Course contents:	1. Insect abundance and distribution: species-area relationships. Diversity of forest insects in relation to tree species, feeding guilds, and to the history of forest stands. Invasive species in forestry: definitions, concepts, and applications. 2. Classification of the outbreaks and related examples. Population dynamics: demographic growth versus mortality. Population cycles in different types of forest ecosystems. 3. Ecological factors affecting the populations of forest insects. Effects of climate and temperature, including climate change. Mechanisms of resistance developed by the host plants and adaptations of the insects. Role of natural enemies in population regulation. 4. Principles of integrated pest managements based on the knowledge of the insect ecology. Prevention, direct and indirect control, economic assessment of costs and benefits of IPM in forestry.

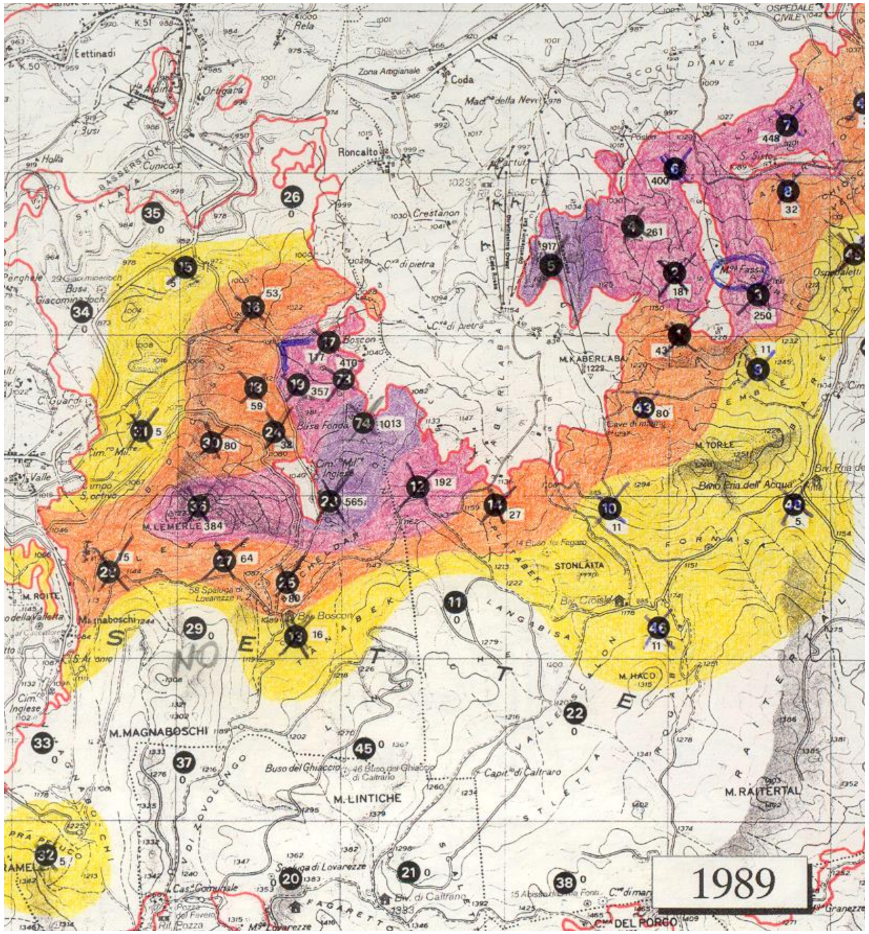
1. Monitoring and prediction

- population predictions (dynamics)

- international and national surveys (detection) (presentation of Davide Rassati

Monitoring and prediction

- mapping (Cephalcia outbreak)



Monitoring and prediction

- Sampling (Cephalcia prepupae in soil 25x25x25 cm)

