

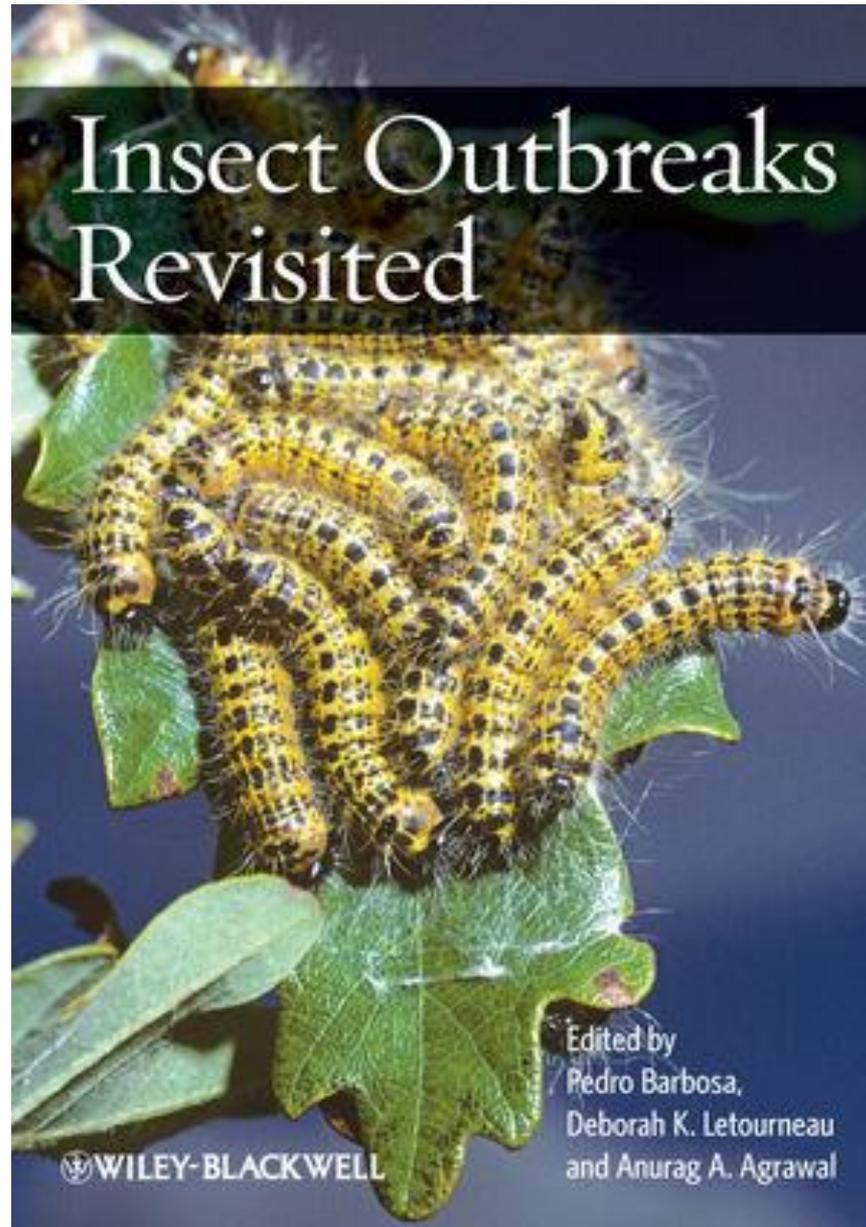
## Learning objectives:

1. Biodiversity
2. Invasive species
3. Structure of forest insect communities and ecological guilds
- 4. Population dynamics of forest insect pests**
5. How forest insects respond to abiotic drivers
6. How forest insects respond to biotic drivers: plant quality
7. How forest insects respond to biotic drivers: competition
8. How forest insects respond to biotic drivers: natural enemies
9. Ecological management of insect pest populations

**Insect outbreaks chapter 6 (spatial synchrony)**

**Insect outbreaks chapter 7 (tree rings)**

# Outbreaks of forest insects and population dynamics

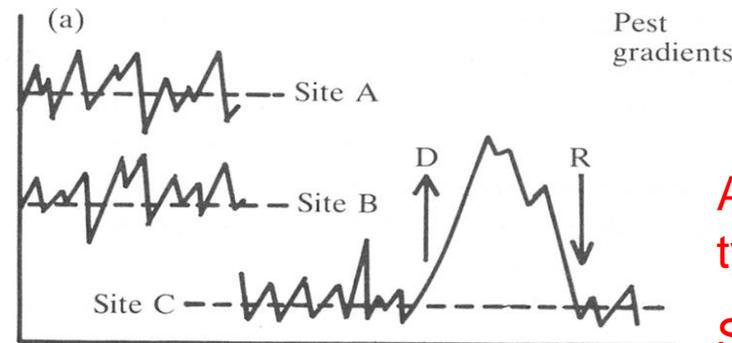


## Insect Outbreaks Revisited

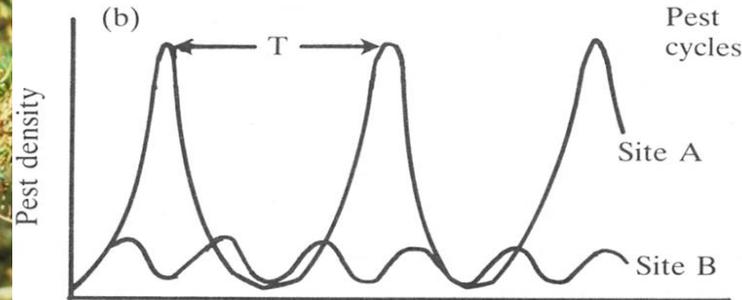
Edited by  
Pedro Barbosa,  
Deborah K. Letourneau  
and Anurag A. Agrawal

 WILEY-BLACKWELL

# Outbreak types: gradients, cycles, eruptions



A. *Ips*  
*typographus*  
Spruce bark  
beetle



C. *Cephalcia*  
*arvensis*  
Spruce web-  
spinning sawfly

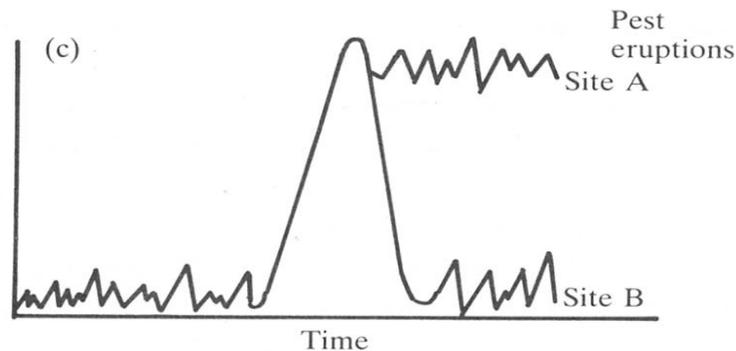


FIG. 1.2. Three major patterns of the population dynamics of forest insects (a) gradients (b) cycles, and (c) eruptions (D = disturbance in environmental conditions, R = return to normality, T = periodicity of population cycle) (see text) (from Berryman and Stark 1985).

# Study of population dynamics

1. Construct a **model of intergeneration change**
2. Develop a **sampling program** and estimate number of individuals passing through each stage in life cycle
3. Construct a **life table**, calculate and interpret birth and death rates
4. Compare **k-factor analysis** as ways to discover factors causing population change
5. Distinguish **major mortality factors, key factors**
6. Distinguish **direct density dependence, inverse density dependence, delayed density dependence, density independence**
7. Critically evaluate methods for assessing role of **density-dependent** and **density-independent** factors in population dynamics

# Classical Approach: Key Factor Analysis

1. Study life history and develop methods of census for each stage
2. Construct a life table that is as complete as possible
3. Accumulate many life tables
4. Plot generation curves and mortalities
5. Assess the key-factors which make the biggest contribution to change in generation mortality
6. Determine the relationship of component mortalities to density
7. Follow up with intensive studies of key factors
8. Make predictions using the model

# Study life history and develop methods of census for each stage

## 1. Life History

- Adult emergence
- Oviposition
- Larvae and Pupae

## 2. Sampling decisions

- Subdivision of the habitat
- Selection of the sampling unit
- Number of samples
- Placement of samples
- Timing of sampling

# Construct a life table that is as complete as possible

1. Designate stage intervals – how?
2. Estimate mortality assuming factors act sequentially, not simultaneously – what are the implications?
3. Estimate k-values as difference between logarithms of the population before and after mortality acts

## Concept Alert!

- Major mortality factor – makes a large contribution to mortality within a generation (large  $k$ )
- Key factors contribute to changes in abundance between generations (component  $k$  most correlated with generation  $K_{\text{total}}$ )
- Density-regulating factors are those  $k$ -values that increase with density of the stage on which they act.
- Population regulation. A regulated population is one that tends to return to equilibrium density or cycle when perturbed from this level or cycle. Precise DD requires that DD factors not be too strong or too weak.

# Test for density dependence: plot $k$ values against density

1. Strength

2. Sign

3. Time Delay

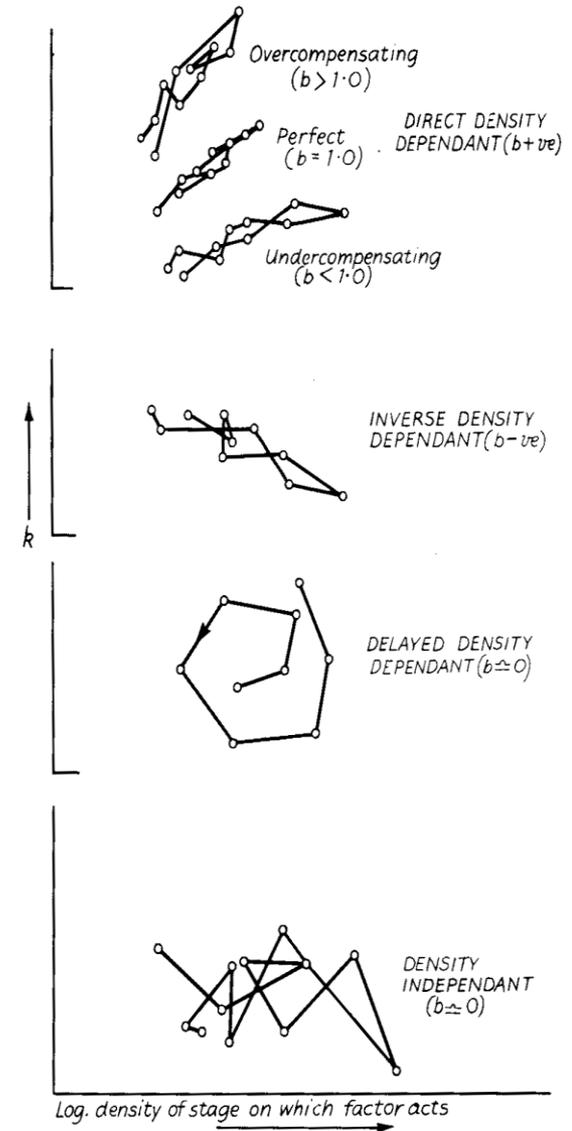


Fig. 10.7 Time sequence plots showing how the different density relationships may be recognized from the patterns produced.

