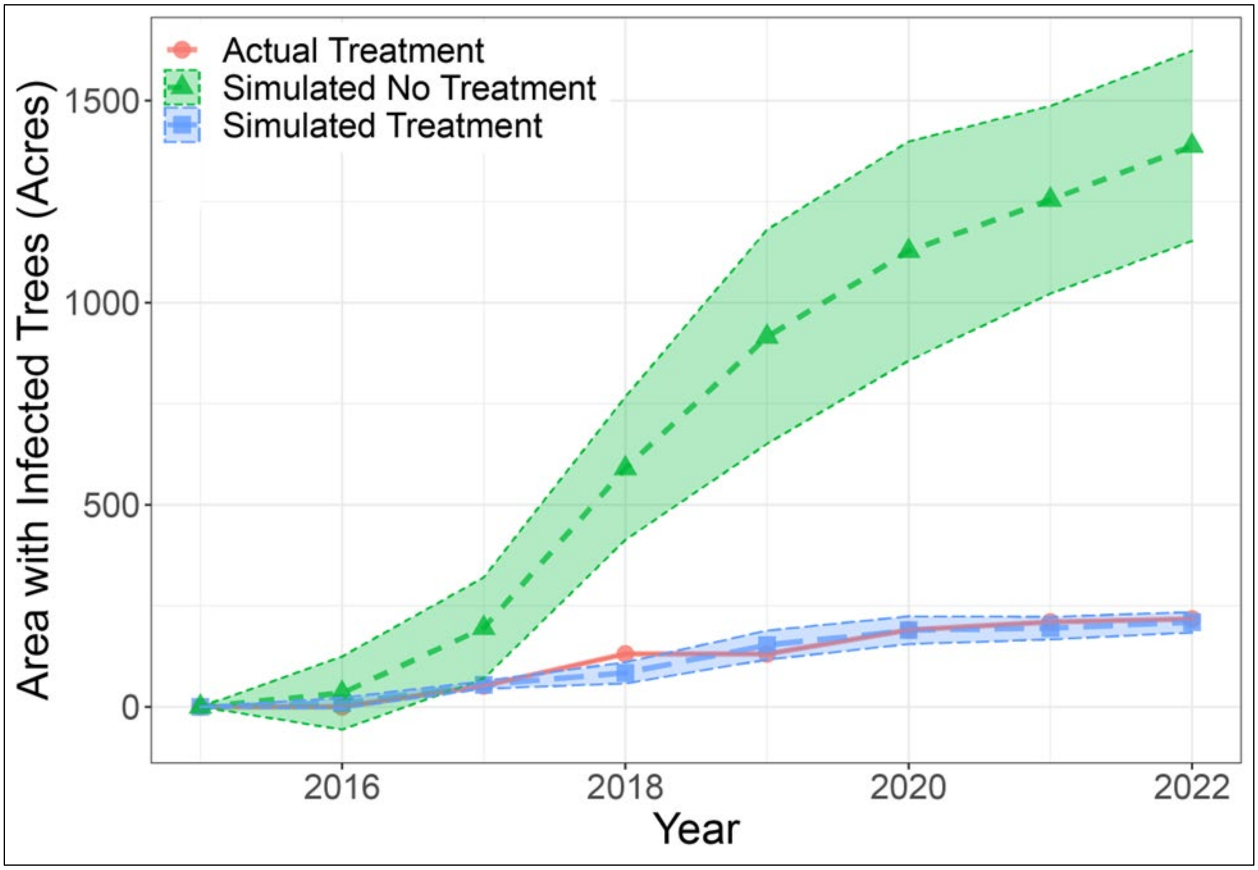


Figure 3. ***EU1-infected Acres in Simulations and Observed Data.*** *Actual Treatment = cumulative area infected with the SOD EU1 variant based on survey observations and treatments. Simulated Treatment = simulated EU1-infected area with actual treatments simulated. Simulated No Treatment = simulated EU1-infected assuming no treatments happened.*

