

Microclimate Environmental Parameters Indexed for Sudden Oak Death in Georgia and South Carolina¹

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Abstract

We monitored Ericaceous habitat in Georgia and South Carolina for temperature, dew point and humidity ranges throughout a two year period. Temperature and humidity data were used to characterize their range in Georgia and South Carolina where potential SOD susceptible hosts occur. This data suggests risk for SOD development may be more widespread in southeastern forest microclimates than current risk maps indicate. A sudden oak death infection risk index based on laboratory infection parameters for *Phytophthora ramorum* was developed for use in the field. In addition, we monitored streams and bleeding bark cankers from different ecotypes throughout Georgia using various methods for detection of *Phytophthora* propagules. Samples cultured from bleeding cankers on oaks yielded a broad assortment of organisms. Most often found associated with these cankers are the fungal genera *Mortierella* and the potential antagonist *Trichoderma*.

Key words: Temperature, humidity, leaf wetness.

Introduction

Since 1995, large numbers of tanoaks and oaks have been dying in the coastal counties of California. The death of these trees has been attributed to the Oomycete or water mold *Phytophthora ramorum*, the causal agent of the disease commonly called sudden oak death (SOD). The potential *P. ramorum* susceptible plant host list has been rapidly expanding as a result of pathological data obtained through controlled environmental testing.

Risk maps prepared by the United States Department of Agriculture Forest Service (USDA-FS), Forest Health Monitoring and the Animal and Plant Health Inspection Service (APHIS) have outlined some of the risk parameters associated with this pathogen, but there are large information gaps on the interaction of environmental conditions necessary for infection. Early prediction/risk analysis maps for SOD, based upon available data on susceptible host occurrence, contained large areas of no risk in the piedmont and coastal areas of South Carolina and Georgia.

Although the region contains many potential hosts for *P. ramorum*, much of north Florida, the Georgia piedmont, and the Georgia coastal plain, throughout much of the year are regarded as low risk areas for SOD. Based upon generalized environmental

¹ A version of this paper was presented at the Sudden Oak Death Third Science Symposium, March 5-9, 2007, Santa Rosa, California.

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data, the regional environment in the southeastern United States has not been regarded as conducive for the pathogen based upon our current knowledge of its biology (W. Smith, Research Triangle Park, Raleigh, NC, personal communication, author of the Forest Health Monitoring risk map for *P. ramorum*). On the other hand, the diverse landscapes, vegetative cover types, and abundant waterways in this region can encompass a considerable number of sites where environmental conditions are conducive to *P. ramorum* infection.

In spring 2004, *P. ramorum* infected nursery stock was shipped from California to many eastern states, including Georgia and South Carolina. Over 80 locations in Georgia have confirmed the presence of *P. ramorum* infections on nursery stock. Some plants were sold to the public before the nursery stock could be quarantined. In the southeastern United States, many susceptible plant species occur where potentially optimal temperature and humidity for *P. ramorum* infection may exist for suitable periods. These optimal conditions may be present outside the areas indicated on current risk maps. *P. ramorum* has a wide host range that includes eastern oaks and Ericaceous plants species, both of which are abundant in southeastern forests (Tooley and Kyde 2007). Many genera of east coast plants can support *P. ramorum* sporulation, potentially infecting the ecologically and economically important eastern oaks. Since economically important tree species are at risk, coupled with the large-scale resolution of current risk maps, we conducted this study to identify potential critical microclimatic variables conducive for *P. ramorum* infection. We also sampled streams, other waterways, and tree wound effluxes for the presence of *P. ramorum* and other *Phytophthora* species in areas having susceptible vegetation. Information gained from this study will strengthen current SOD risk maps and models by developing an SOD susceptibility index. Such an index can identify where monitoring resources could be more efficiently deployed.

Materials and Methods

HOBO H8 Pro-Series® data loggers were placed in high SOD risk areas according to the APHIS SOD risk map for Georgia and South Carolina. The data loggers were placed in areas that supported *P. ramorum*-susceptible vegetation. These recorders collected the temperature, humidity and dew point at the location every hour of the day. Our *P. ramorum* infection index was formulated as a function of the dew point being equal to the optimum temperature ($\pm 0.5^{\circ}\text{C}$) for infection (between 18 and 22 $^{\circ}\text{C}$), for greater than or equal to six consecutive hours in a day (Garbelotto and others 2003). These criteria theoretically indicate free water presence on surfaces when the temperature and dew point conditions are met. Data were collected throughout the entire two years and expressed graphically when the criteria were met, but criteria for infection index was only met in those months present on the graph.

