A CLIMEX model for the potential establishment of *P. ramorum* in the Eastern US: Development, validation, and sensitivity

Rob Venette
Research Biologist, RWU-4502, Forest Diseases,
North Central Research Station

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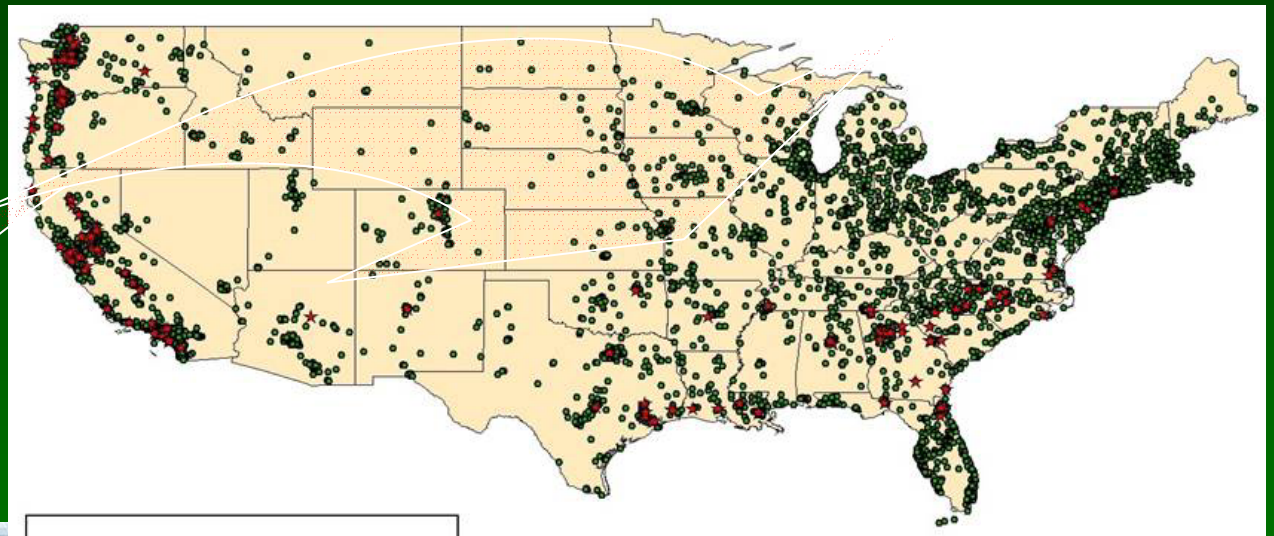
Movement of infected host plants into the Eastern US is a concern



Map: USDA, APHIS, PPQ (July 2004)

Phytophthora spp. in oak forests

(Balci, Gottschalk, MacDonald, Juzwik, and Long)

Base-line survey for *Phytophthora* species in oak forests

State	Sites	Positive	*Phytophthora* spp.
Maryland	**12**	**6**	***cinn.***
W. Virginia	**27**	**19**	*cinn*, *citr*, *euro*, uk1,uk3
Pennsylv.	**8**	**1**	*cinn*, uk2, uk3
Ohio	**8**	**6**	*cinn*, *citr*, *euro*, uk2,uk3
Indiana	**8**	**6**	*cinn*
Michigan	**6**	**0**	none
Illinois	**8**	**1**	Results in progress
Wisconsin	**8**	**3**	*citr*, uk3, uk4
Minnesota	**8**	**2**	*citr*

Objectives

- Identify areas within the contiguous US that have a suitable climate for establishment of *P. ramorum*.
- Validate the predictions with independent data sets.
- Through sensitivity analysis, identify critical data gaps in the biology of the pathogen .

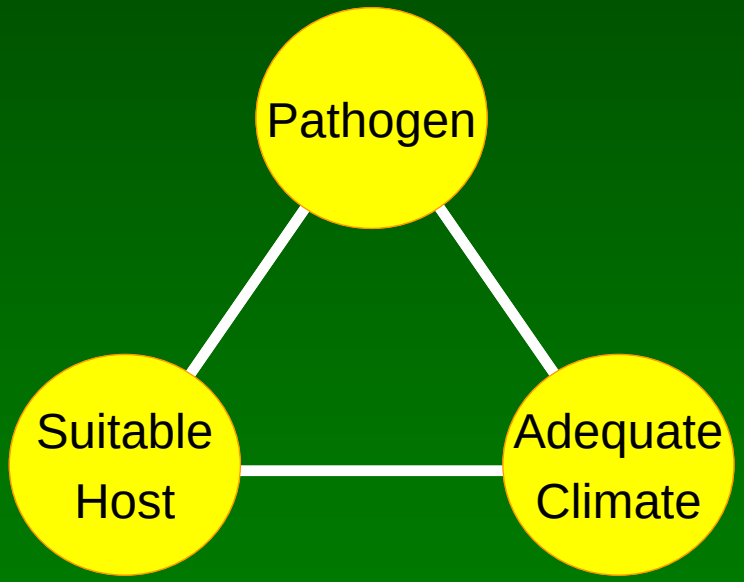
CLIMEX models have been published extensively

CLIMEX v2
Match Climates

Climatic database and modeling framework to predict climatic limits to the distribution of species.

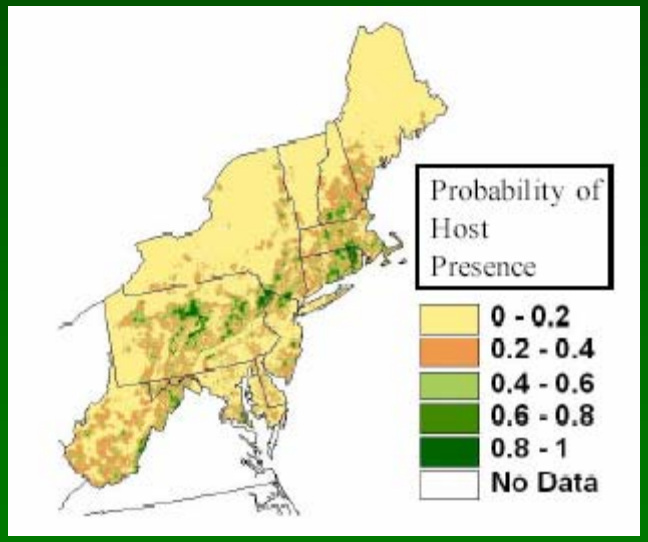
- Applied to:
  - Insects
  - Weeds
  - Pathogens
  - Vertebrates

Common assumptions in CLIMEX models for pathogens



- Adequate inoculum is present to initiate an infection.
- Susceptible hosts are present at adequate densities to initiate an infection.
- Monthly climate normals are reflective of local weather.

