Climate and Host Risk Map for Sudden Oak Death Risk (*Phytophthora ramorum*).

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National model

A climate and host risk map was constructed for Sudden Oak Death (SOD) using the NAPPFAST pest mapping system (Borchert and Magarey, 2005). The climatic map was based upon an infection model and 10-year daily climatic data. The model was constructed using a generic 'fill-in-the-blanks' template for creating models 'on the fly.' The model uses the daily combination of average temperature and total leaf wetness hours per day to estimate the number of days in each year suitable for infection.

In constructing our model, we assumed that *P. ramorum* would climatically be limited by temperature for growth and moisture requirements for zoosporic infection. The temperature thresholds (minimum, optimum, maximum temperature) for *P. ramorum* infection were 3, 20, 28 C respectively (Werres et al., 2001; Orlikowski and Szkuta, 2002; Tooley et al., 2005). The moisture requirement of at least 12 hours, was estimated from data describing zoosporic infection of *Umbellularia californica* leaves (Huberli et al., 2003). An infection model (Magarey et al., 2005) was used to estimate the number of days favorable for infection. It was considered that the climatic probability of at least 60 favorable days for infection might be a useful indicator of climatic risk (Smith, 2002). For each 10 km pixel, each day was assigned a value between 0 (unfavorable for infection) and 1 (favorable for infection) and these values were accumulated over the year. The resulting layer represents the probability of having a sum of at least 60 favorable days over the whole year. This layer was averaged with a susceptible host area layer based on the sum of 100% of the hardwood and 50% of the mixed forest density (USFS, 1991) to produce a relative risk map (Figure 1). A second modeling effort examined the implications of extreme low soil temperatures < - 25^{o} C which are known to reduce survival of the pathogen: sporangia and chlamydospores in laboratory tests (DEFRA, 2004). This cold temperature exclusion zone reduced the northern extent of the disease (Figure 2). Snow cover may provide insulation that is not considered in the model. Additional cold temperature survival data is needed.

There are certain limitations associated with model output. The model is based on 10 km^2 data and consequently may not perform ideally in mountainous terrain. (It is hoped to upgrade to a 1 km^2 spatial resolution at some time in the future.) The model was compared with *P. ramorum* observations in the field (UC Berkeley 2005) (Figure 3). All *P. ramorum* observations appear in the most favorable 9 year band visualized by the infection model in California. Some scientists believe the model over-predicts in coastal California. This may be because the model does not account for sporulation and dispersal. Sporulation requires at least 24 hours of wetness. We hope to improve the model when more advanced model building tool kits come on-line.