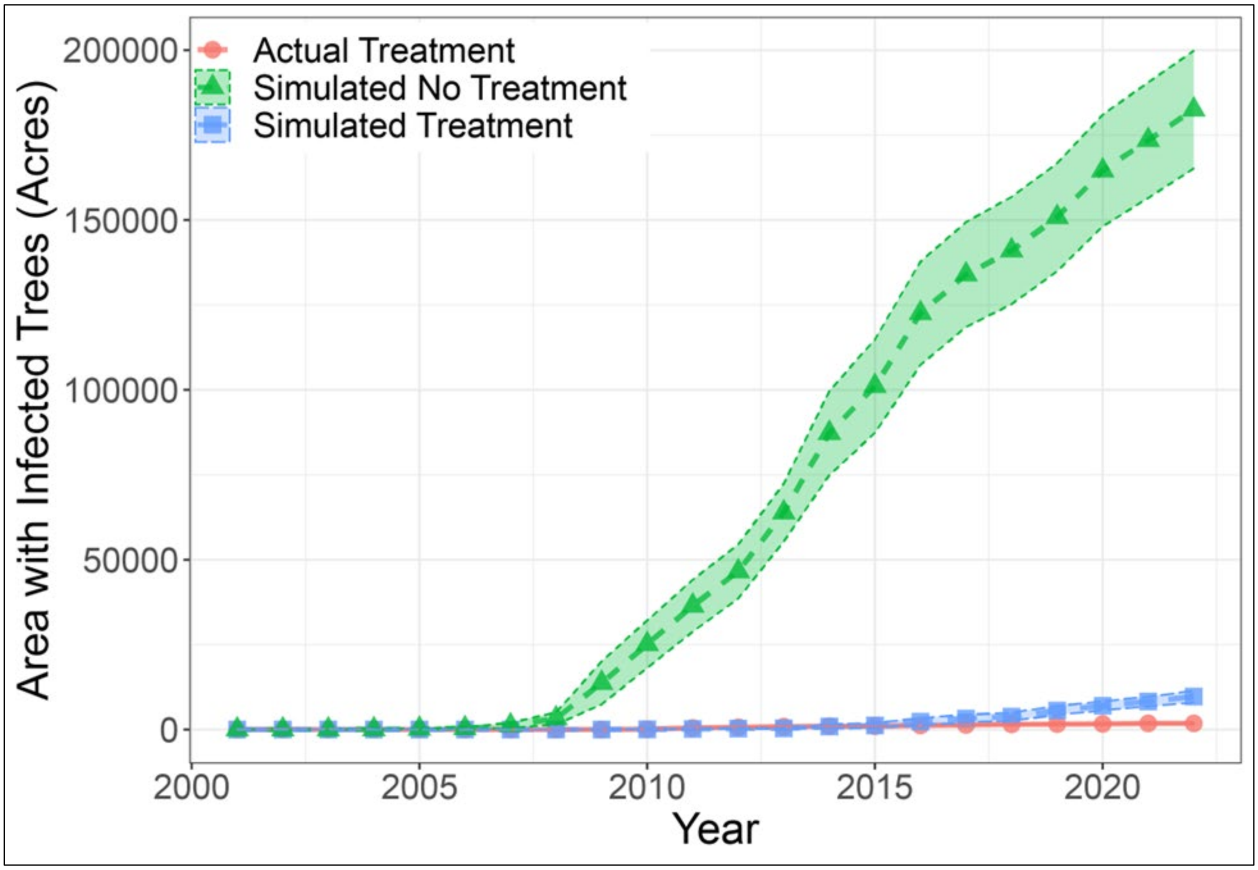


Figure 4. ***NA1-infected Acres in Simulations and Observed Data.*** *Actual Treatment = cumulative area infected with the SOD NA1 variant based on survey observations and treatments. Simulated Treatment = simulated NA1-infected area with actual treatments simulated. Simulated No Treatment = simulated NA1-infected assuming no treatments happened.*