Rationale for assumptions



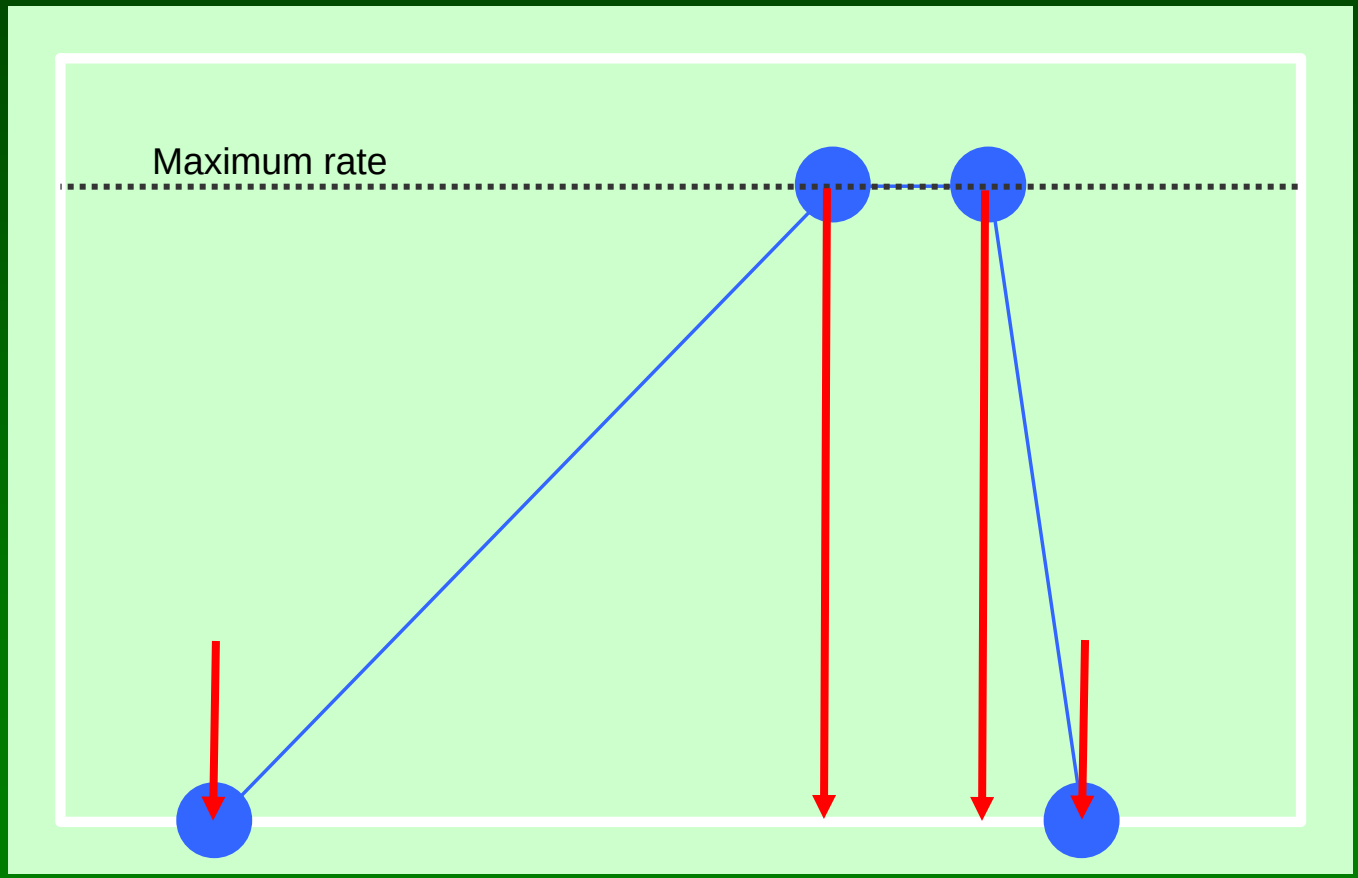
Morin, Gottschalk, & Liebhold 2003

- Assumptions about inoculum and host availability reduce the likelihood of Type II errors (concluding that *P. ramorum* will not establish when it fact it can).
- Type II errors are less acceptable than Type I errors.
- Climate normals reduce computing time and have been widely used.

Overview of Procedures

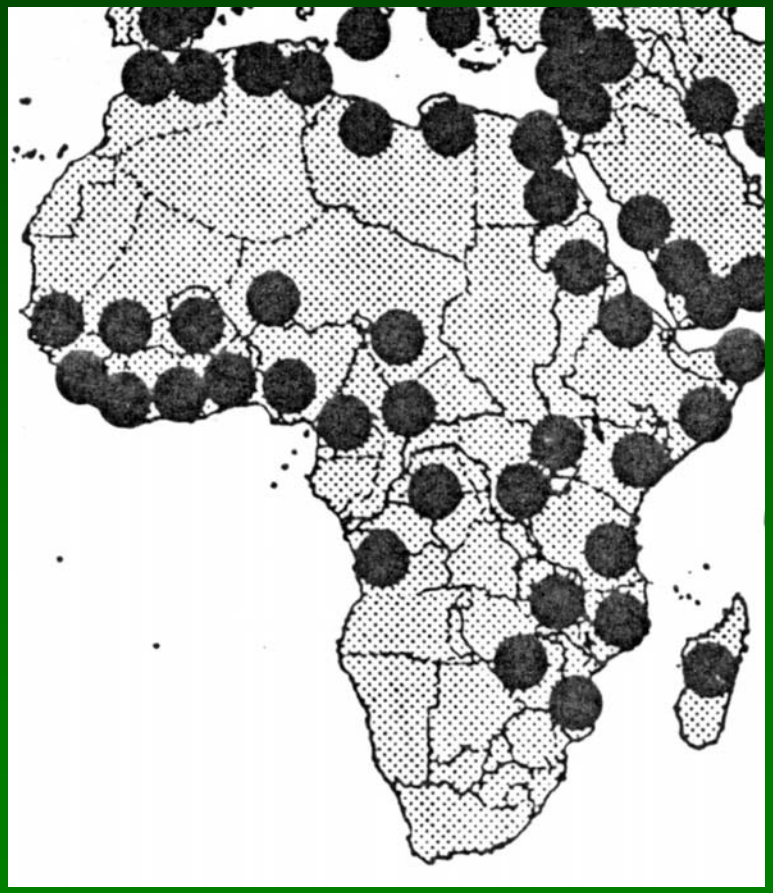
- Estimate model parameters from literature
- Import latest climate normals (1971-2000)
- Calculate Ecoclimatic Index in Climex
- Export georeferenced values to GIS (ArcView 3.2)
- Interpolate surface (2.5km grid) using optimized inverse distance weighting.
- Calculate area within the contiguous US that falls into one of suitability classes: unsuitable, marginal, favorable, and very favorable