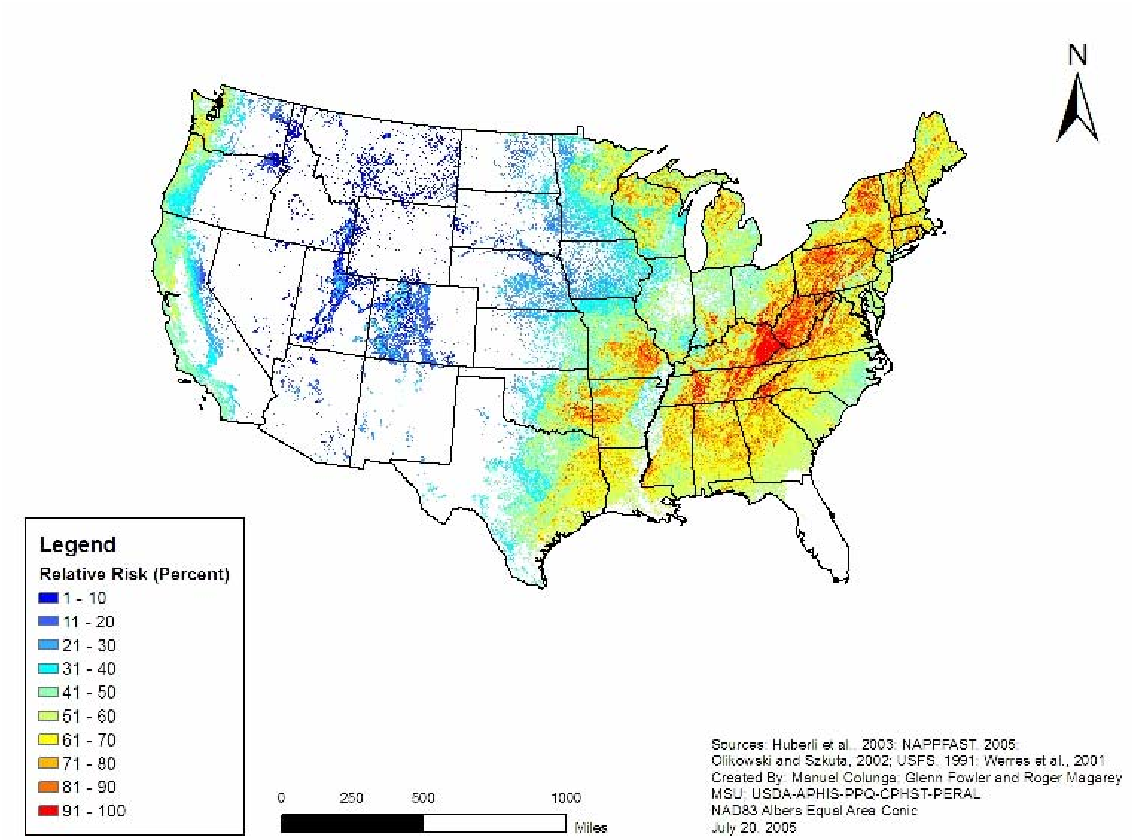

Figure 1. The probability of at least 60 favorable days for infection by *P.ramorum.* Map based on 10-year climatic data at a 10 km^2 resolution and includes forest density data (USFS, 1991).

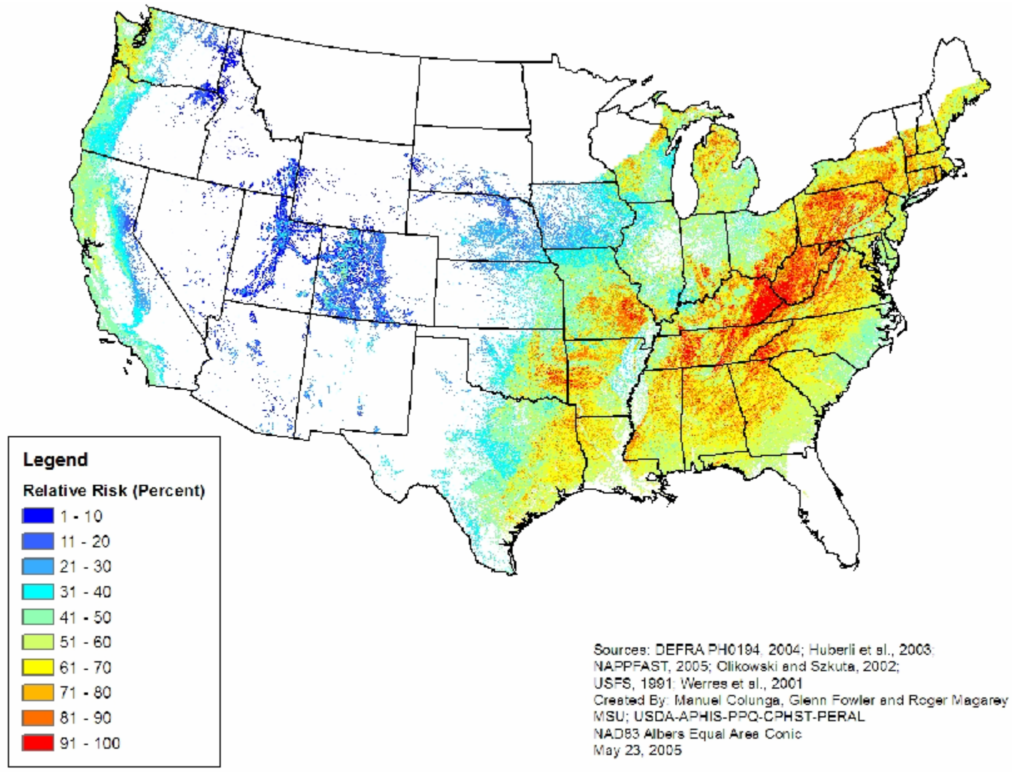

Figure 2. The probability of establishment based upon at least 60 favorable days for infection by *P. ramorum* and -25 C soil temperature for lethal cold temperature exclusion. Map based on 10-year climatic data at a 10 km^2 resolution and includes forest density data (USFS, 1991).