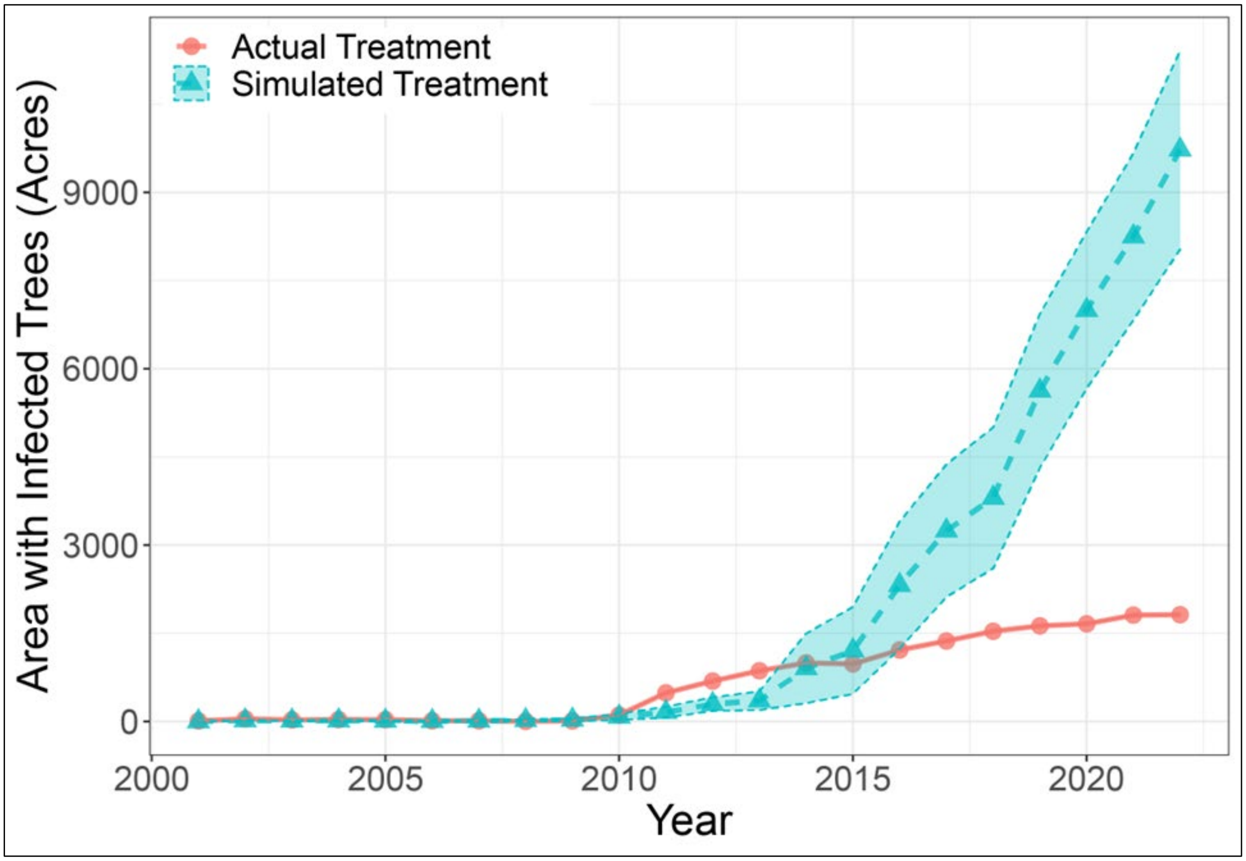


Figure 5. ***Closer Look at NA-1 Actual Treatment and Simulated Treatment Scenarios.*** *Actual Treatment = cumulative area infected with the SOD NA1 variant based on survey observations and treatments. Simulated Treatment = simulated NA1-infected area with actual treatments simulated.*