Stylized description of CLIMEX parameters for growth requirements



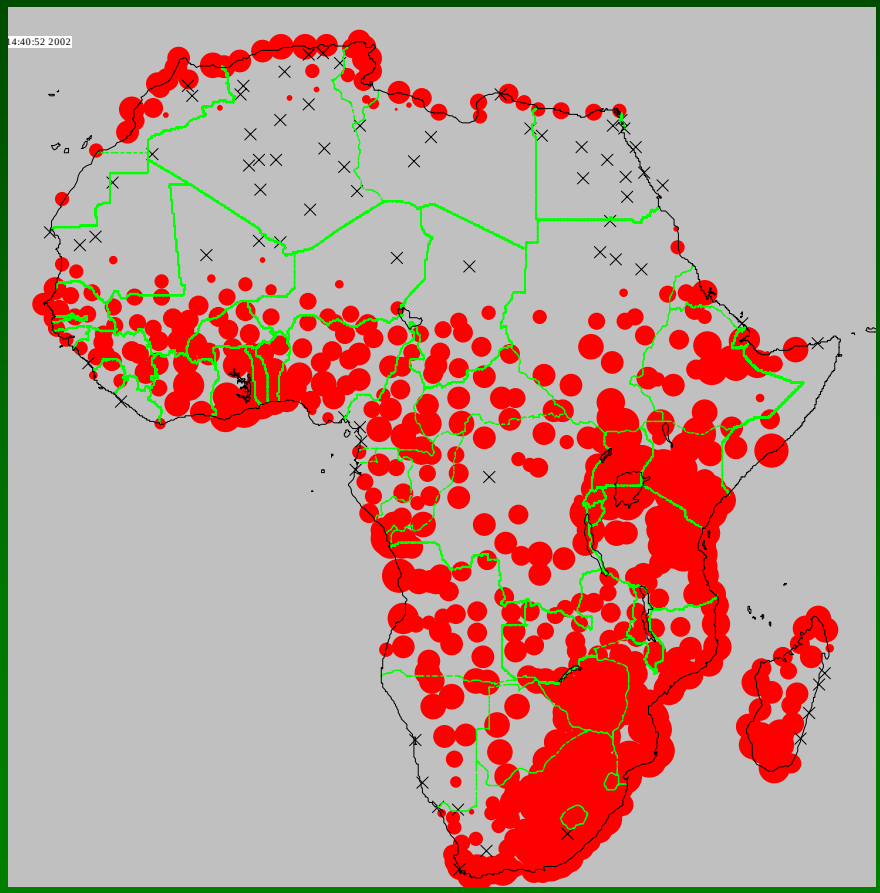
Iterative geographic fitting is frequently used to estimate CLIMEX parameters

Known



Distribution Maps of Insects Pests, CAB 1990

Predicted



Venette & Hutchison

Temperature requirements inferred from literature

- Studies describing growth of mycelia at different temperatures:
  - Werres et al. 2001 Mycol Res 105: 1155
  - Orlikowski & Szkuta. 2002. Phytopathol. Polonica 25: 69.
  - DEFRA. 2004. Report PH0194. On-line.

Cardinal temperatures (°C) for vegetative growth of *P. ramorum* (Werres et al. 2001)

Isolate (CBS 10xxxx)	Minimum	Optimum	Maximum	Rate (mm/d) @ Optimum
1327	2	20	27	2.6
1328	2	20-25	27	2.6
1329	2	20	27	2.8
1330	2	20	27	2.6
1331	2	20	27	2.5
1332	2	20	27	2.6
1548	2	17-20	26	3.0-3.5
1549	2	20	26	2.8
1550	2	25	27	2.8
1551	2	20	27	2.7
1552	2	20	27	2.7
1553	2	20	26	2.8
9278	2	20	28-30	3.5
9279	2	20	28-30	3.2