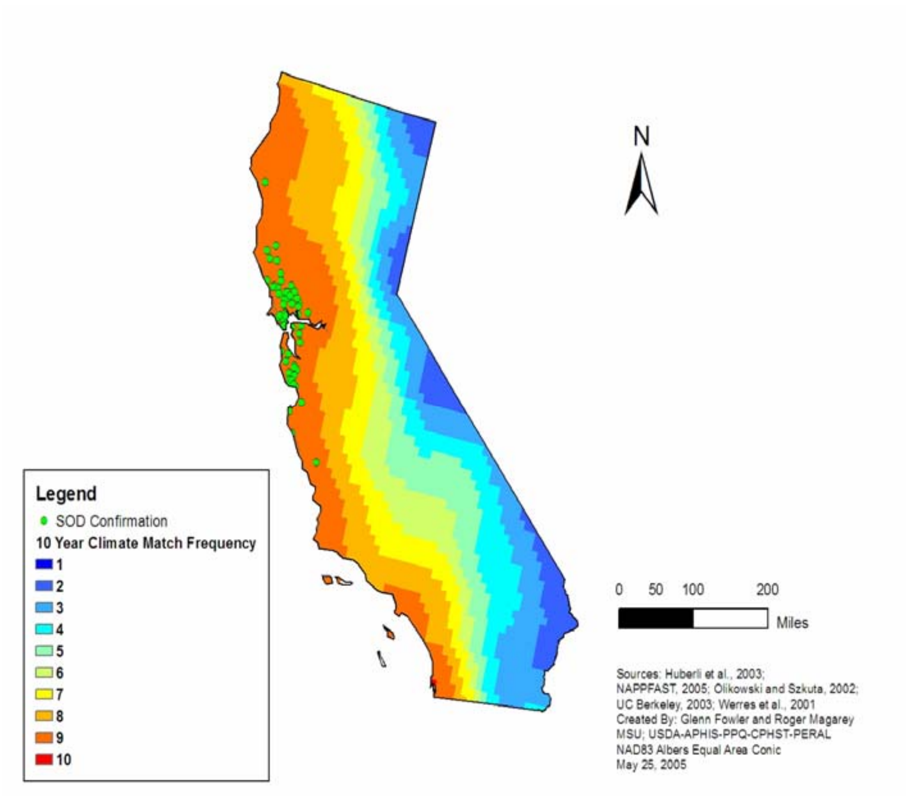

Figure 3. Comparison of sudden oak death observations compiled by UC Berkeley with predictions made by an infection model in NAPPFAST using ten year climate data.

International model

NAPPFAST was also used to create an international model for *P. ramorum*. The input data set was the International Panel on Climate Change (IPCC) data set. The International Panel on Climate Change dataset (IPCC) (http://ipcc-ddc.cptec.inpe.br) is a global monthly data set with a 0.5 degree grid (55 km) resolution. The data set contains 67420 grid points over land and contains weather data from 1901 to 2002. (Currently, in the NAPPFAST system selection of data is limited to after 1978). The data set contains variables describing average temperature, precipitation, humidity and cloud cover.
The model was based on a favorable month requiring average maximum monthly temperature to be less than 28 C, average minimum temperature to be greater than 3 C and at least 10 days with precipitation.