0-20 m^2

20-100 m^2

100-500 m^2

> 500 m^2

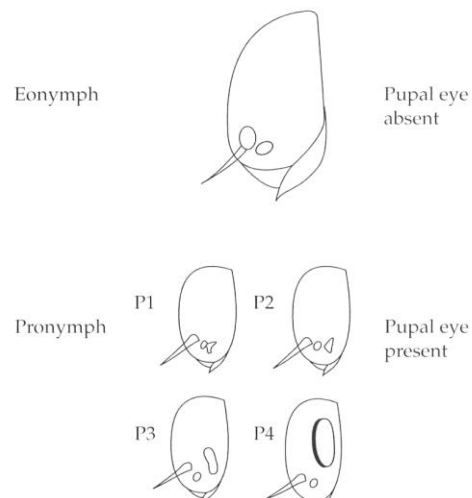


Figure 3.21 Diapausing stages of *Cephalcia arvensis*. Prolonged diapause can occur in the eonymph stage and in pronymph stages P1 and P2 distinguished by the degree of development of the pupal eye. An annual cycle is indicated when the eonymph stage is reduced or absent and the P4 stage is evident a few days after larvae enter the soil (from Battisti 1994; after Eichhorn and Pausch 1986).

Extended diapause

Annual life cycle

Monitoring and prediction

- Sampling (Cephalcia adults

  20x20 yellow trap)

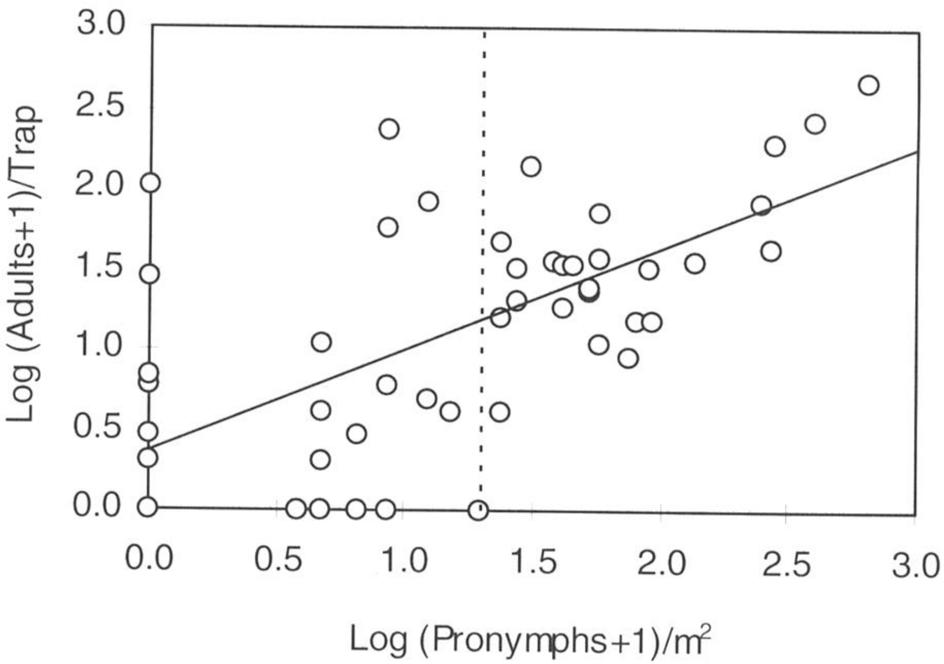


Figure 1. Linear regression including a spatial autoregressive error term between the total number of adults caught on the traps and the density of pronymphs in the soil sampled in spring. The dashed line represents the defoliation threshold (20 pronymphs/m^2, according to Martinek et al., 1987).