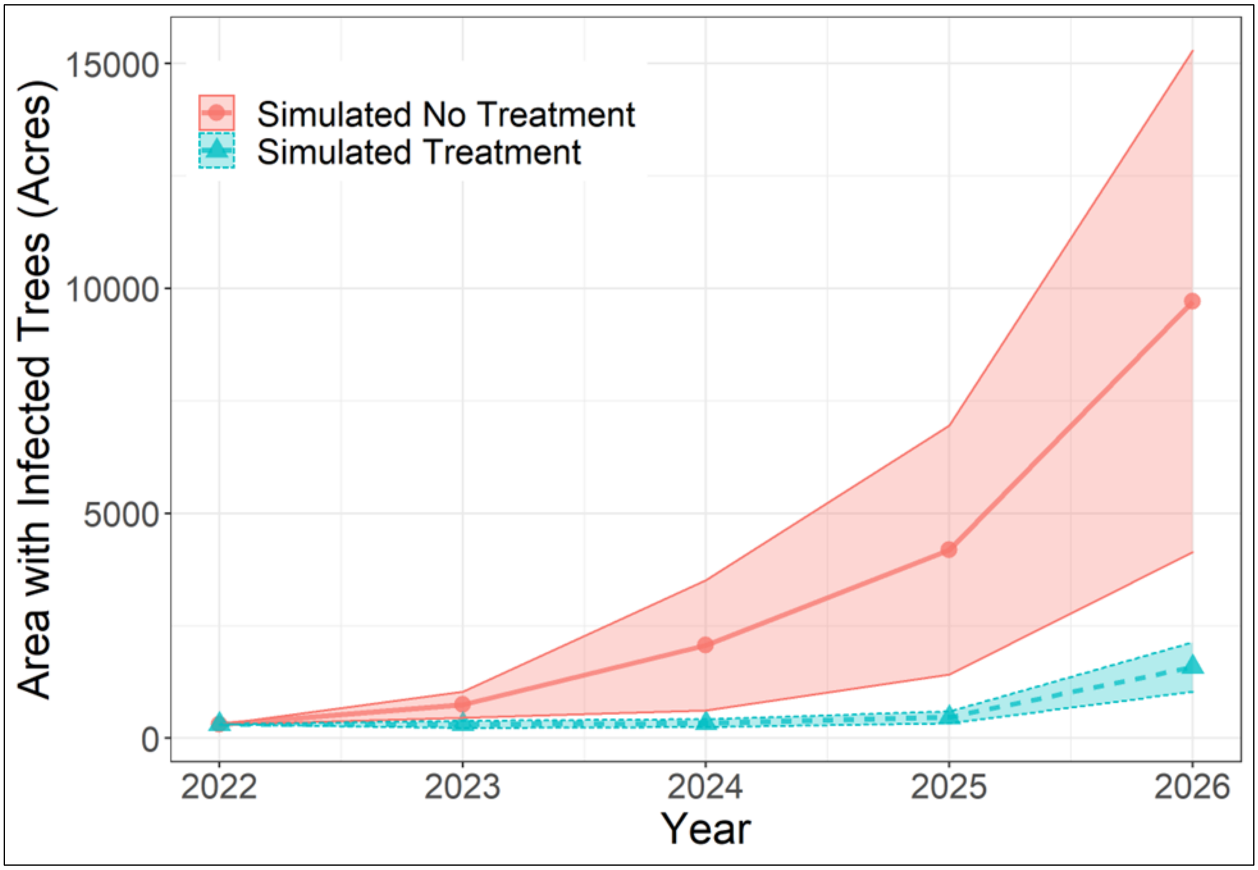


Figure 6. ***EU1 Simulated Future Treatment Scenarios.*** *Simulated Treatment = simulated EU1-infected area with treatments simulated. Simulated No Treatment = simulated EU1-infected assuming no treatments happened.*

