

Is Sudden Oak Death Becoming a Threat to California's Chaparral Ecosystem? First Indications for *Phytophthora ramorum* Moving into Drier and Warmer Habitats

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Chaparral habitat on Mt. Tamalpais, Marin Co.



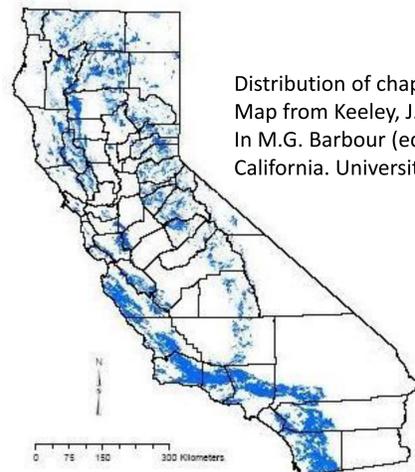
Symptomatic chinquapin



Symptomatic manzanita



'Bait plant' for transmission detection



Distribution of chaparral in California
Map from Keeley, J.E. and F.W. Davis. 2007. Chaparral. In M.G. Barbour (ed), Terrestrial vegetation of California. University of California Press, Los Angeles.

Since its introduction into California, *Phytophthora ramorum* was found predominately on a rather narrow band along the coast characterized by mild temperatures and abundant year-long moisture (the 'fog belt'). The presence of foliar hosts, especially California bay laurel (*Umbellularia californica*), common in this ecosystem, is an essential driver for the spread of the disease to 'dead-end hosts', such as coast live oak (*Quercus agrifolia*) and tanoak (*Notholithocarpus densiflorus*).

Chaparral plant community

Shrublands in California, known as chaparral, are shaped by Mediterranean climate with mild, wet winters and hot dry summers and the regular occurrence of wildfires. Chaparral covers approximately 5% of California, especially along the coast and the foot hills, and contains many endemic species. More than 40 species of manzanitas (*Arctostaphylos* sp., Ericaceae) are found in the California chaparral, many of them with a very limited distribution and not found outside the state.

Recently, *P. ramorum* was detected on several plants typical for the chaparral plant community (*Arctostaphylos* spp.; and chaparral pea *Pickeringia montana*; Fabaceae) on a high, sun-exposed ridge in Marin County. In addition, *P. ramorum* was isolated from dying chinquapin (*Chrysolepis chrysophylla*; Fagaceae) from the same location (Rooney-Latham et al. 2017). Chinquapins are small to mid-size trees native to California and the Pacific Northwest, found mainly on warm, dry, exposed locations.

During 2018, a severe outbreak of disease was observed on chaparral plants on Mt. Tamalpais in Marin Co., with symptoms including wilting, branch dieback and occasionally plant death. Leaves and branches of several plants showed a positive reaction for *Phytophthora* spp. using immuno-strips; *P. ramorum* was detected using PCR from a manzanita stem. In addition, *Neofusicoccum australe* (Botryosphaeriaceae) was isolated from a symptomatic plant. The infested area is on a southern slope with no apparent presence of California bay laurel or tanoak. *P. cinnamomi* is also known to occur in the area, and can infect several manzanita species through the root system, causing plant death. However, *P. cinnamomi* seems to spread rather slowly through the soil

Inoculations performed at U.C Berkeley on detached leaves of *A. glandulosa* and *A. canescens* were positive, but both infection success and sporulation rates were rather low, indicating it is not likely these two species may play an important epidemiological role in the spread of SOD.

Effect of climatic factors on *P. ramorum* transmission

The transmission of *P. ramorum* inoculum from symptomatic bay laurels to healthy potted rhododendrons was tested during three rainy seasons (2016/17-2018/19) at the campus of Dominican University to gain a better understanding of the effect of environmental parameters such as rainfall on the timing and appearance of disease symptoms. Transmission occurred from late December until May, and was more common in winters with high rainfall (Figure 1). *P. ramorum* was also detected from rainwater collected from the canopy of the bay laurels (Figure 2). Potted rhododendrons were also placed near symptomatic chaparral plants on Mt. Tamalpais during winter 2018/19, but no transmission was detected on the trap plants so far.