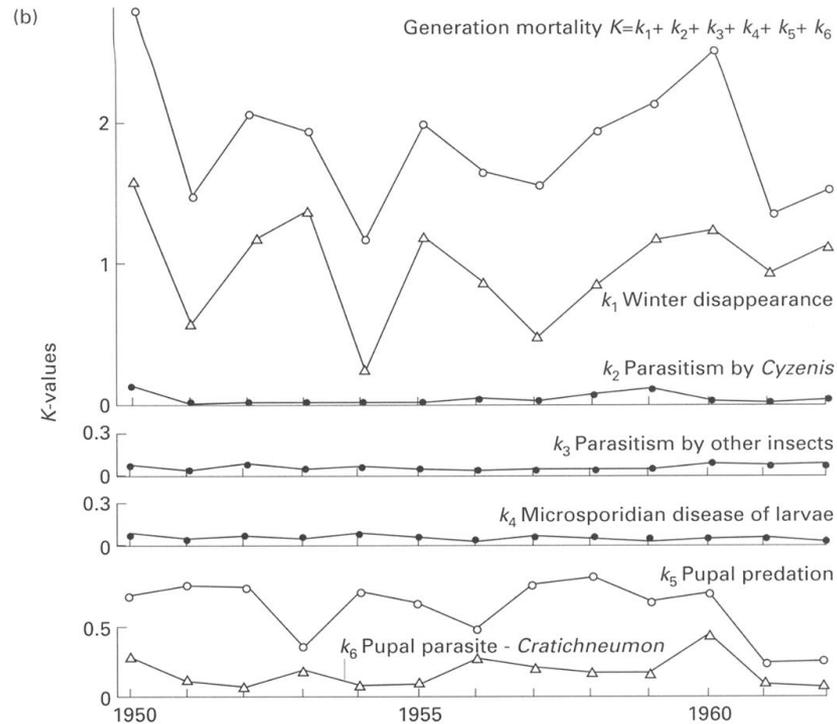
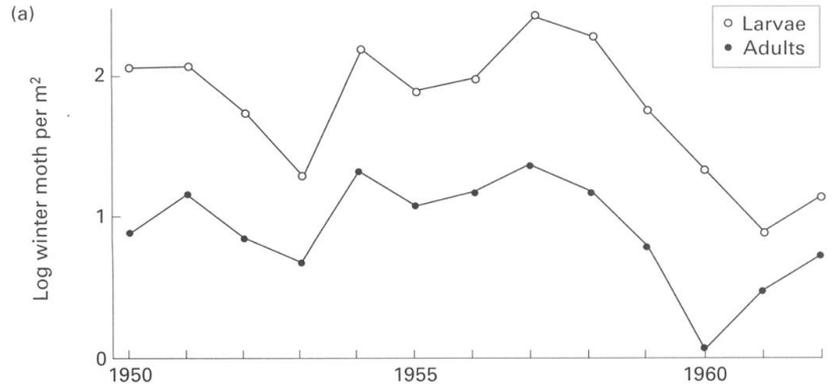
Case study  
Winter Moth  
*Operophtera brumata*  
*Geometridae*



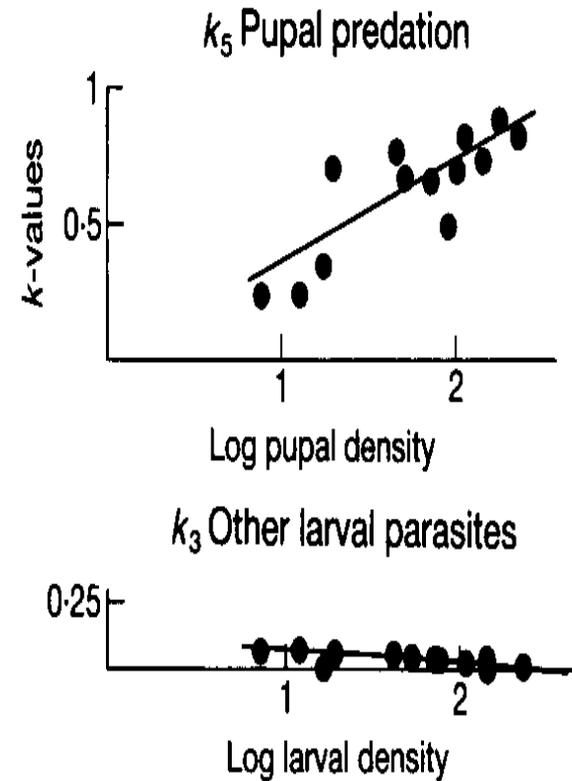
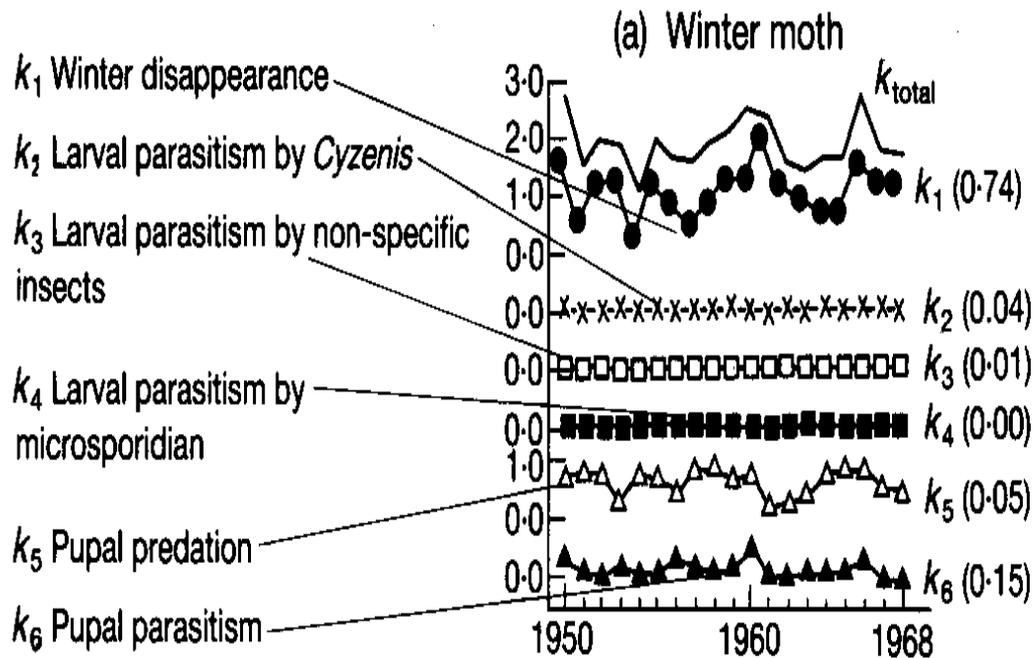
# *Operophtera brumata* the winter moth

- Univoltine -one generation per year
- Female flightless
- Cyclic dynamics: 9-10 years between population peaks. Parasitoids important factor for cycles.
- Main host species: *Quercus robur*- Pedunculate Oak native to large parts of Europe. Birch-*Betula* sp. in northern Europe.
- Other host tree species: mountain ash, fruit trees (mostly Rosacea) and other.

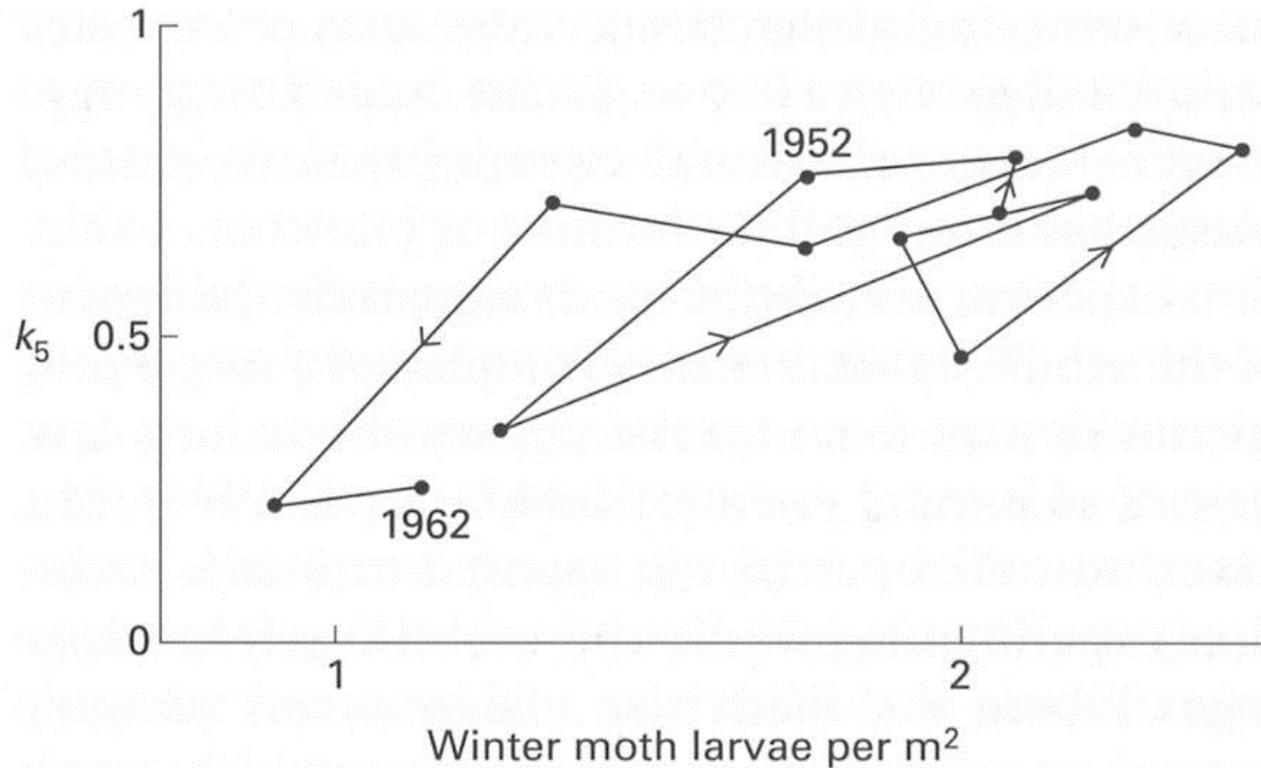
# Winter moth life table of Varley and Gradwell 1970



# Plot k against time and density



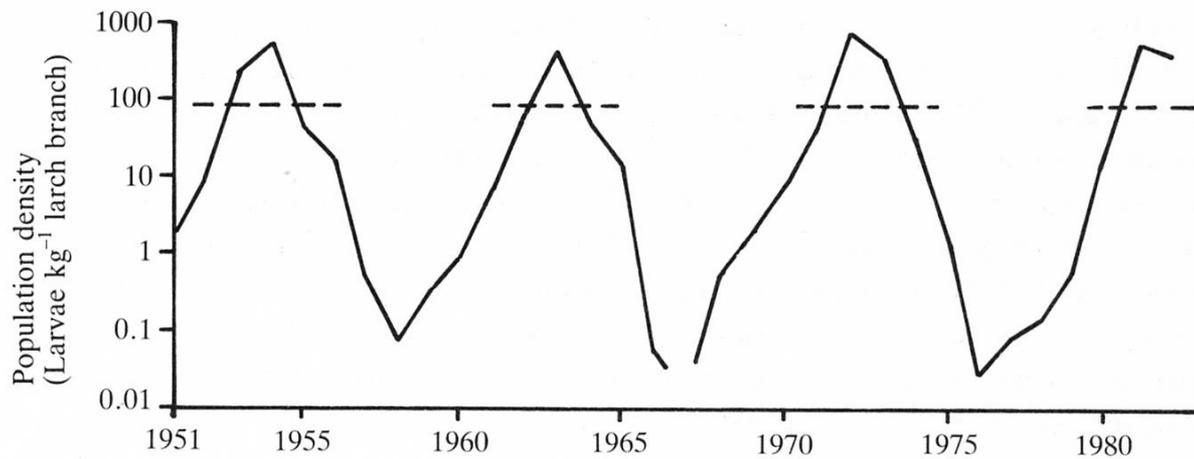
# Plot $k$ against time and density: delayed dd and anti-clockwise direction



**Fig. 5.14** Time series plot of pupal predation of the winter moth, the spiral form suggesting a delayed density-dependent component to this mortality. (Source as Fig. 5.12.)