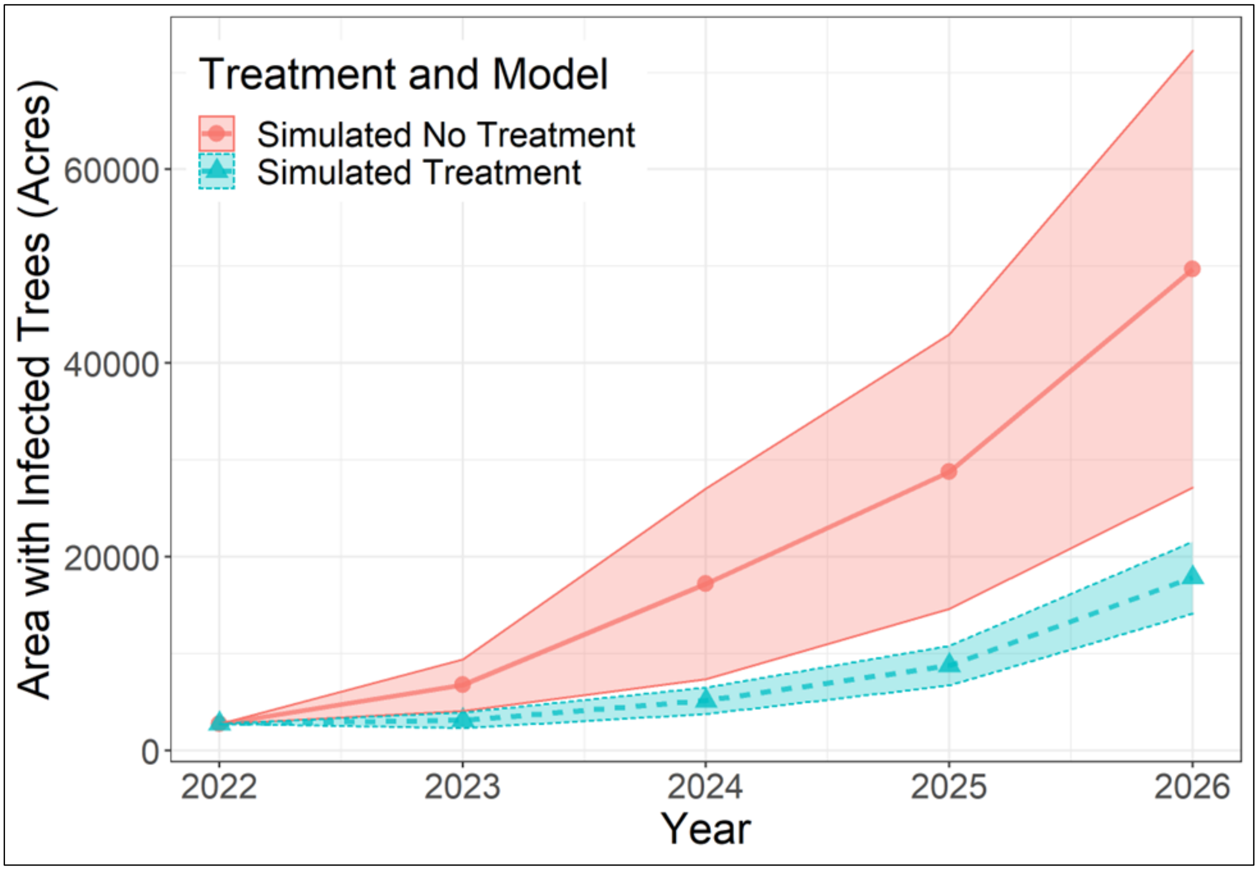


Figure 7. ***NA1 Simulated Future Treatment Scenarios.*** *Simulated Treatment = simulated NA1-infected area with treatments simulated. Simulated No Treatment = simulated NA1-infected assuming no treatments happened.*