Climex parameters

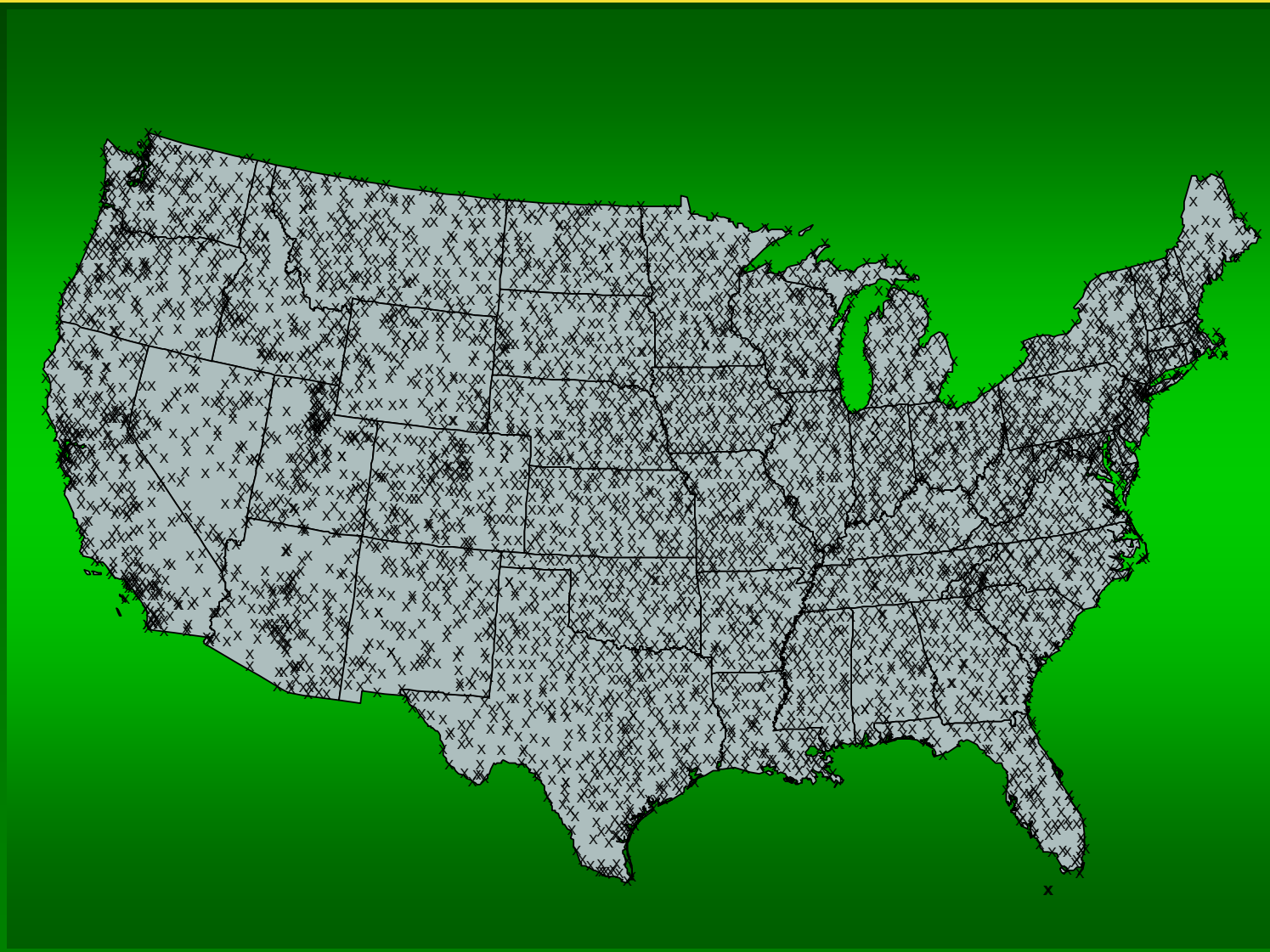
Parameters for growth

Parameter	Definition	Value
Temperature (° C)		
DV0	Lower limit for growth	2
DV1	Lower optimum for growth	17
DV2	Upper optimum for growth	25
DV3	Upper limit for growth	30
Moisture (MHC)		
SM0	Lower limit for growth	0.4
SM1	Lower optimum for growth	0.7
SM2	Upper optimum for growth	1.3
SM3	Upper limit for growth	3.0