# The special case of population cycles

- Larch bud moth *Zeiraphera diniana*
- Gypsy moth *Lymantria dispar*
- Winter moth *Operophtera brumata*



**Larch bud moth**  
***Zeiraphera diniana***  
**Engadine,**  
**Switzerland**

FIG. 1.3. Fluctuation in numbers of larvae of *Zeiraphera diniana* on larch at Sils in the Engadine Valley, Switzerland. Dotted line is the defoliation threshold (from Baltensweiler 1984).

**Special Edition: Obituary Werner Baltensweiler, 1926-2008**



Werner Baltensweiler measuring larch needle length near Zuoz, Switzerland, September, 2002

### DYNAMICAL EFFECTS OF PLANT QUALITY AND PARASITISM ON POPULATION CYCLES OF LARCH BUDMOTH

PETER TURCHIN,<sup>1</sup> SIMON N. WOOD,<sup>2</sup> STEPHEN P. ELLNER,<sup>3</sup> BRUCE E. KENDALL,<sup>4</sup> WILLIAM W. MURDOCH,<sup>5</sup>  
ANDREAS FISCHLIN,<sup>6</sup> JÉRÔME CASAS,<sup>7</sup> EDWARD MCCAULEY,<sup>8</sup> AND CHERYL J. BRIGGS<sup>9</sup>

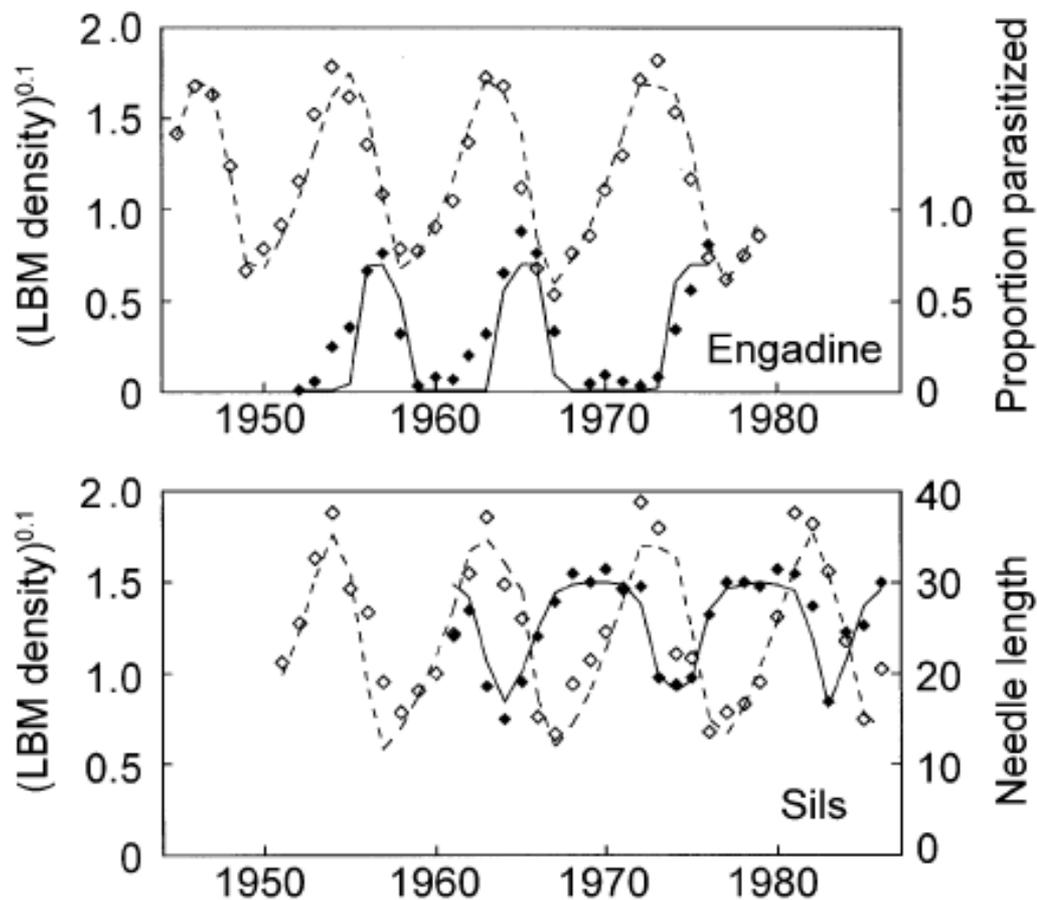


FIG. 3. Results of trajectory matching. Upper panel: Engadine data set (hollow symbols indicate budmoth density; filled symbols indicate proportion parasitized). Lower panel: Sils data set (hollow symbols indicate budmoth density; filled symbols indicate needle length).

# Geographic variation in North American gypsy moth cycles: subharmonics, generalist predators, and spatial coupling

OTTAR N. BJØRNSTAD,<sup>1,4</sup> CHRISTELLE ROBINET,<sup>2,3</sup> AND ANDREW M. LIEBHOLD<sup>3</sup>

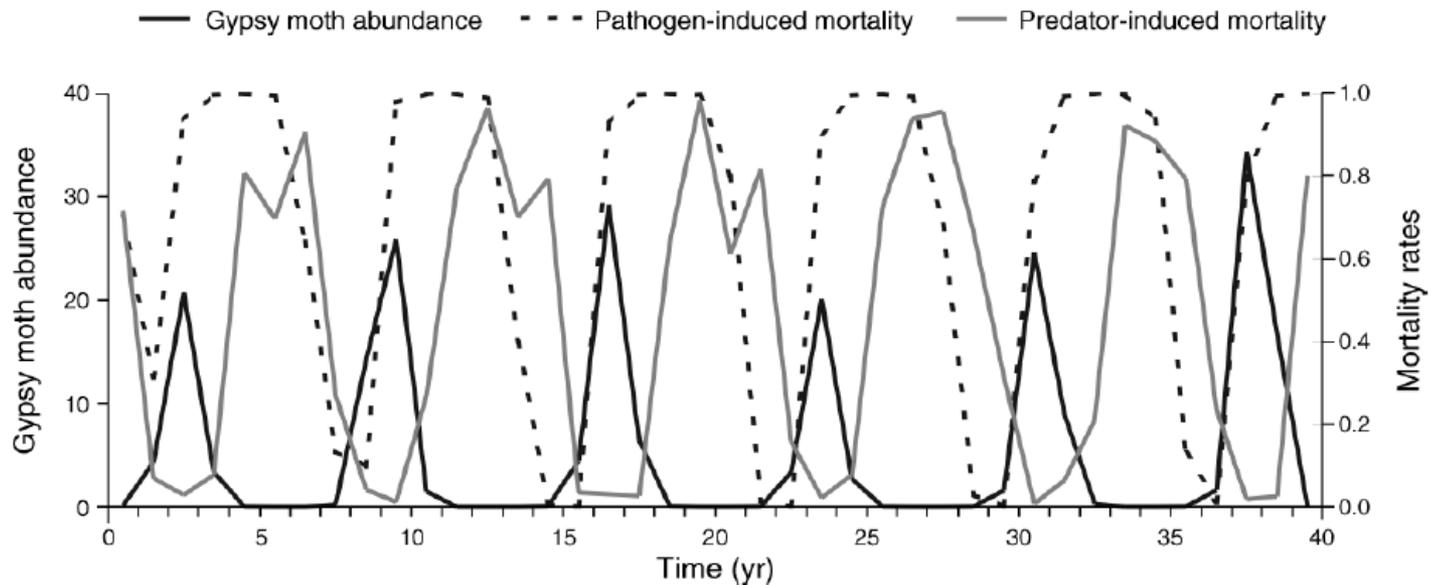


FIG. 2. An example of fluctuations of gypsy moth abundance (in arbitrary units) predicted by the stochastic model with associated mortality rates due to predators and pathogens when predator carrying capacity  $K = 5$ , and predator growth rate is log-normal with  $r$  (the mean instantaneous rate of increase) = 2 and  $\tilde{\sigma} = 0.3$ .