A water baiting technique was employed to sample streams for *Phytophthora* species in areas of SOD susceptible vegetation. Using a generic portable submersible pump, an eight foot piece of flexible plastic tubing was taped to a 3.05 m (10 ft) pole affixed to the outlet end of the pump. A brass sieve of 300 to 400 μ was fixed to the bottom of the intake to prevent large debris from entering the pump. This apparatus was then suspended out into the river where 8 to 12 l of water were collected and placed in several Erlenmeyer flasks. This water was then filtered through 20 and 30 μ Millipore filters (Hong and Kong 2002) using a hand held vacuum pump. The filters were kept

cold and transported back to the lab within one hour of collection. The contents of the Millipore® filters were then washed off with 10 to 15 ml of sterile distilled water from a sterile syringe and plated onto PARP plus hymexazole medium (Ferguson and Jeffers 1999) in 100 µl drops on five spots per plate.

Additional isolations were conducted on effluxes from the bark of white and red oaks. Pieces of the wet bark samples were cultured on modified PARP medium (Ferguson and Jeffers 1999).

Results and Discussion

We developed an index of *P. ramorum* infection risk parameters for microsites based on research done on the physiology of *P. ramorum* infection parameters (Garbelotto and others 2003). Data shown represent two years analysis of infection index values at the four locations (fig. 1). The bars represent the infection index expressed as number of days with six or more hours of leaf wetness occurrence at the optimum temperatures for *P. ramorum* infection (Garbelotto and others 2003).

In 2005, our *P. ramorum* infection susceptibility index revealed that the Brunswick, GA (elevation = 11 m) coastal site was bimodal (fig.1), with infection indices ranging from May to January, with a peak in September. Sites in Atlanta (elevation = 266 m) had infection indices from May to October, with a peak in June (fig. 1). A site at Chatsworth, GA (elevation = 250 m) also had infection indices from May through

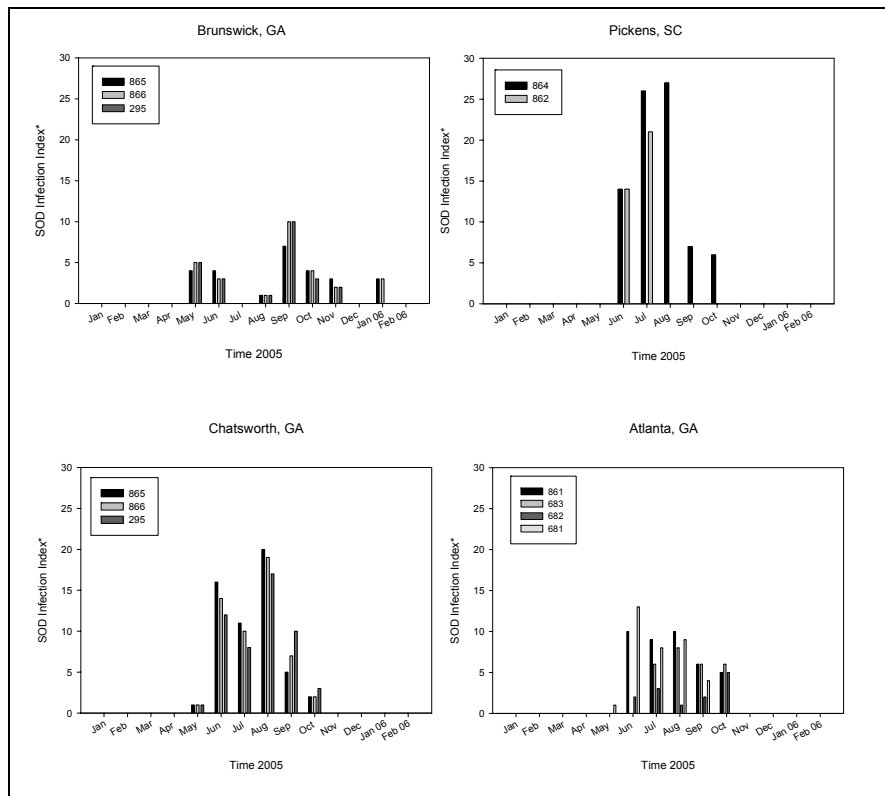


Figure 1—*Phytophthora ramorum* infection index for number of days when infection criteria are met during 2005-2006. Legend key represents specific HOB0® data collectors.

October, but the peak index value was in August (fig. 1). Our highest elevation site, Pickens, SC (elevation = 362 m), had the highest number of infection index days during July and August, but had the narrowest infection index range, extending only from June through October (fig. 1). Our microsite specific temperature and humidity data showed greater SOD risk in the Georgia coastal environments and western South Carolina than the USDA-FS (Smith and others 2002) or APHIS risk maps (Fowler and others 2005). Mid-level elevations such as Chatsworth have the same amount of risk as coastal Brunswick, GA in the month of September. Pickens, Chatsworth and Atlanta areas had extremely high infection indices for the month of August, greater than indicated by the APHIS risk map. The infection index was present for a greater number of months in Brunswick, Georgia probably due to high humidity along the coast throughout much of the year. Many genera of east coast plants could support *P. ramorum* sporulation, thus potentially impacting the ecologically and economically important eastern oak species.