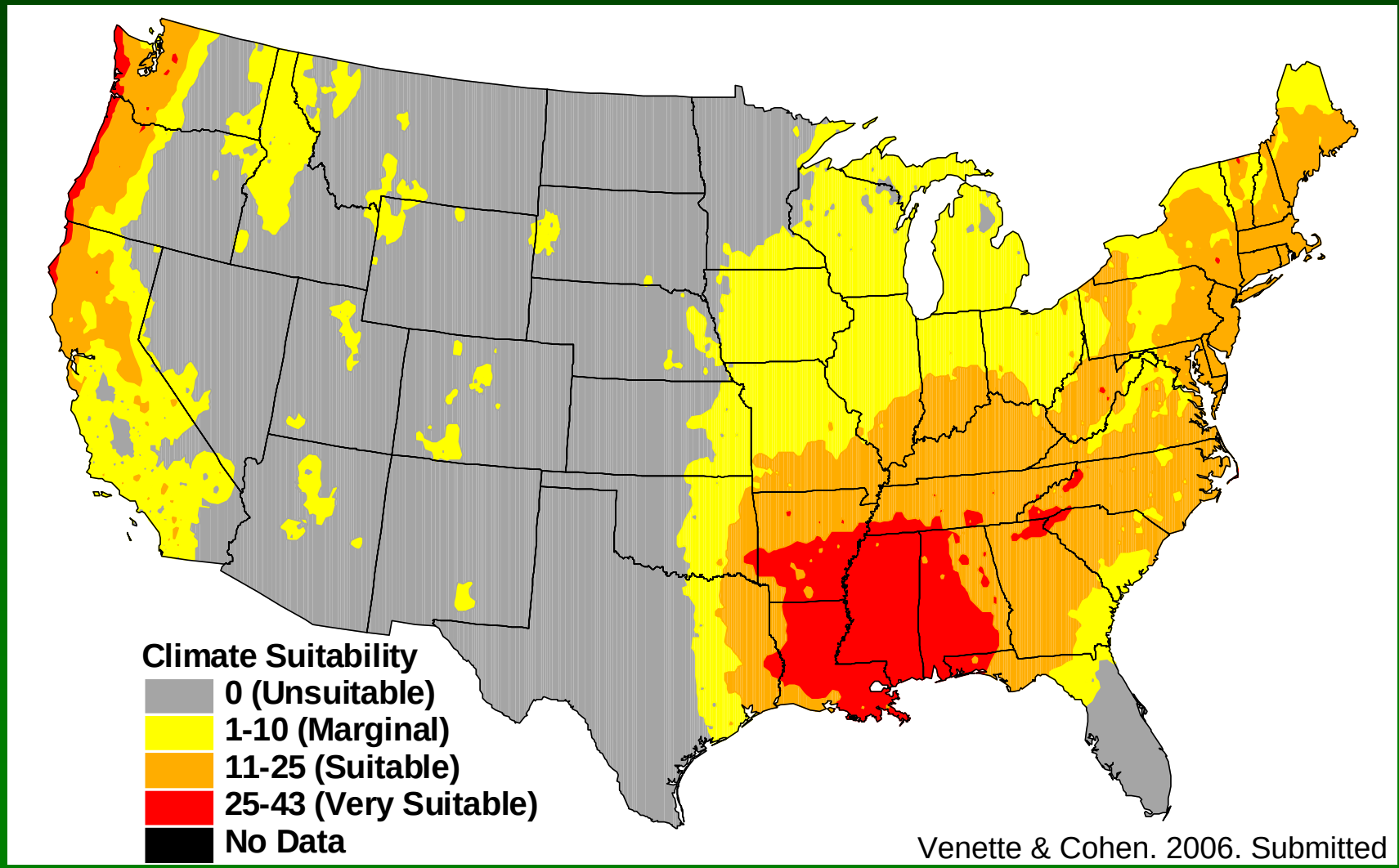
Parameters for stress

Parameter	Definition	Value
Cold Stress		
DTCS	Cold stress degree day threshold	15
DHCS	Cold stress degree day rate	-0.0001
Heat Stress		
TTHS	Stress threshold	30
THHS^{f}	Stress accumulation rate	0.005
Dry Stress		
SMDS	Stress threshold	0.2
HDS	Stress accumulation rate	-0.005
Wet Stress		
SMWS	Stress threshold	2.5
HWS	Stress accumulation rate	0.002