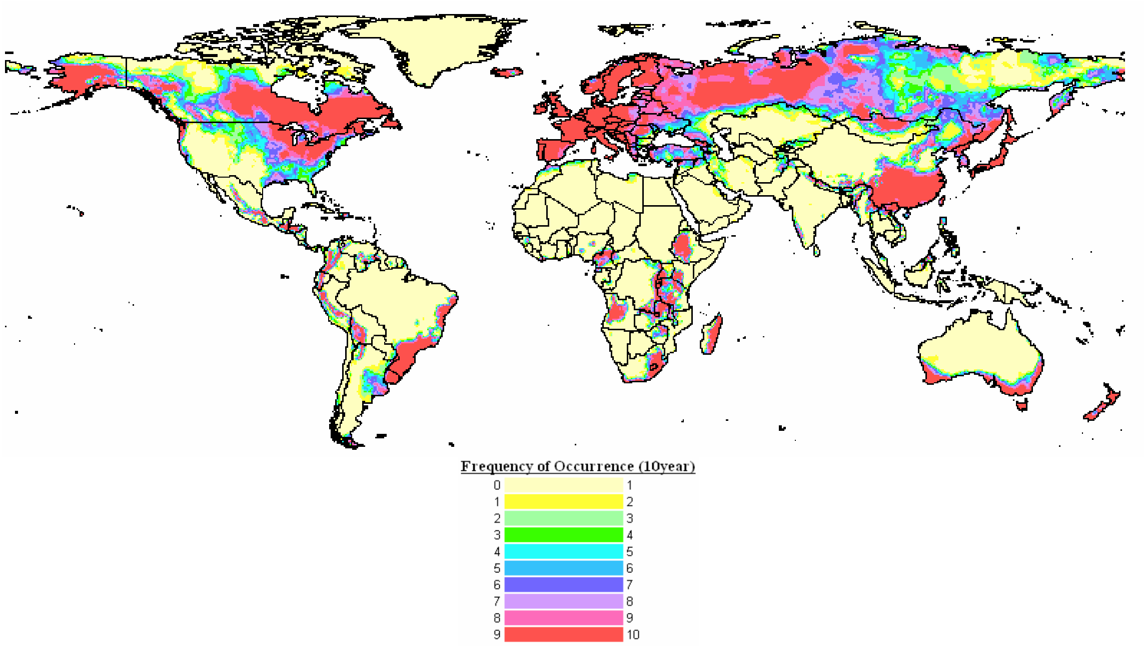

Figure 4. NAPPFAST IPCC model for *P. ramorum* assuming at least two favorable months.

The most favorable areas for *P.ramorum* correspond to climates with high rainfall such as eastern United States, equatorial Africa and South America and east Asia. At this stage, we believe the model is over estimating potential areas of establishment because the model should also include a minimum precipitation variable, as well as the precipitation frequency variables. The total precipitation is available in IPCC but NAPPFAST can not yet combine more than three variables at once.

References

Borchert, D. M., and R. D. Magarey. 2004. A guide to the use of NAPPFAST. (www.nappfast.org).

DEFRA. 2005. *Phytophthora ramorum* epidemiology: infection, latency and survival. DEFRA Project Report PH0194.

Hüberli, D., Van Sant, W., Swain, S., Davidson, J. and M. Garbelotto. 2003. Susceptibility of *Umbellularia californica* to *Phytophthora ramorum*. [abstract]. In Eighth International Congress of Plant Pathology. p. 268. Christchurch, New Zealand.

Magarey, R.D., Sutton, T.B. and C. L.Thayer. 2005. A Simple Generic Infection Model for Foliar Fungal Plant Pathogens. Phytopathology 95:92-100.

Orlikowski, L.B. and G. Szkuta. 2002. First record of *Phytophthora ramorum* in Poland. Phytopathologia Polonica. 25:69-79.

Smith, W. 2002. Sudden Oak Death National Detection Survey and For Forests and Risk/Hazard Map. United States Forest Service.

Tooley, P. and Kyde, K. 2005. The effect of temperature and moisture period on infection of *Rhododendron* 'Cunningham's White' by *Phytophthora ramorum.* [abstract]. Phytopathology 95:S104.

UC Berkley. 2005. Last Accessed. OakMapper. Monitoring Sudden Oak Death with GIS. (http://kellylab.berkeley.edu/OakMapper/viewer.htm).

USFS. 1991. Forest Density. Southern Forest Experiment Station, Forest Inventory and Analysis research unit. http://www.epa.gov/airmarkets/cmap/data/category3.html

Werres, S., Marwitz, R., Man Int Veld, W. A., D. E. Cock, A.W., Bonants, P. J., De Weerdt, M., Themann, K., Ilieva, E. and Baayen, R. P. 2001. *Phytophthora ramorum* sp. nov., a new pathogen on Rhododendron and Viburnum. Mycol. Res. 105:1155-1165.