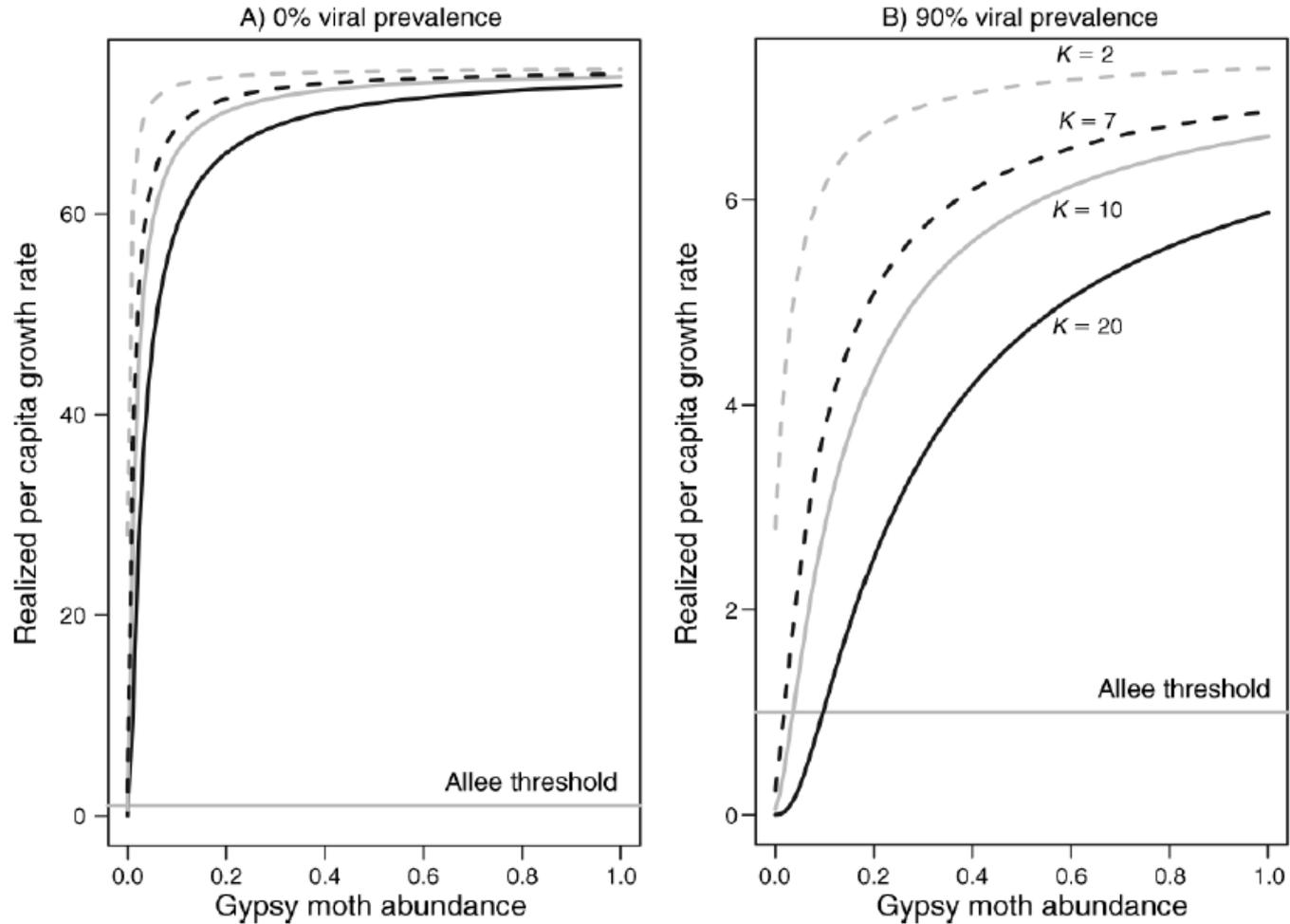


FIG. 3. Effects of predator abundance on low-density populations of gypsy moth, when (A) no host is infected with virus, and when (B) 90% of larvae are infected with virus. The solid black line refers to  $K$  (carrying capacity) = 20, the solid gray line refers to  $K=10$ , the dashed black line refers to  $K=7$ , and the dashed gray line refers to  $K=2$ . The horizontal gray line indicates a realized per capita growth rate of 1 (the Allee threshold).

# Allee effect Liebhold and Tobin Ann Rev

## ECOLOGY LETTERS

*Ecology Letters*, (2011)

doi: 10.1111/j.1461-0248.2011.01614.x

### REVIEW AND SYNTHESIS

## Exploiting Allee effects for managing biological invasions

Patrick C. Tobin,<sup>1\*</sup> Luděk Berec<sup>2</sup>  
and Andrew M. Liebhold<sup>1</sup>  
<sup>1</sup>*Forest Service, U. S. Department of  
Agriculture, Northern Research  
Station, 180 Canfield Street,  
Morgantown, WV 26505-3101, USA*  
<sup>2</sup>*Department of Theoretical Ecology,  
Institute of Entomology, Biology  
Centre ASCR, Branisovska 31, 37005  
České Budejovice, Czech Republic*  
\*Correspondence: E-mail:  
ptobin@fs.fed.us

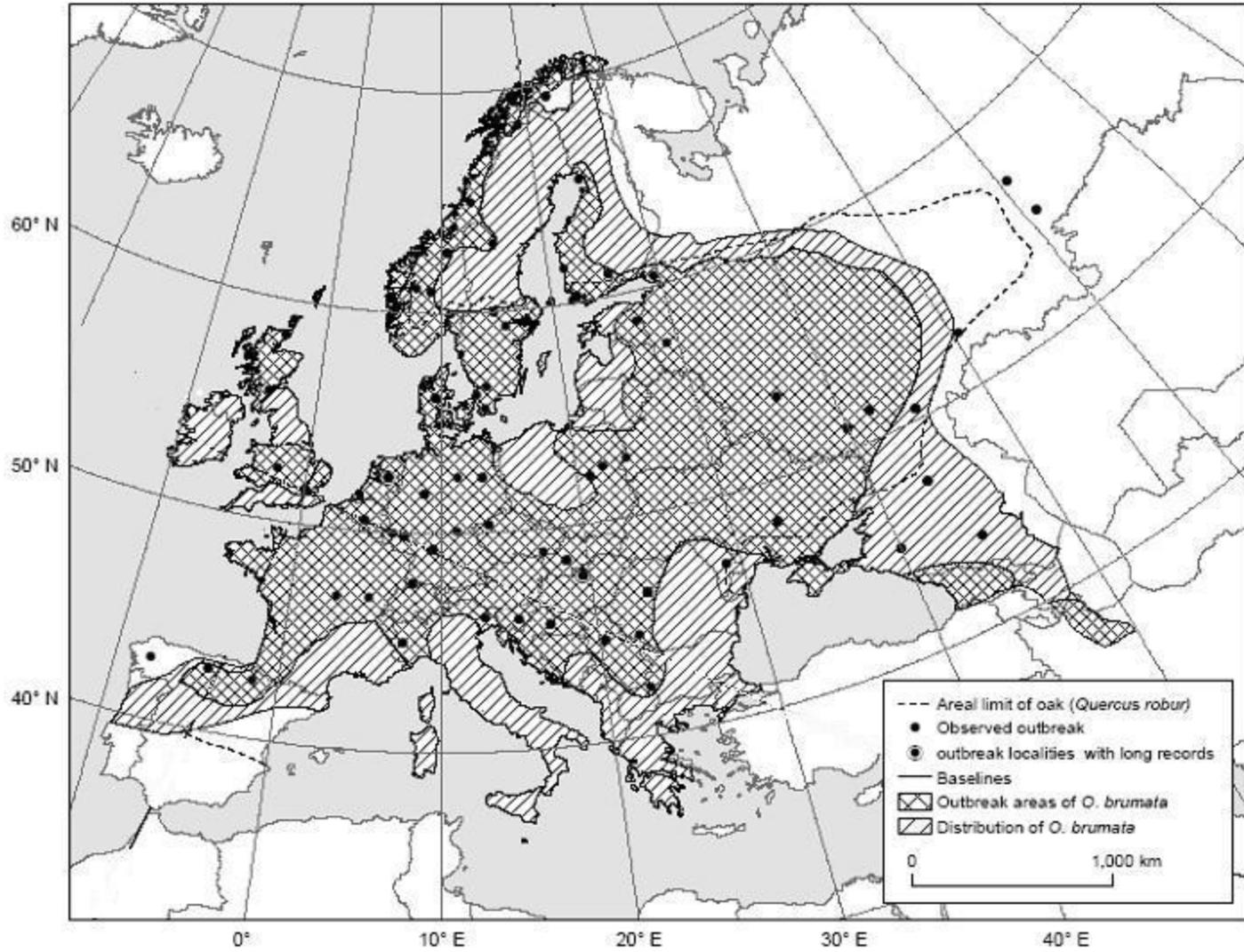
### Abstract

Biological invasions are a global and increasing threat to the function and diversity of ecosystems. Allee effects (positive density dependence) have been shown to play an important role in the establishment and spread of non-native species. Although Allee effects can be considered a bane in conservation efforts, they can be a benefit in attempts to manage non-native species. Many biological invaders are subject to some form of an Allee effect, whether due to a need to locate mates, cooperatively feed or reproduce or avoid becoming a meal, yet attempts to highlight the specific exploitation of Allee effects in biological invasions are surprisingly unprecedented. In this review, we highlight current strategies that effectively exploit an Allee effect, and propose novel means by which Allee effects can be manipulated to the detriment of biological invaders. We also illustrate how the concept of Allee effects can be integral in risk assessments and in the prioritization of resources allocated to manage non-native species, as some species beset by strong Allee effects could be less successful as invaders. We describe how tactics that strengthen an existing Allee effect or create new ones could be used to manage biological invasions more effectively.