While it is still unclear whether the observed symptoms are caused by a disease complex, and which role *P. ramorum* has in it, mounting evidence indicates that *P. ramorum* is expanding its host range from the early infestation sites in moist and shaded habitats with high densities of California bay laurels towards drier and more sun-exposed areas characterized by a chaparral-type vegetation.

Year	Sample	November	December	January	February	March	April	May
2016/17	Tree 1 - plating	Red	Red	Red	Red	Green	Red	Grey
	Tree 1 - baiting	Red	Red	Red	Red	Green	Red	Grey
2017/18	Tree 1 - plating	Green	Green	Green	Green	Green	Green	Green
	Tree 1 - baiting	Red	Green	Green	Green	Green	Green	Green
	Tree 2 - plating	Green	Green	Green	Green	Green	Green	Green
	Tree 2 - baiting	Green	Green	Green	Green	Green	Green	Green
	Tree 3 - plating	Green	Green	Green	Green	Green	Green	Green
	Tree 3 - baiting	Green	Green	Green	Green	Green	Green	Green
2018/19	Tree 1 - plating	Green	Red	Red	Red	Green	Red	Red
	Tree 1 - baiting	Green	Red	Red	Red	Green	Red	Red
	Tree 2 - plating	Green	Green	Green	Green	Green	Green	Green
	Tree 2 - baiting	Green	Green	Green	Green	Green	Green	Green
	Tree 3 - plating	Green	Green	Green	Green	Green	Green	Green

Figure 2: Presence of *P. ramorum* in water samples from bay laurel canopy. Water samples were collected repeatedly during three consecutive winters (2016/17; 2017/18 and 2018/19) and tested for P.r. using direct plating and BOB (Bait in bottle). Red: positive; green: negative; grey: not tested (mainly because of little rainfall).

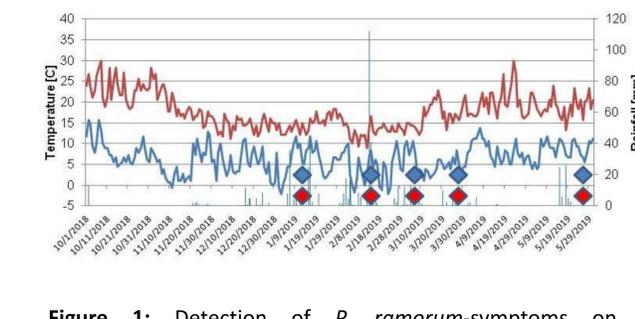
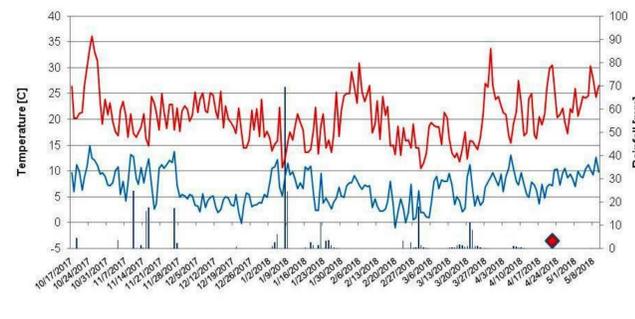
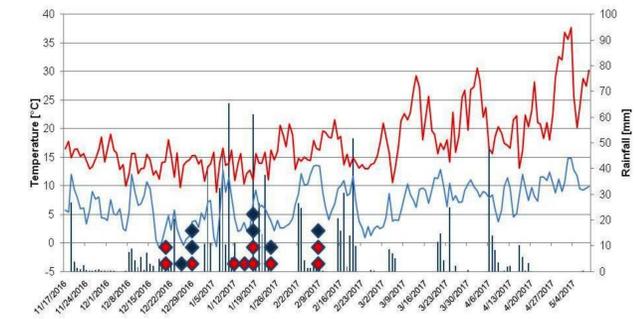


Figure 1: Detection of *P. ramorum*-symptoms on Rhododendrons during the winters 2016/17, 2017/18 and 2018/19. Red diamond: symptoms detected under 'symptomatic area' of the California bay laurel; blue diamond: symptoms detected under 'asymptomatic area' of the California bay laurel.

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