1970-2000 Monthly Climate Normals for 5320 weather stations



Climate suitability for *P. ramorum*



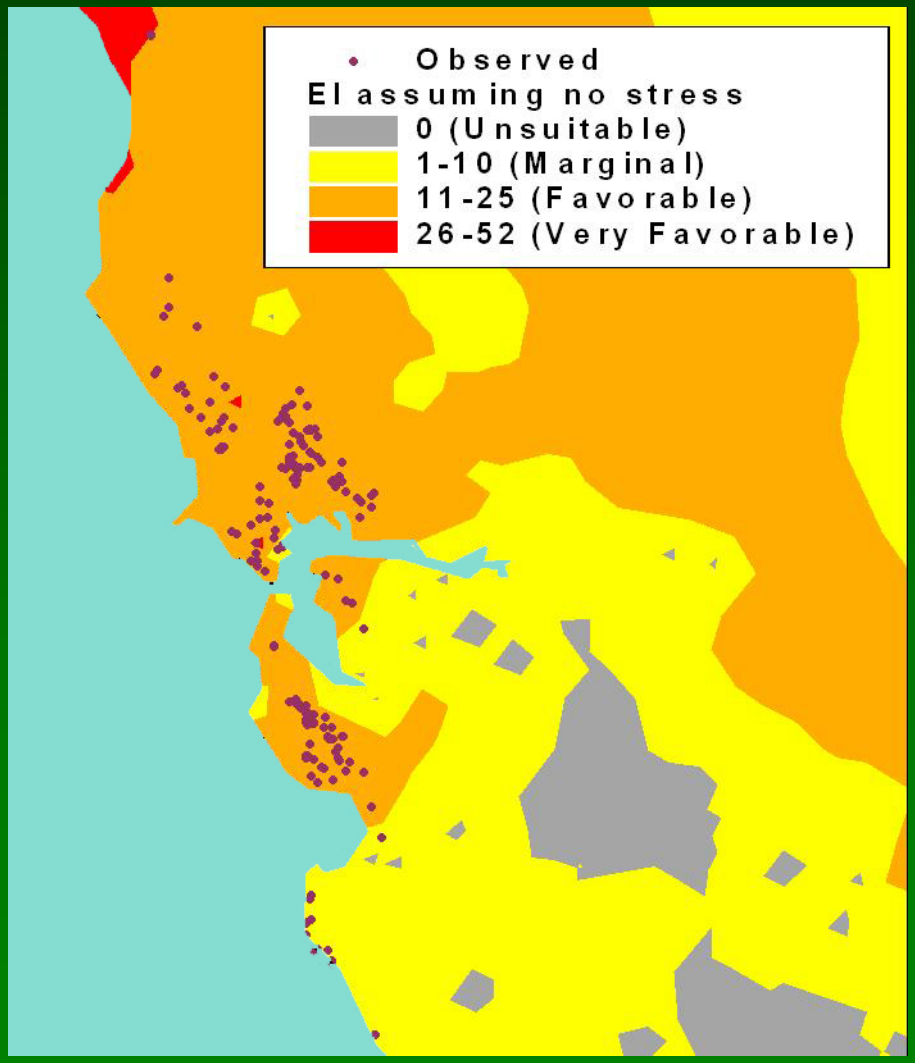
Venette & Cohen. 2006. Submitted

Validation based on field occurrences of *P. ramorum*

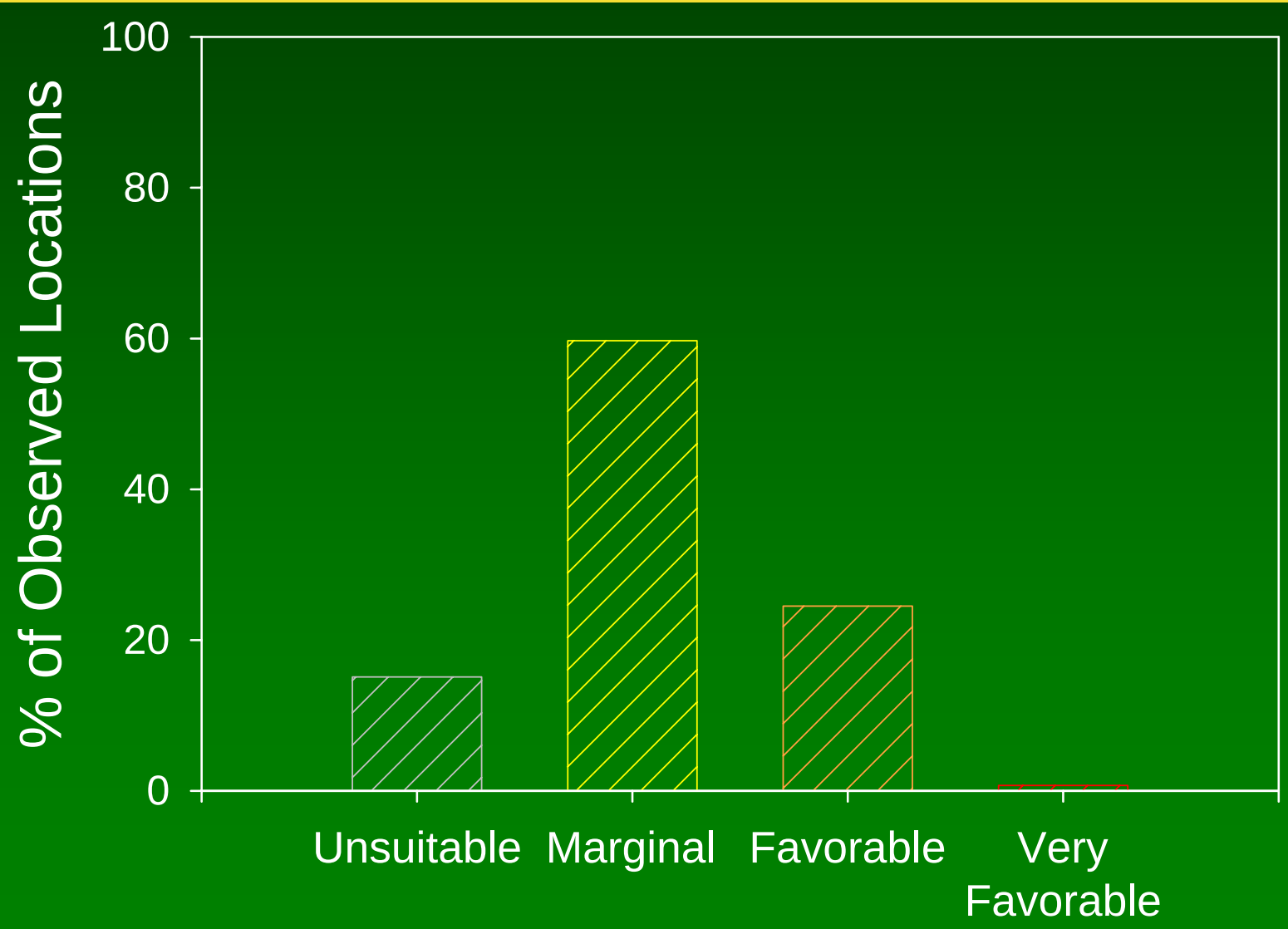
- Sudden Oak Death Project, Center for the Assessment of Forestry and Environmental Resources, University of California, Berkeley

- 499 observations through 24 March 2005

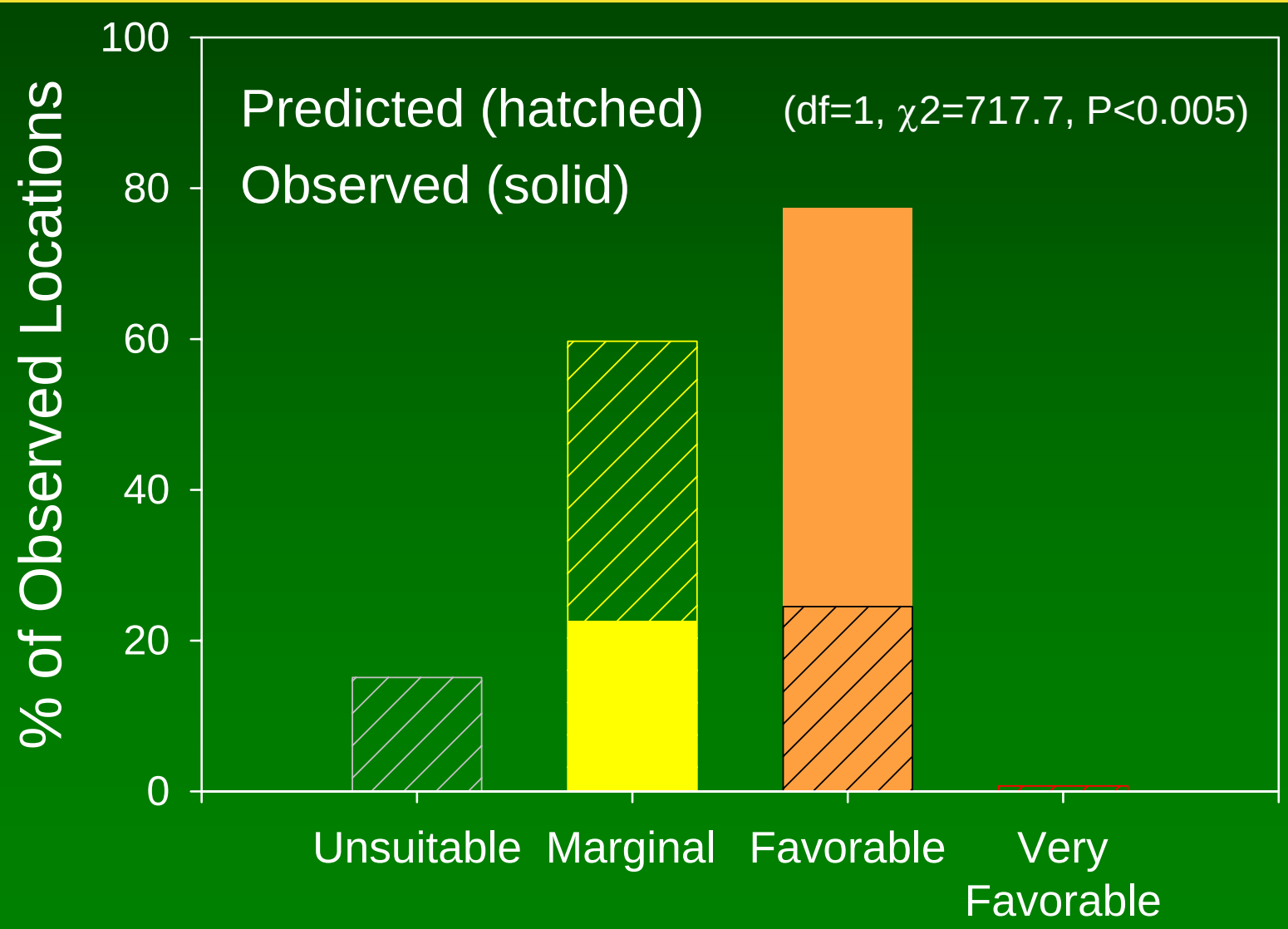
Comparison of predicted vs observed distribution of *P. ramorum*



