

## Intraspecific Diversity of Californian Clade 3 *Phytophthora* Isolates<sup>1</sup>

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### Abstract

Within the large plant-pathogenic genus *Phytophthora*, lies an enigmatic phylogenetic cluster of five species known as “clade 3.” Conflicting studies have suggested that this group of species may be native to Europe or North America. At the turn of the 20<sup>th</sup> century, clade 3 was known only from a single species, *P. ilicis*, which had been isolated in North America and Europe. In 2002, a second species, *P. psychrophila* was described from declining European oak forests. In 2003, two additional species were introduced, with *P. nemorosa* found only in North America and *P. pseudosyringae* from both Europe and North America. In 2013, *P. pluvialis*, another North American species was added.

Despite being distantly related to *P. ramorum*, the sudden oak death (SOD) pathogen, *P. nemorosa* and *P. pseudosyringae* cause indistinguishable symptoms on native Californian hosts, albeit with less frequency and virulence. Because SOD is an emerging disease caused by a non-native pathogen, this led to speculation that *P. nemorosa* and *P. pseudosyringae* were also introduced to North America. In 2009, a study of genome-wide diversity of the two species suggested highly clonal populations, and (for *P. pseudosyringae*), that the North American isolates were derived from the European population. The 2009 study, combined with a lack of association with landscape-level disease in Europe and a lack of aggressiveness on native European hosts led to a 2015 assessment that *P. ilicis*, *P. pseudosyringae* and *P. psychrophila* were the only species of *Phytophthora* (out of about 60 categorized) native to Europe.

*Phytophthora nemorosa* and *P. pluvialis* have still never been documented in Europe. Originally described only from Oregon, *P. pluvialis* was found causing significant disease in *Pinus radiata* (Monterey or radiata pine) plantations in New Zealand as well as native stands of *Pseudotsuga menziesii* (Douglas-fir) in Oregon; this New Zealand occurrence represented the first documentation of clade 3 outside of North America or Europe. A worldwide collection of *P. pluvialis* strains from Oregon, California and New Zealand suggested that the New Zealand

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population was derived from North America, although these results do not necessarily indicate this is the native range of *P. pluvialis*. Most recently, *P. pseudosyringae* was isolated from South America.

Another source of evidence regarding geographic origins is the diversity of sequences derived from *Phytophthora* clade 3 isolates available in public databases, the expectation being that the greatest genetic diversity will be found in the native range. So-called “barcoding sequences” including the ITS rDNA and various sections of the mitochondrial *cox2-cox1* region are commonly deposited for *Phytophthora* isolates, allowing for the identification and comparison of isolates across space and time. A 2017 study demonstrated that all five clade 3 species are either common or uncommon but consistent in *Phytophthora* surveys of Oregon natural ecosystems, and that more intraspecific diversity can be found across Oregonian than European isolates. This evidence is consistent with the notion that at least some species in clade 3 may, in fact, be native to North America.

We obtained barcoding sequences from more than one hundred Californian isolates in *Phytophthora* clade 3, comprising four of the five species. These isolates were obtained from various UC Davis, Rizzo Lab projects sampling California natural ecosystems for purposes of research and management over the course of more than a decade. Preliminary results suggest in regards to *Phytophthora* clade 3 that California, like Oregon, is a source of great intraspecific diversity.