Monitoring the pine processionary moth

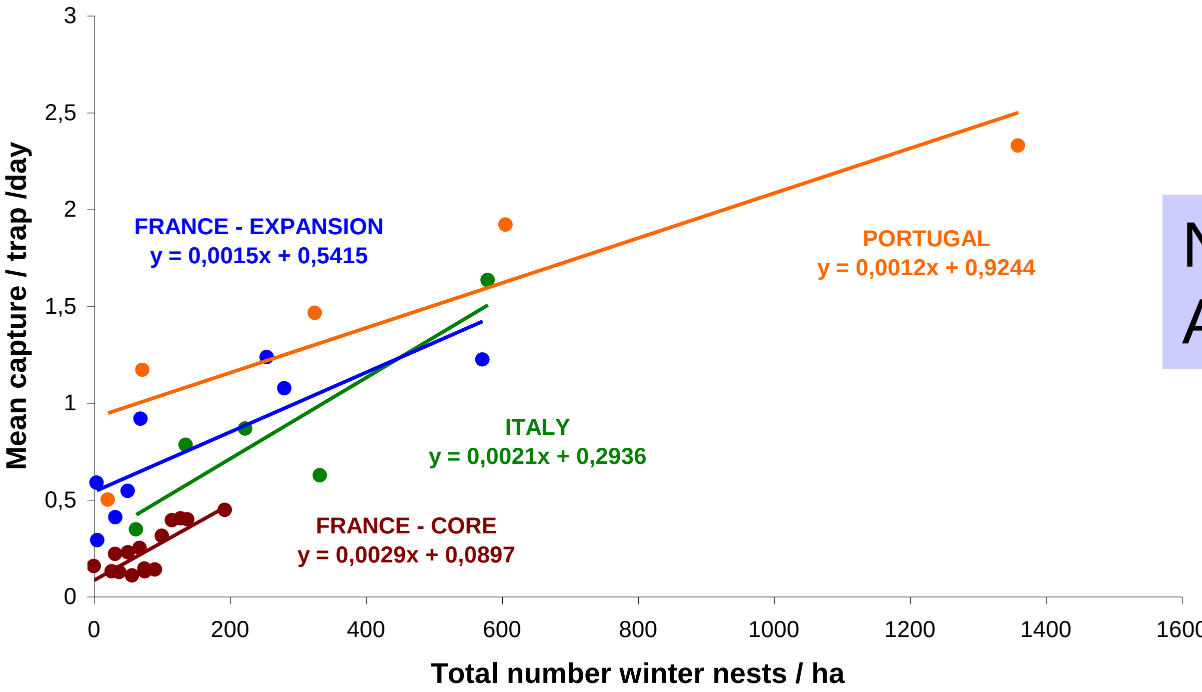
Traps for T. pityocampa

Box trap (Spain)

Funnel trap (Portugal)

Wing trap (Italy)

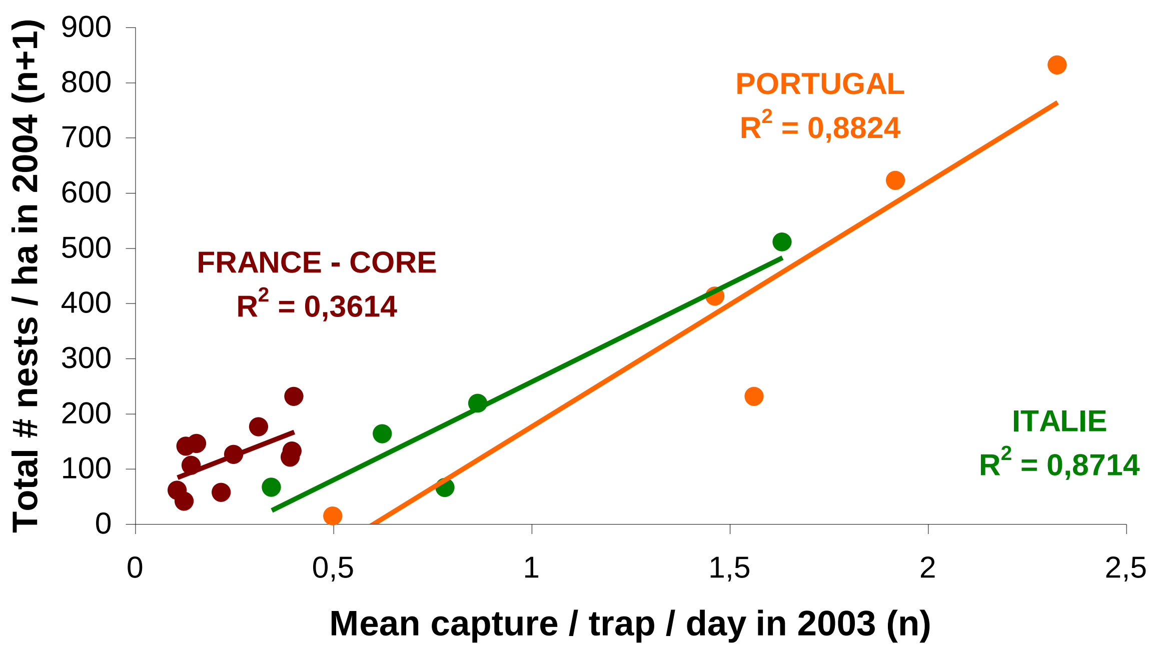
Plate trap (France)