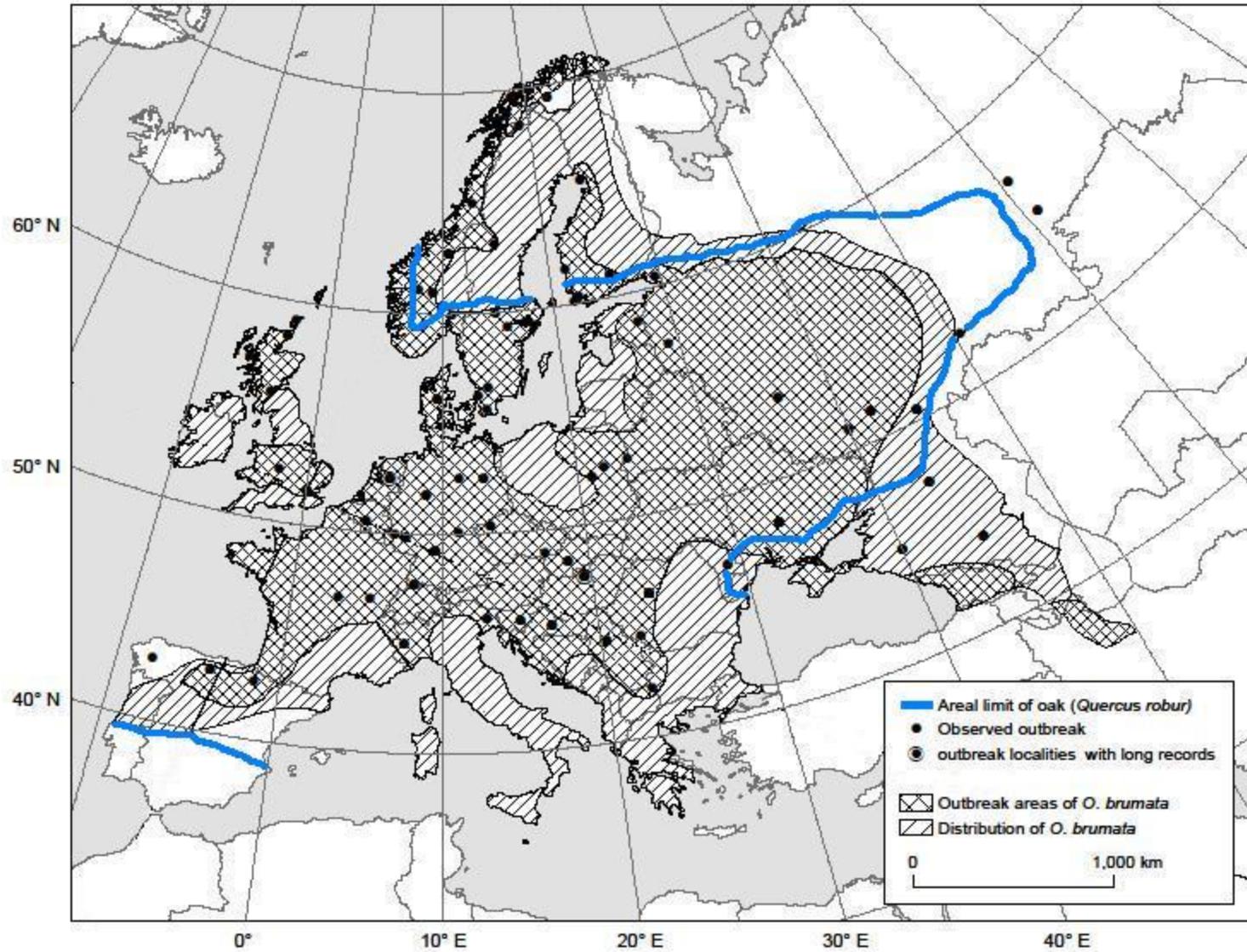


Winter moth defoliation at Lapporten-Lappland Photo S. Hörnell

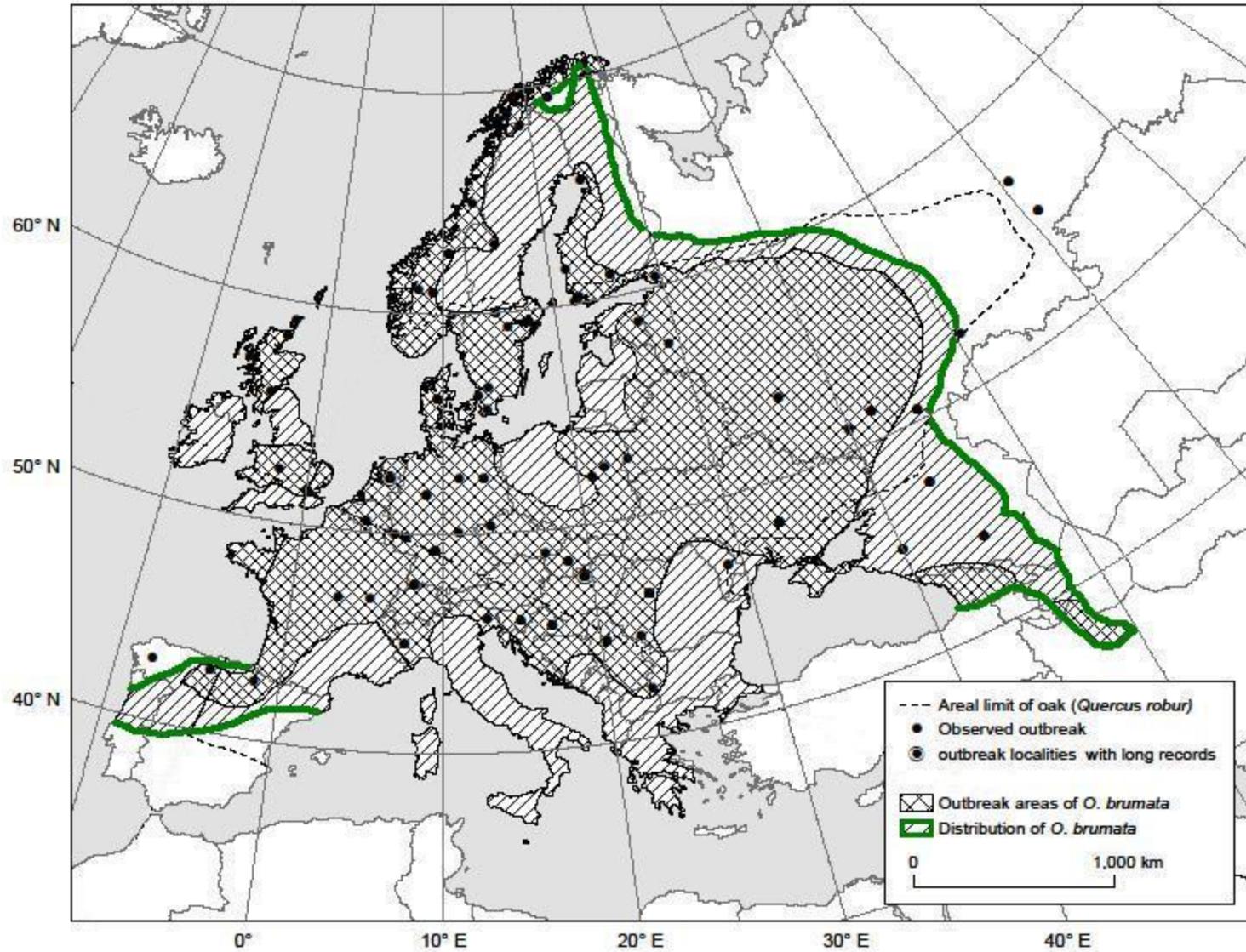
# Reported Outbreak localities 1948-2008