In 2006, our monitored sites continued to have similar infection index values (fig 2). Generally warmer temperatures and higher humidity throughout the year contributed to the infection index values appearing earlier in the spring and later into the fall months at the Brunswick site. Overall, Brunswick microsites had up to 10 index days over a period of 10 months. The number of months yielding index days in Brunswick was at least four months longer compared to the three other locations. Based upon the results of our infection index, *P. ramorum* can become established along the southeastern coastline as it has along the northern California coastal region.

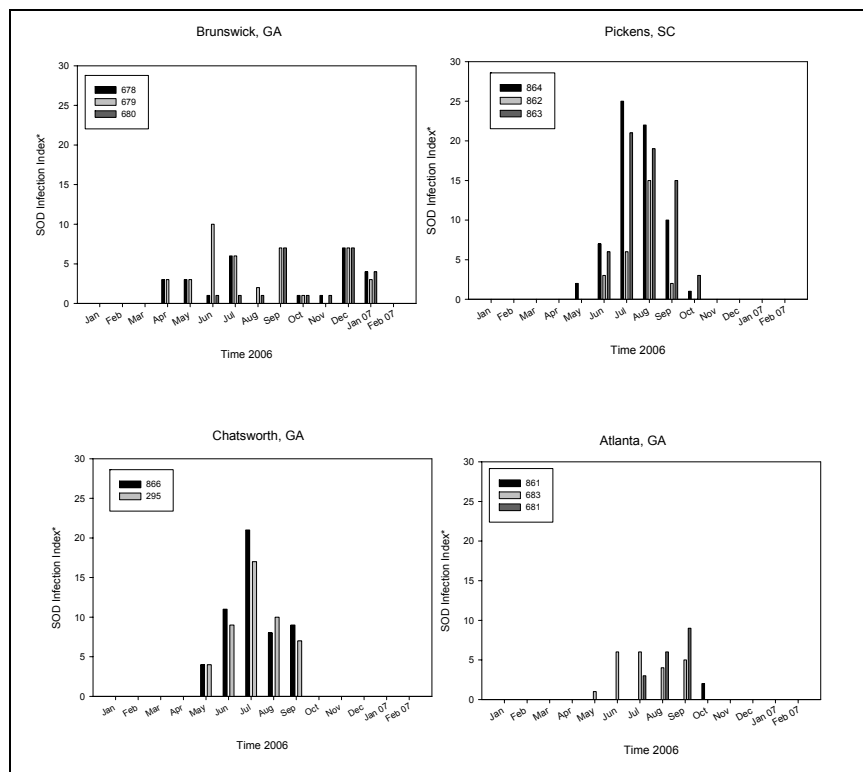


Figure 2—*Phytophthora ramorum* infection index for number of days when infection criteria are met during 2006-2007. Legend key represents specific HOBO® data collectors.

Also in 2006, Chatsworth, GA and Pickens SC had the greatest number of days that met the infection index criteria from May through September and May through October, respectively (fig. 2), indicating that microclimate in these locations was suitable for infection. The infection index had some variation among monitoring devices within a location, indicating the importance of considering microclimate conditions in assessing risk.

In Atlanta, the number of infection index days in 2006 was nine or less for any particular month (fig 1). In general, the Atlanta sites are not buffered by large areas of vegetation to modify temperature extremes. The contrast between Atlanta and the three more rural environments we monitored may have been due to the urban heat island effect, where higher temperatures reduced the number of days falling within the infection index criteria.

Overall, our index could be used to monitor locations for SOD disease risk in combination with vegetation maps. The infection index may also be valuable in the early stages of *P. ramorum* introductions and detection in forests. Dirac and Menge (2003) found that the infection by *Phytophthora* sp. was dependent on carbohydrate flow in the roots of host plants. The flow of carbohydrates generally corresponds to warmer temperatures conducive for plant growth. Many genera of susceptible east coast plants could become infected with *P. ramorum* during the warmer months, as shown by our data. Our infection index could be used as a risk assessment tool in ecologically important eastern oak microclimatic areas that support *P. ramorum* susceptible understory vegetation. This would be particularly important when understory plants are infected but overstory trees are not yet symptomatic. Resources can then be directed to areas where moisture and temperature conditions for infection of at risk tree species are probable. On the other hand, once infection is established within the host, there is no information on how *P. ramorum* is affected by local environmental conditions. Such information can only be gathered from field research on important host species such as the eastern oaks.

Sampling water from streams in and around the piedmont in Georgia yielded several *Phytophthora* species, but no presence of *P. ramorum*. Our methodology of high volume surface water sampling (8 to 12 l per location) may enhance early detection of *P. ramorum* by increasing the probability of encountering its propagules in water ways. Species commonly found were identified as *P. cinnamomi* Rands, *P. cryptogea* Pethybr. et. Laff., and *P. nicotianae* Breda de Haan. Sampling and isolations from wet bark effluent consistently yielded genera such as *Mortierella* sp., *Fusarium* sp., and *Tricoderma* sp., with *Mortierella* as the predominate genus found in these effluxes. Continued study of the mycoflora associated with potential *P. ramorum* infection sites is important for finding possible antagonists to this economically significant pathogen.

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