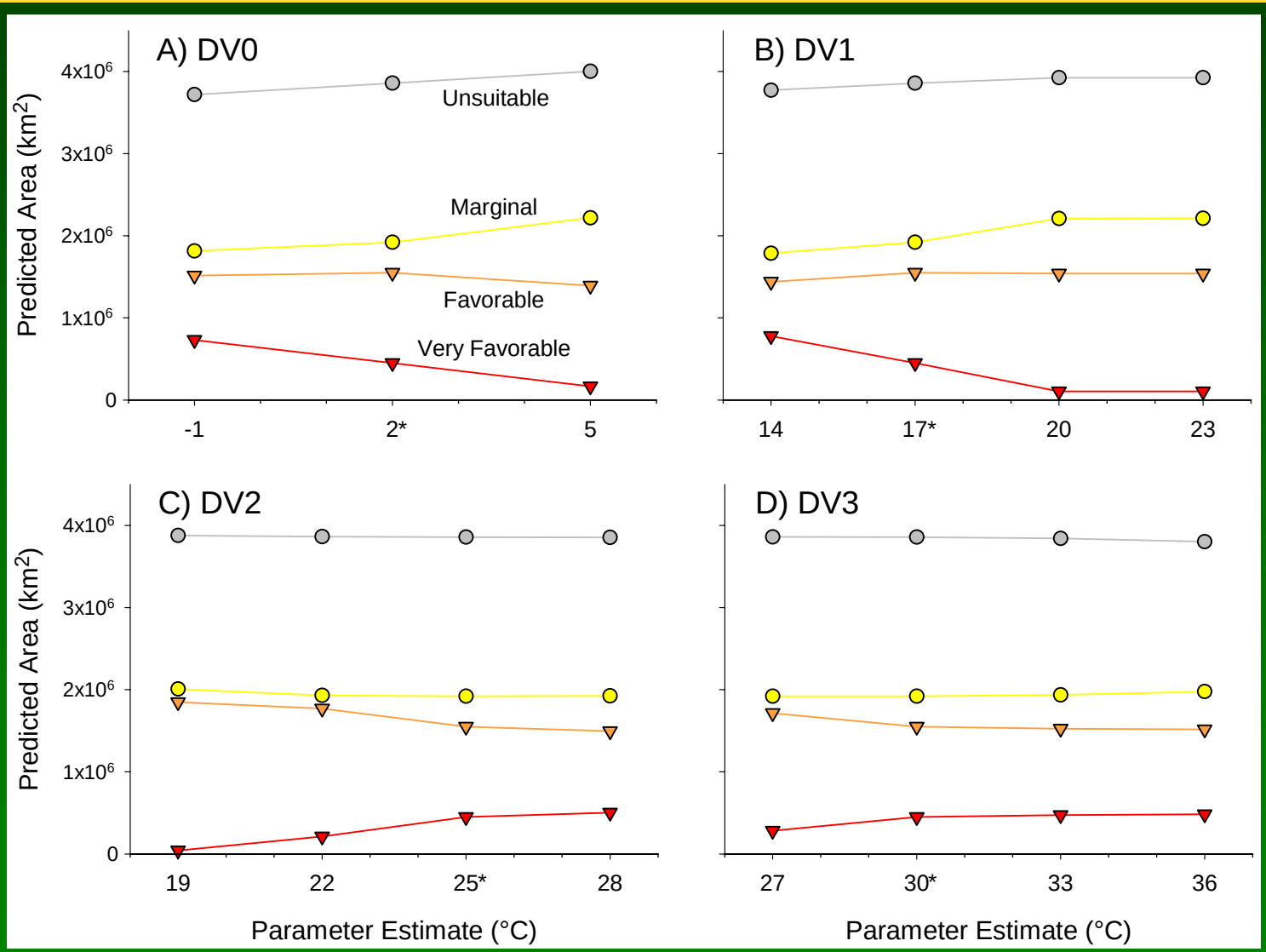
Expected distribution of *P. ramorum* finds if distributed at random in California



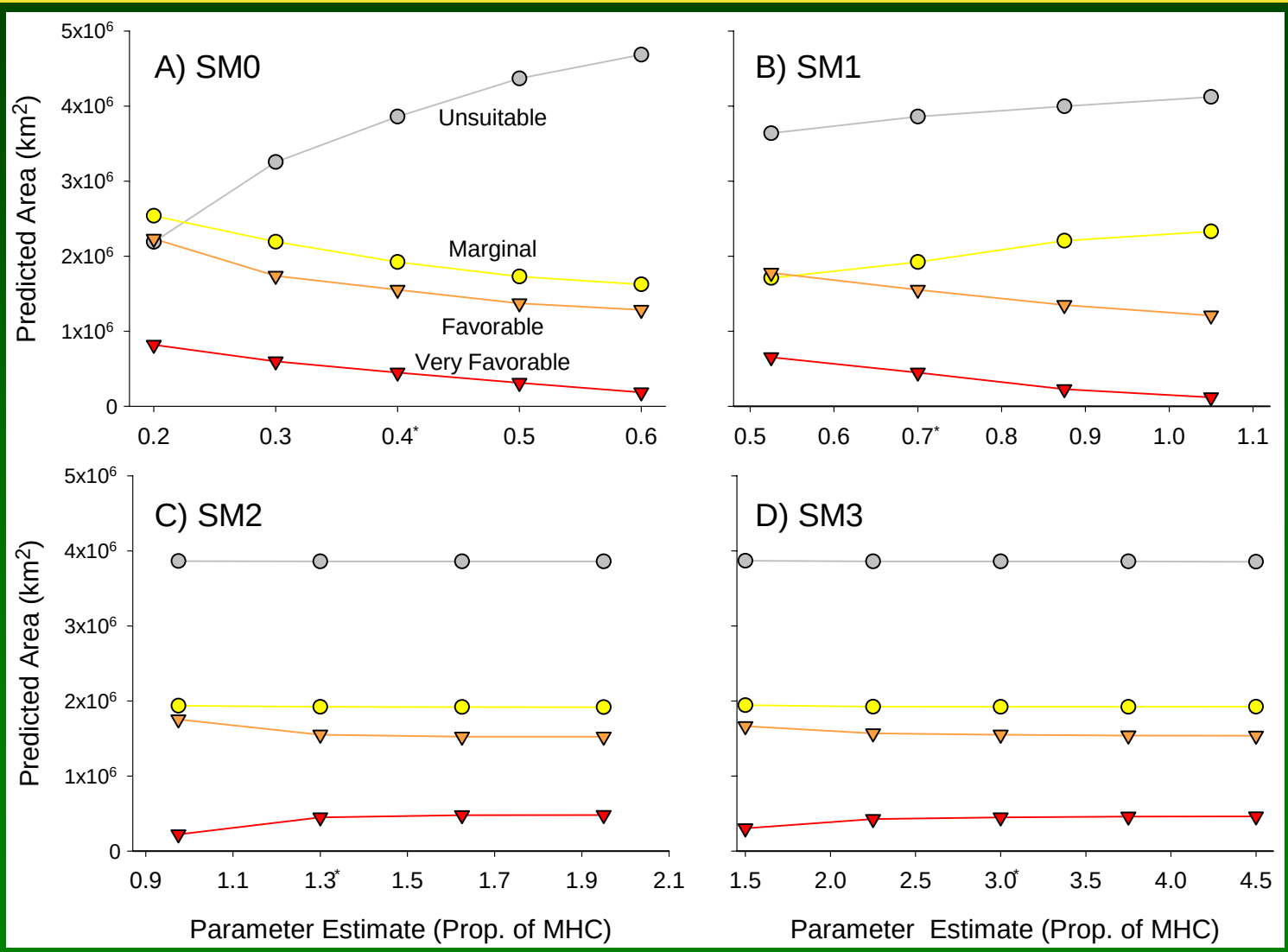
Observed vs predicted distribution of *P. ramorum* finds in California