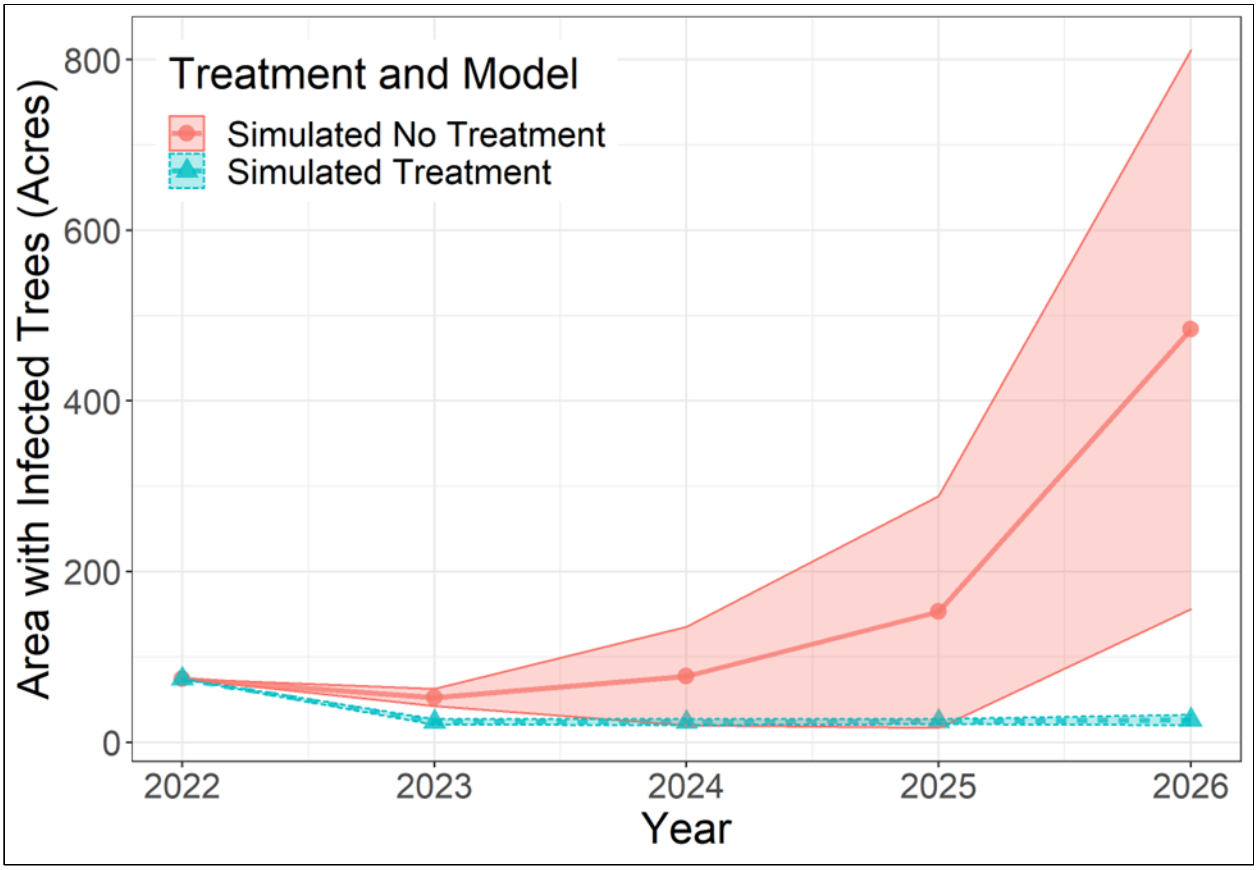


Figure 8. ***NA2 Simulated Future Treatment Scenarios.*** *Simulated Treatment = simulated NA2-infected area with treatments simulated. Simulated No Treatment = simulated NA2-infected assuming no treatments happened.*

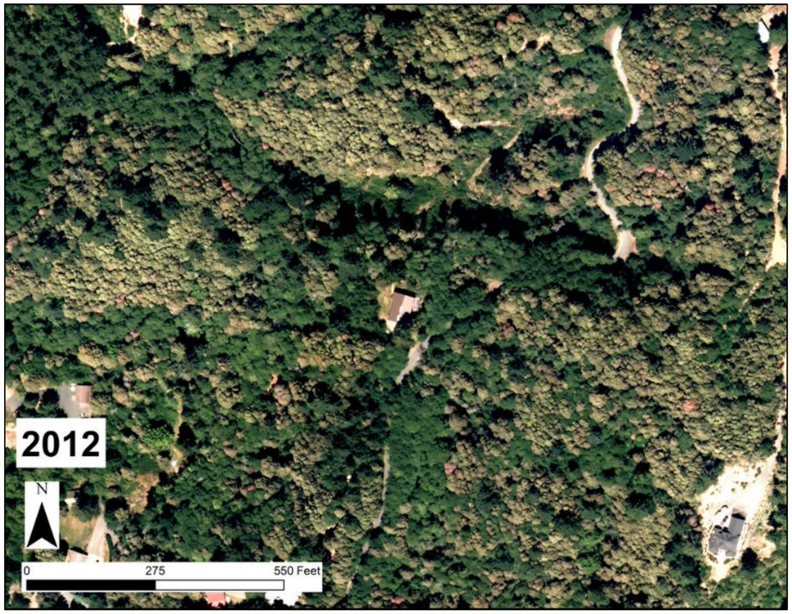
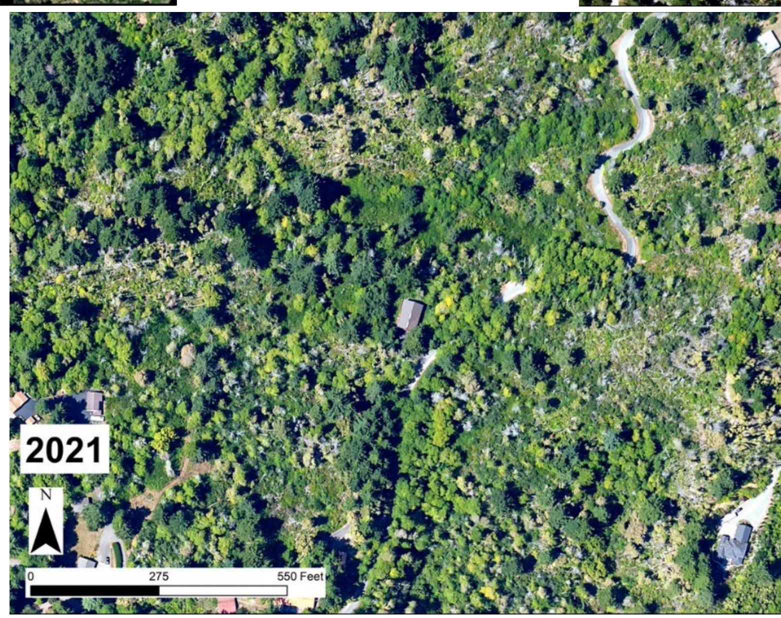


Figure 9. High-resolution aerial photography taken just north of Brookings, OR near Cape Ferrelo.SOD was initially detected in the tanoak stands in 2011 without subsequent eradication treatments as area was placed in the GIA (photo from 2012). After 4 years (2016), 80 to 90% tanoak mortality can be observed in the stands. In 2021, many of the tanoak stands have been replaced by shrub fields consisting of salmonberry and Himalayan blackberry. (From: LeBoldus et. al. 2022)



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