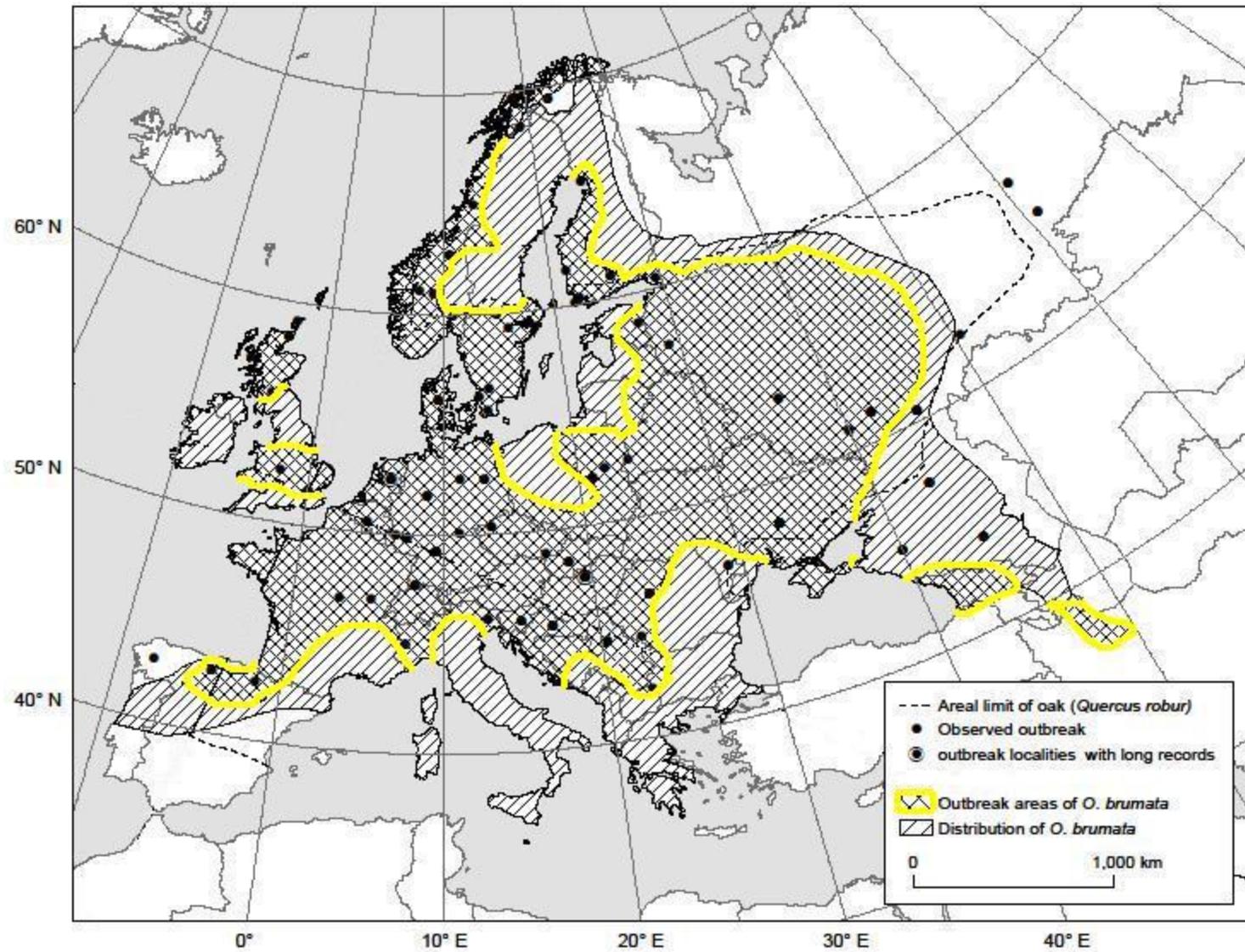
# Oak distribution range



# Distribution range of *Operophtera brumata*

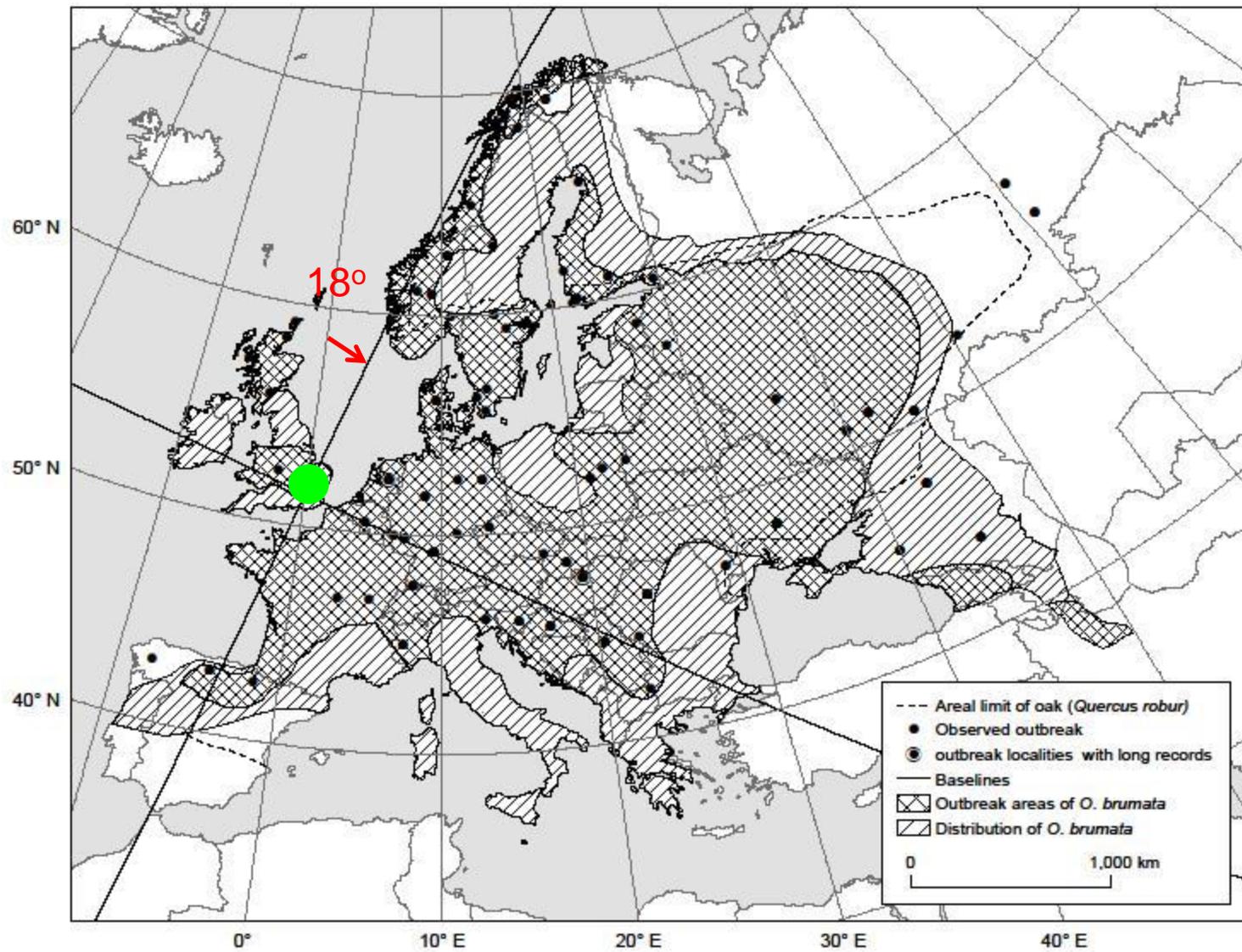


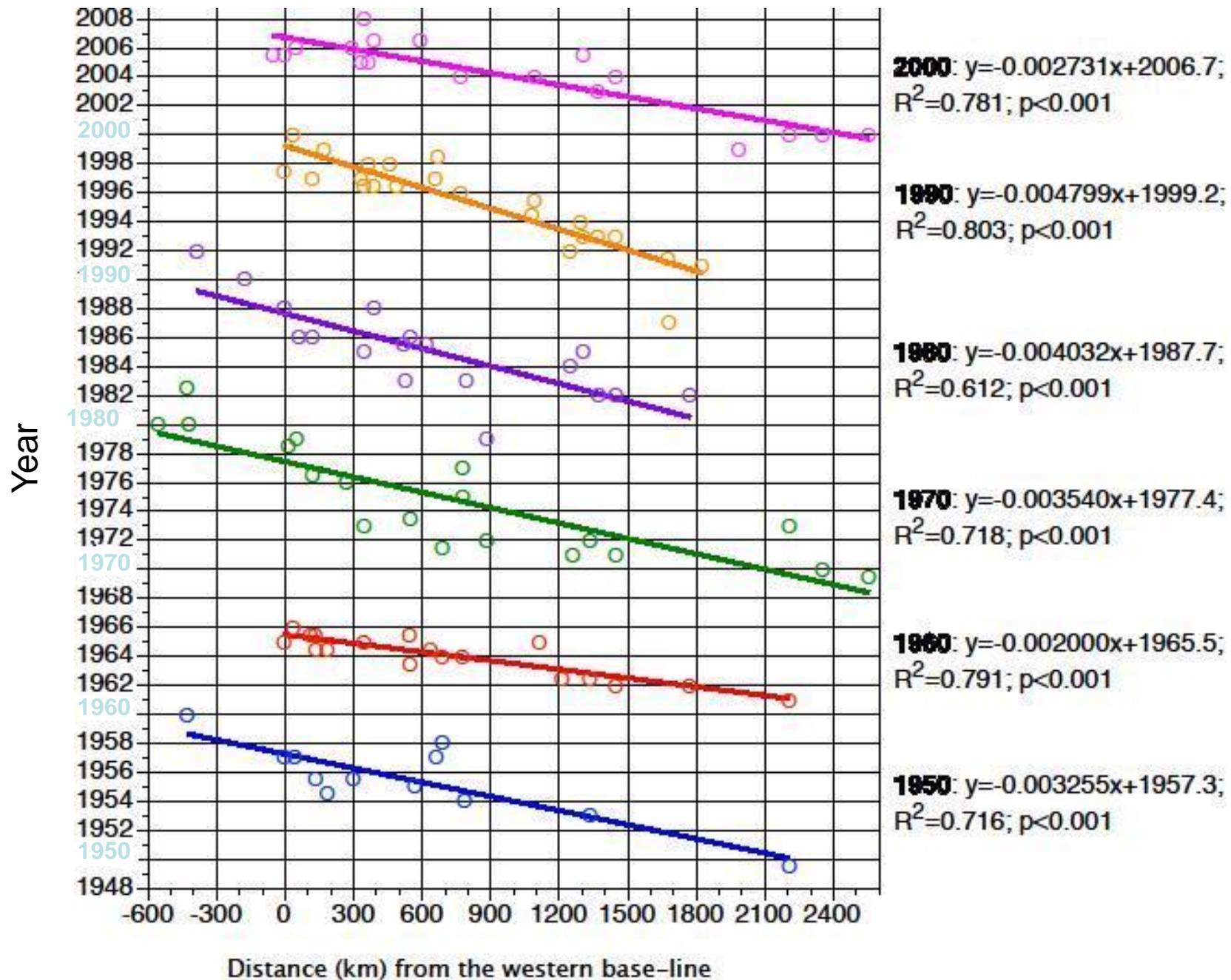
# Outbreak range of *Operophtera brumata*



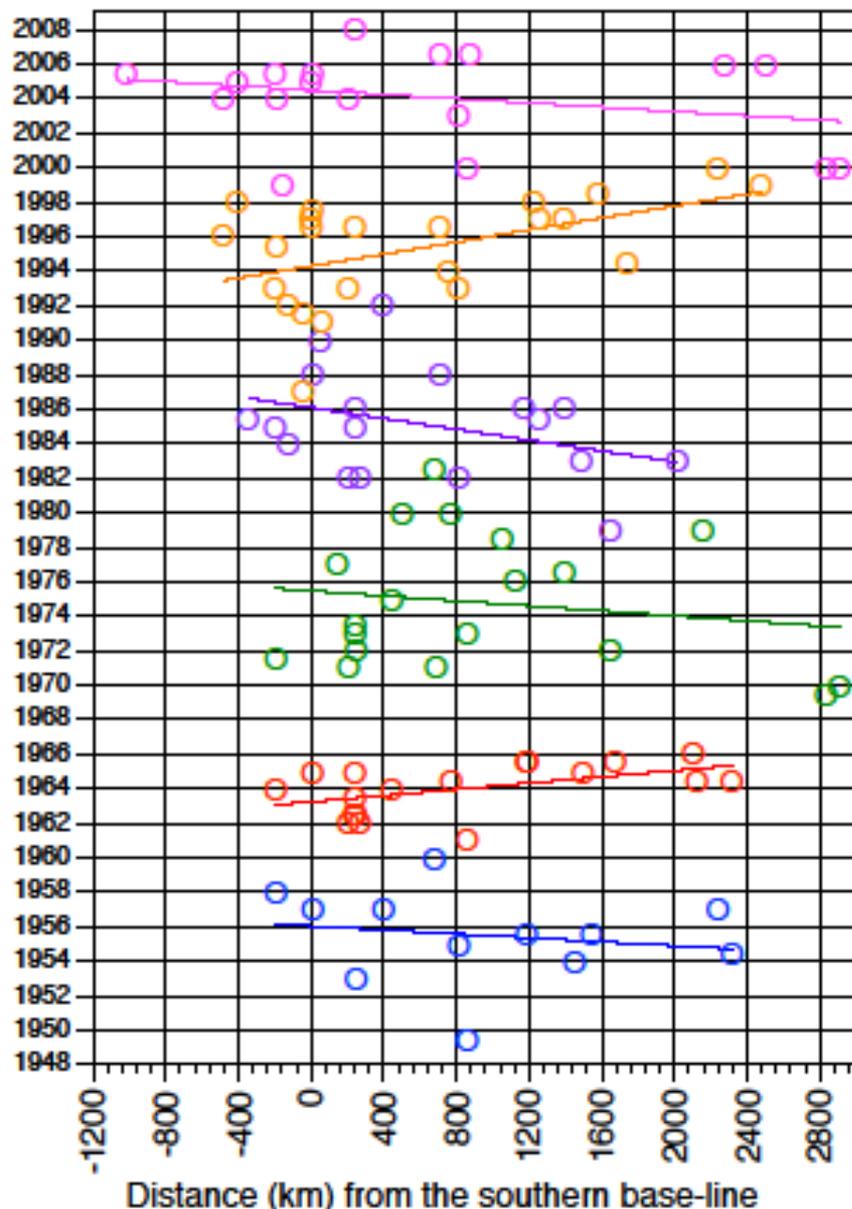
# Methods

- The perpendicular great circles that intersect at Greenwich on the GR80-ellipsoid were rotated  $18^\circ$  from the true north so the N-S oriented great circle became ~parallel to the Scandes and the North Atlantic coast.









**2000:**  $f(x) = -6.181705E-4x + 2.004490E+3$   
 $R^2 = 7.865144E-2$ ;  $p=0.26$

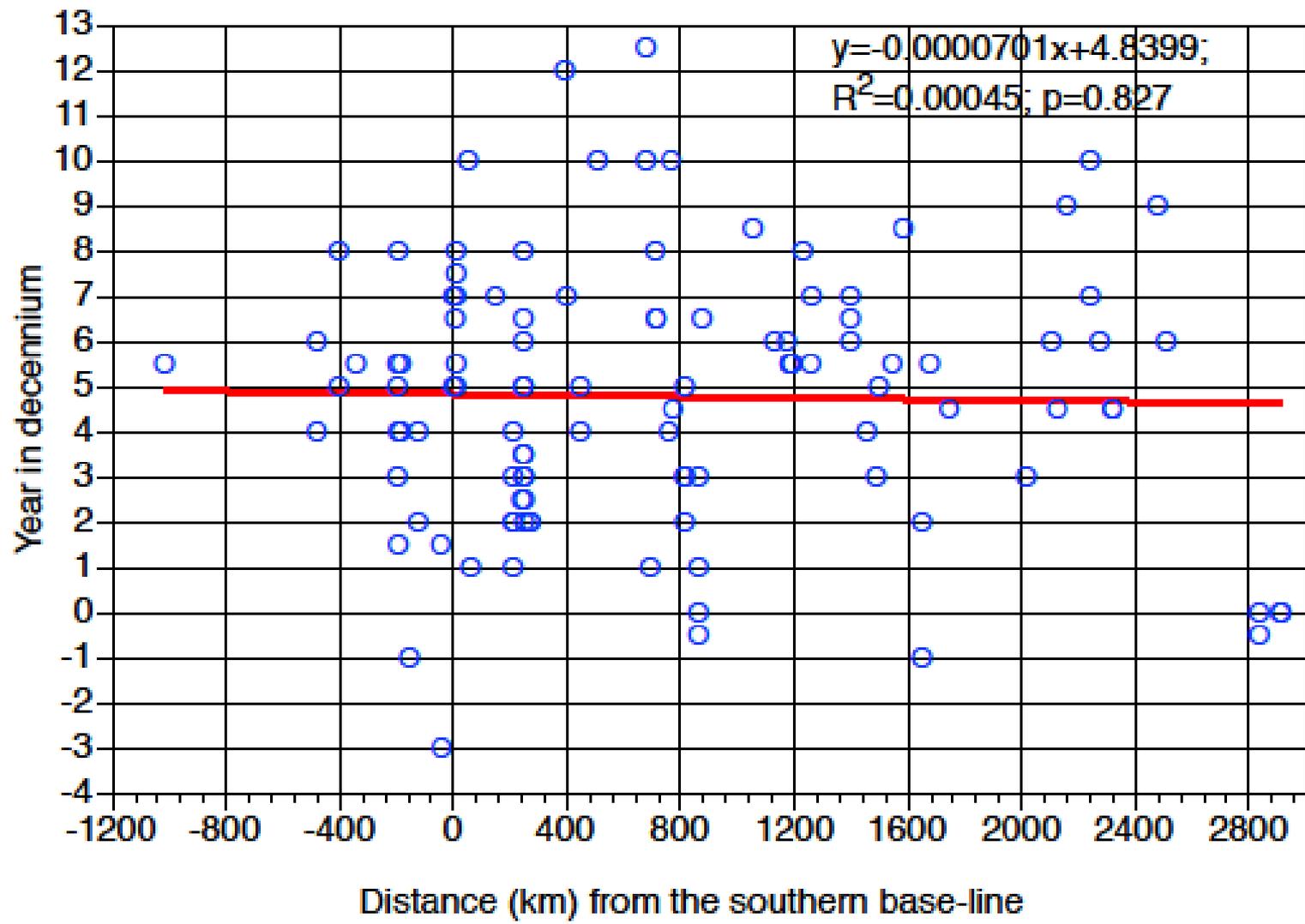
**1990:**  $f(x) = 1.741942E-3x + 1.994298E+3$   
 $R^2 = 2.375048E-1$ ;  $p=0.018$