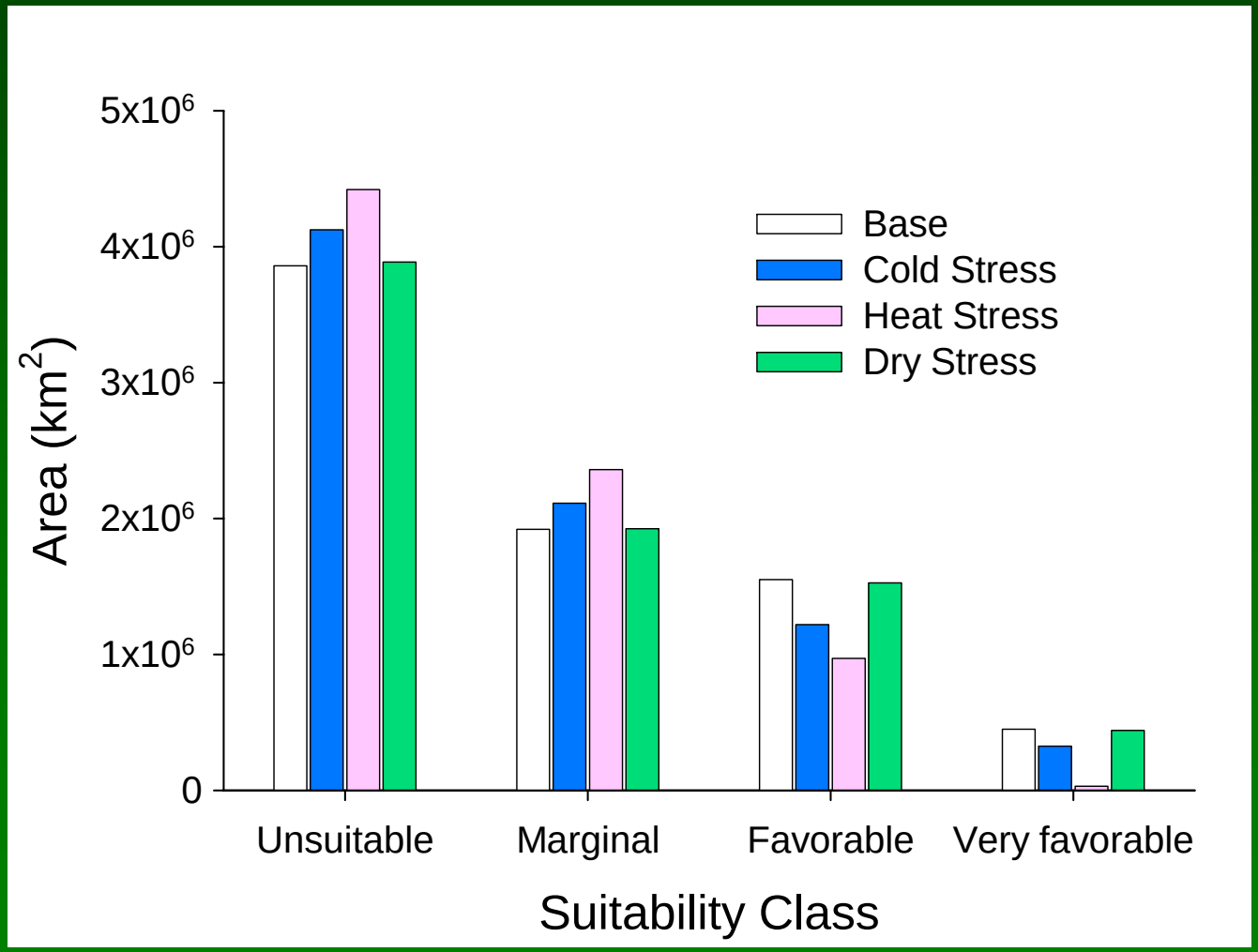
Sensitivity to changes in parameters describing temperature requirements for growth



Sensitivity to changes in parameters describing soil moisture requirements for growth



Inclusion of stresses affects distribution of *P. ramorum*



Conclusions

- Gulf States identified as having a very suitable climate within the US.
- Climatically suitable areas extend into southern MO, IL, IN, MO, and OH.
- Independent data validated the model.
- Model is most sensitive to parameters describing response to heat stress and initial moisture for growth. These should be areas of future research.

Acknowledgments

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