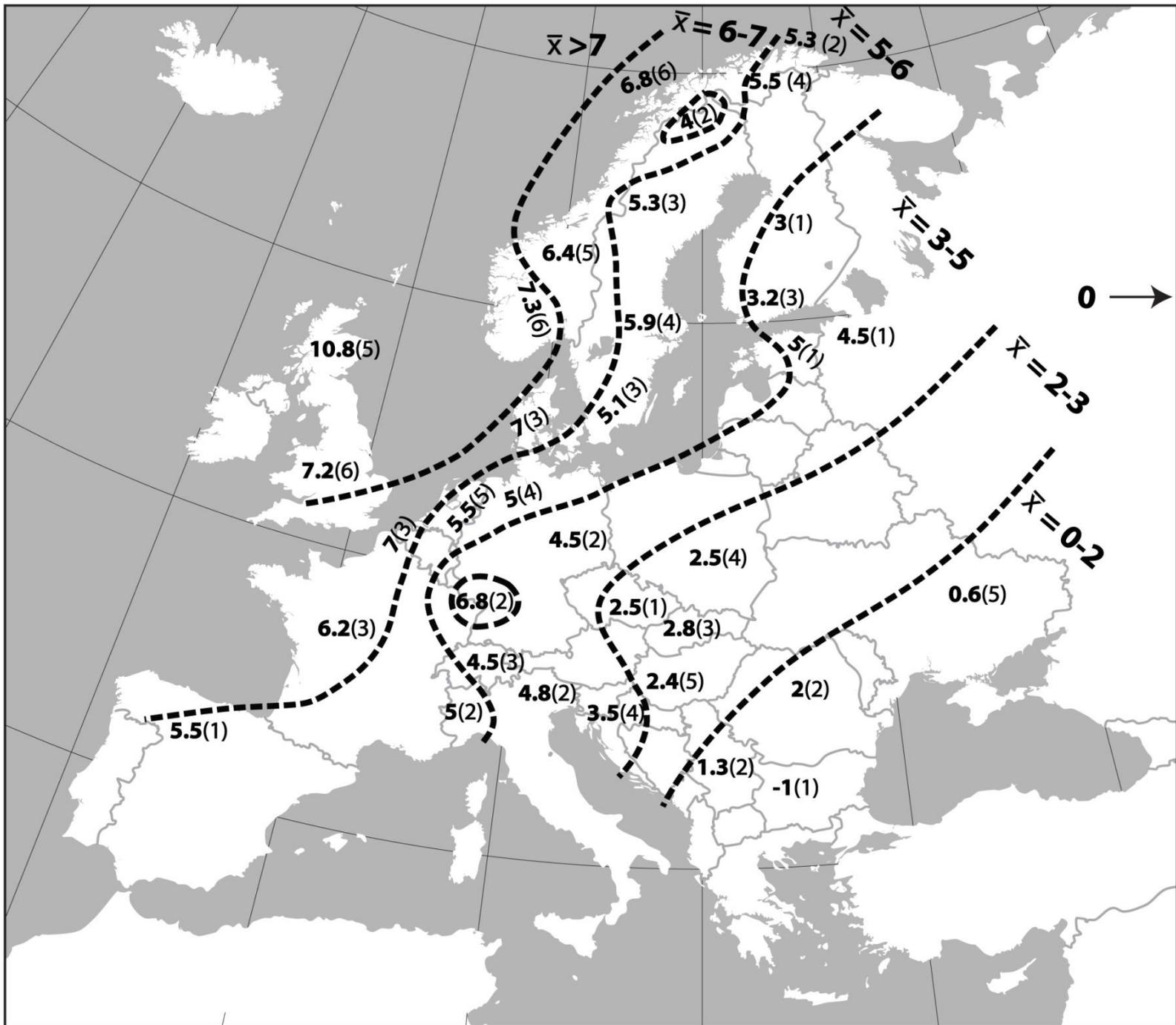
**1980:**  $f(x) = -1.568720E-3x + 1.986094E+3$   
 $R^2 = 1.263348E-1$ ;  $p=0.15$

**1970:**  $f(x) = -7.250959E-4x + 1.975476E+3$   
 $R^2 = 2.779776E-2$ ;  $p=0.50$

**1960:**  $f(x) = 9.034942E-4x + 1.963251E+3$   
 $R^2 = 2.446256E-1$ ;  $p=0.037$

**1950:**  $f(x) = -5.722624E-4x + 1.956052E+3$   
 $R^2 = 3.022850E-2$ ;  $p=0.59$





# Why lagged synchrony and waves?

Reaction-diffusion models:

- **trophic interactions** - Dispersal prey or natural enemies or plant-herbivore interactions.
- Boundaries with hostile environment:
  - a) Eastern climatic boundary
  - b) Eastern limit of regular oak distribution

# Population growth model

applicable with long data sets

$$R = \ln (N_t / N_{t-1})$$

where  $N_t =$

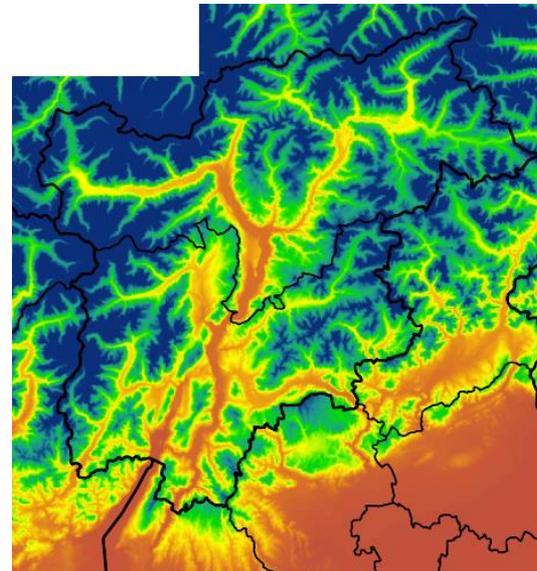
- Number of individuals per unit area in year t
- Number of infested trees per unit area in year t
- attacked area of year t
- ....

# Long-term survey of *Thaumetopoea pityocampa* population dynamics in the Italian Alps

## Objectives

Identify endogenous and exogenous factors driving the population dynamics in Trentino Alto Adige, a mountain area where the pest is present since many years.

1. Assemble survey data
2. Apply a population model
3. Test climatic factors



Orange to green: 90 to 1450 m of altitude

# Materials and methods

Two unpublished time-series of attacked area surveys: twenty years in Trentino (from 1990 to 2009) and thirty-seven in Alto Adige (from 1975 to 2011).

Altitude span: 91 – 1450 m

Host species: *Pinus sylvestris* and *Pinus nigra*

Host area: 20,740 ha (Trentino), 24,864 (Alto Adige)

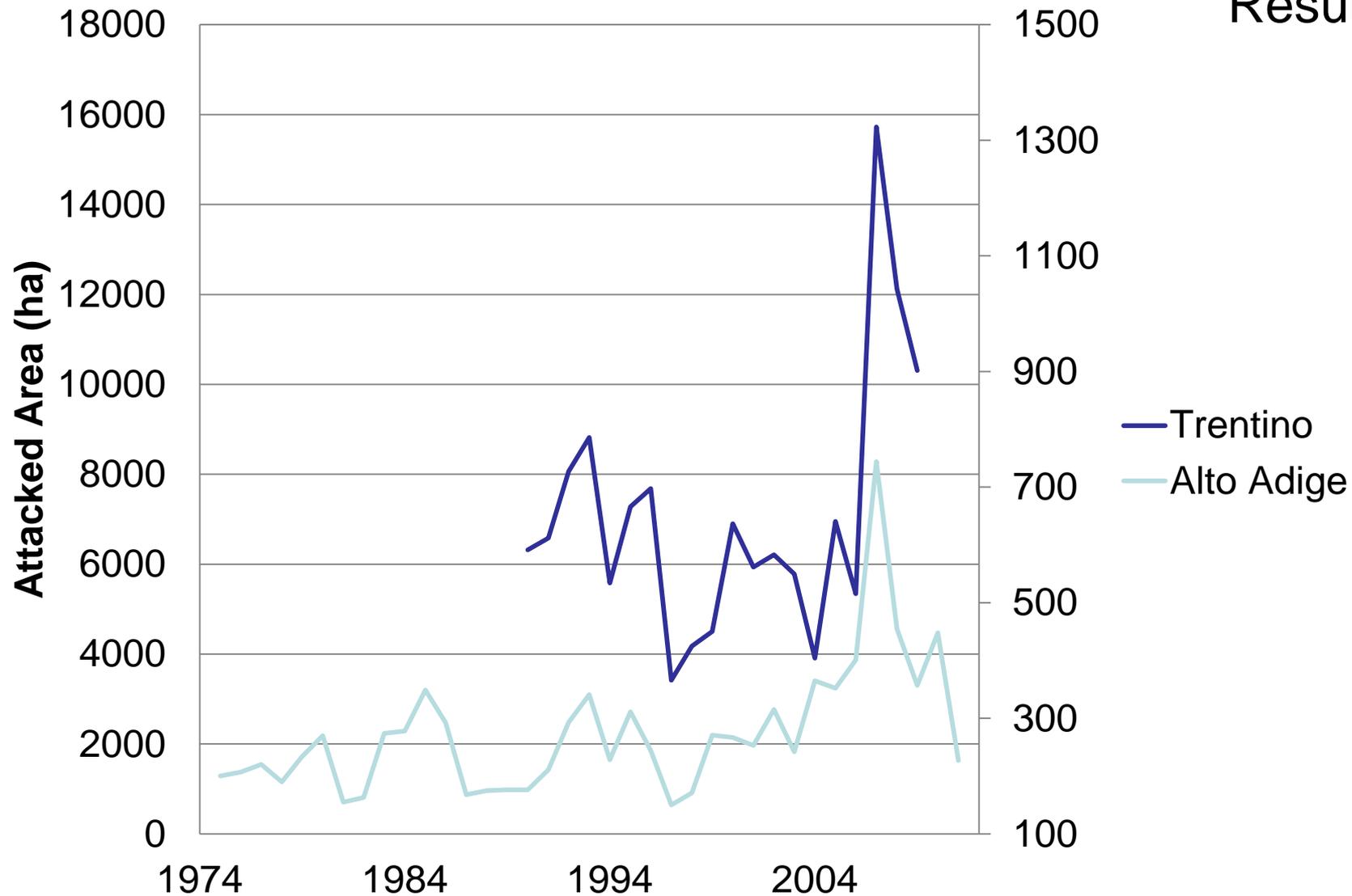
Climate: T-Winter min t-1, T-Summer, R-Spring, R-Autumn

Model

Population growth rate as per capita rate of increase

$R = \ln(N_t/N_{t-1})$  (where  $N_t$  = attacked area of year t)

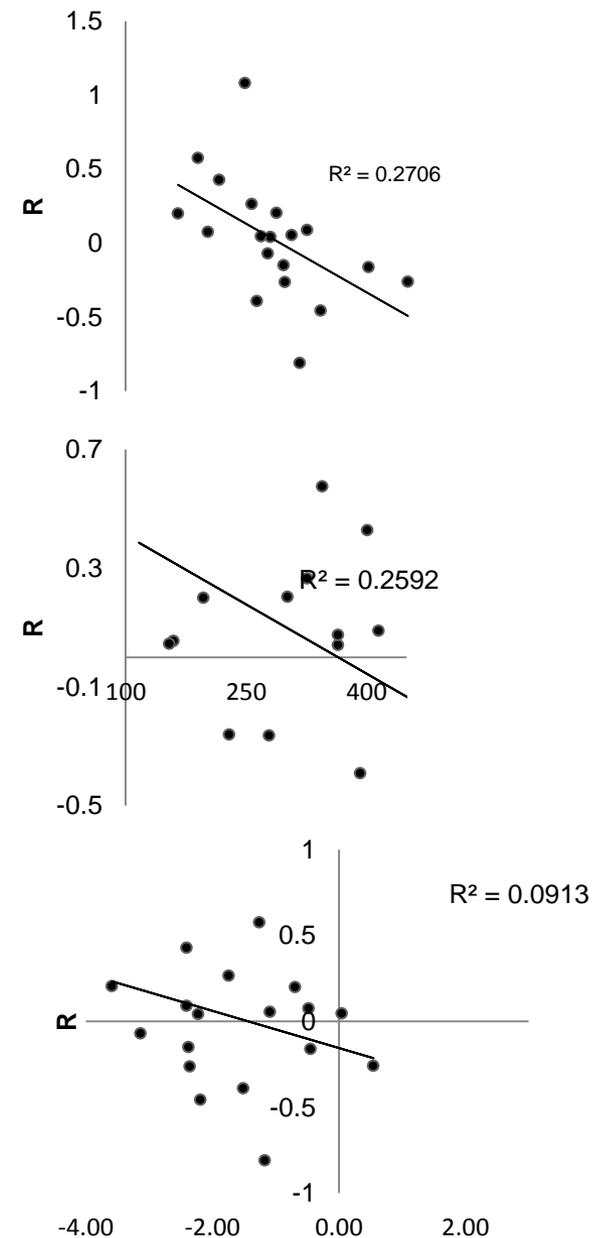
$R_t = f(N_{t-1}) + \varepsilon$  with  $\varepsilon$  representing sampling error plus exogenous (i.e. density independent) effects



Population fluctuations in Trentino and in Alto Adige (vertical scale on the left is referred to Trentino attacked area, on the right to Alto Adige, in hectares).

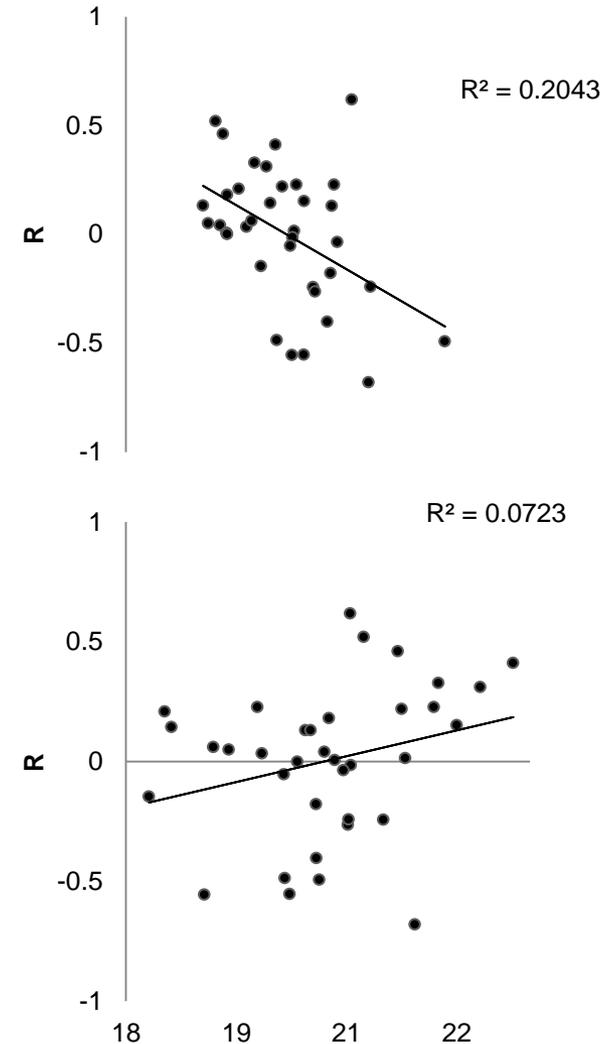
# Trentino BEST MODEL : 51% of variance explained

Factors	%
Density N t-1	27
Autumnal Rainfall	26
Min Winter Temperature t-1	9

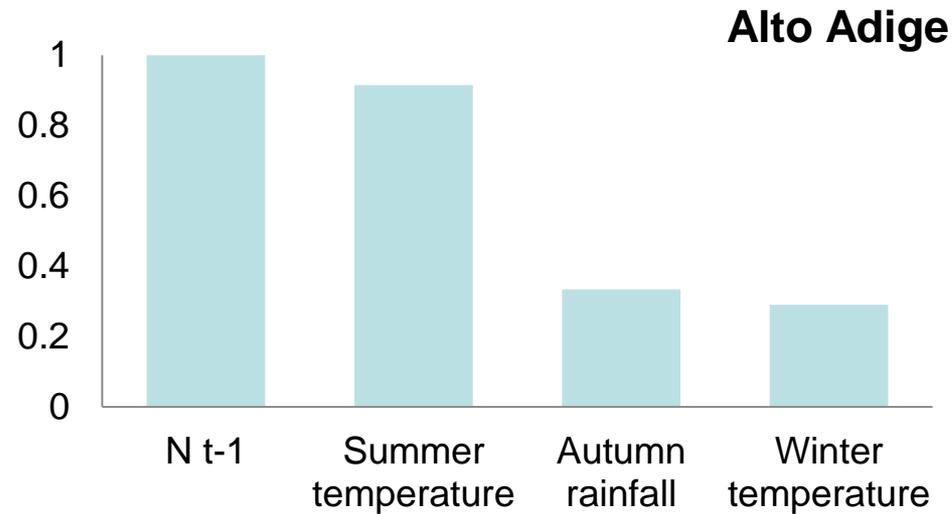
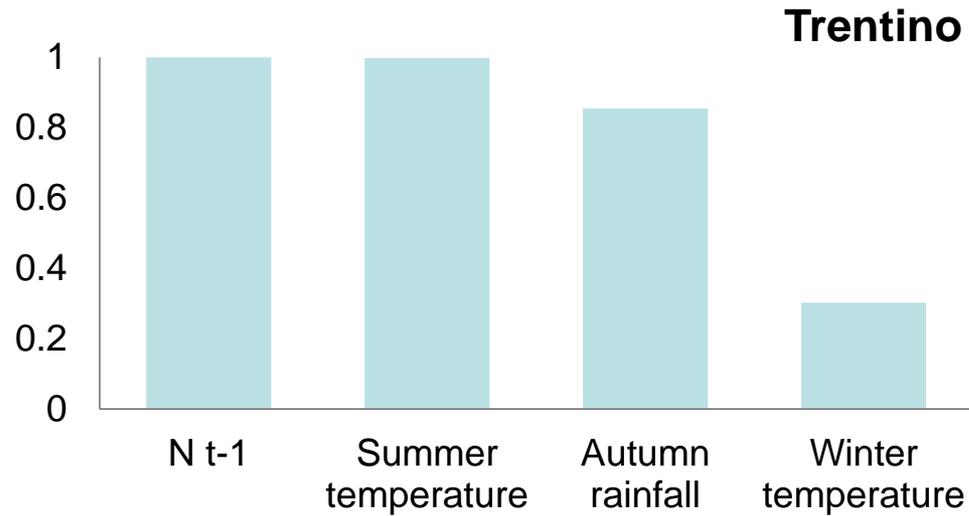


# Alto Adige BEST MODEL : 27% of variance explained

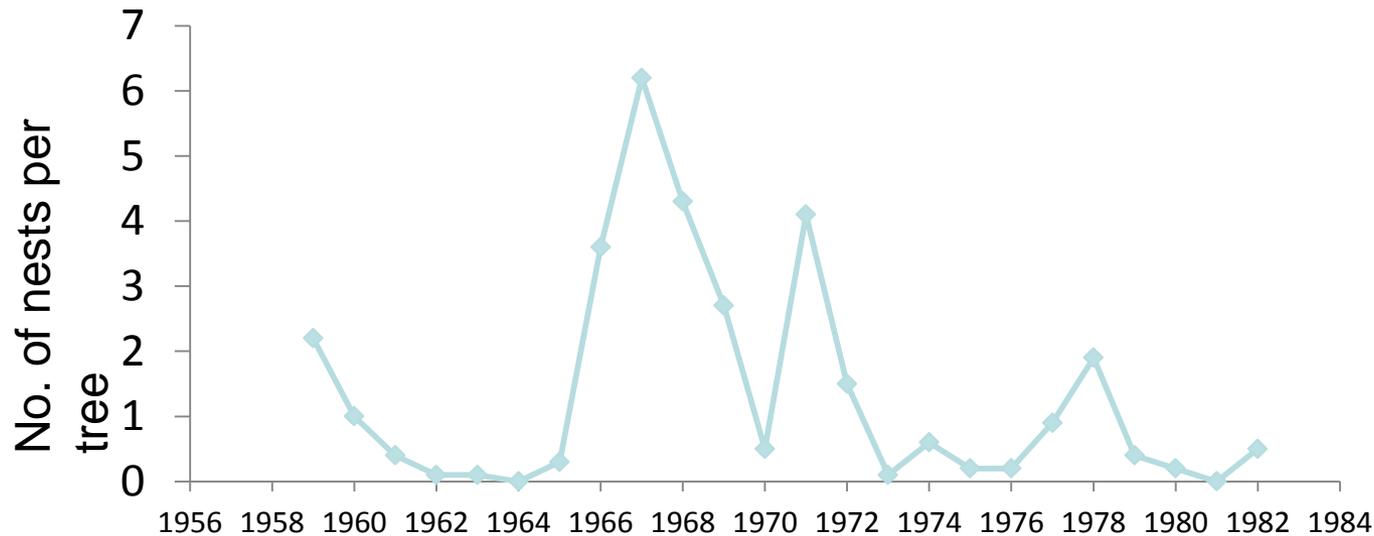
Factors	%
Density N t-1	20
Summer Temperature	7



Weights of  
variables  
included in the  
best model



## Comparison with other historical series: Mont Ventoux 1959-1982 (Geri 1983)



Availability of other historical series?  
Standardization of the data needed.

## Preliminary conclusions

- Consistency of the pattern between Trentino and Alto Adige
- Density in the previous year as main driving factor of the population dynamics → emphasis on the regulation by the host plant (food quantity and quality)
- Delayed density-dependence by natural enemies not significant in the area
- Climatic factors important at local scale