Nests year n
Adults year n

Adults year n
Nest year n + 1

Prediction



Monitoring and prediction

- Degree-days models to predict phenology and period of attack

$$DD = (T_{max} + T_{min})/2 - T_{threshold}$$

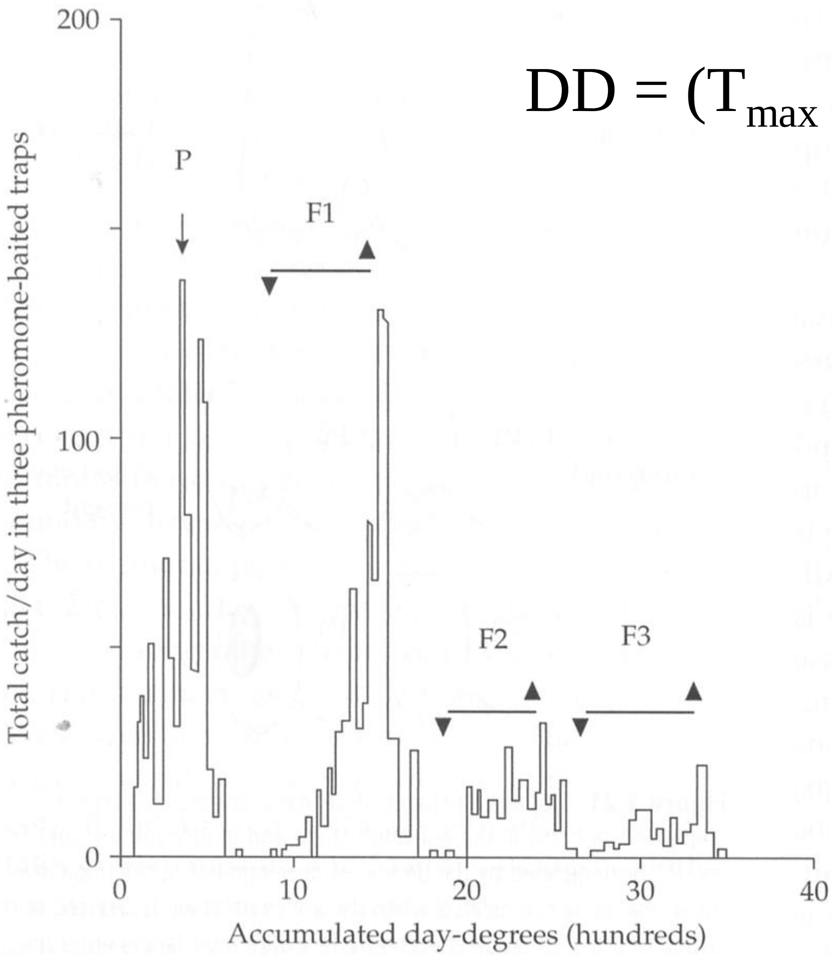
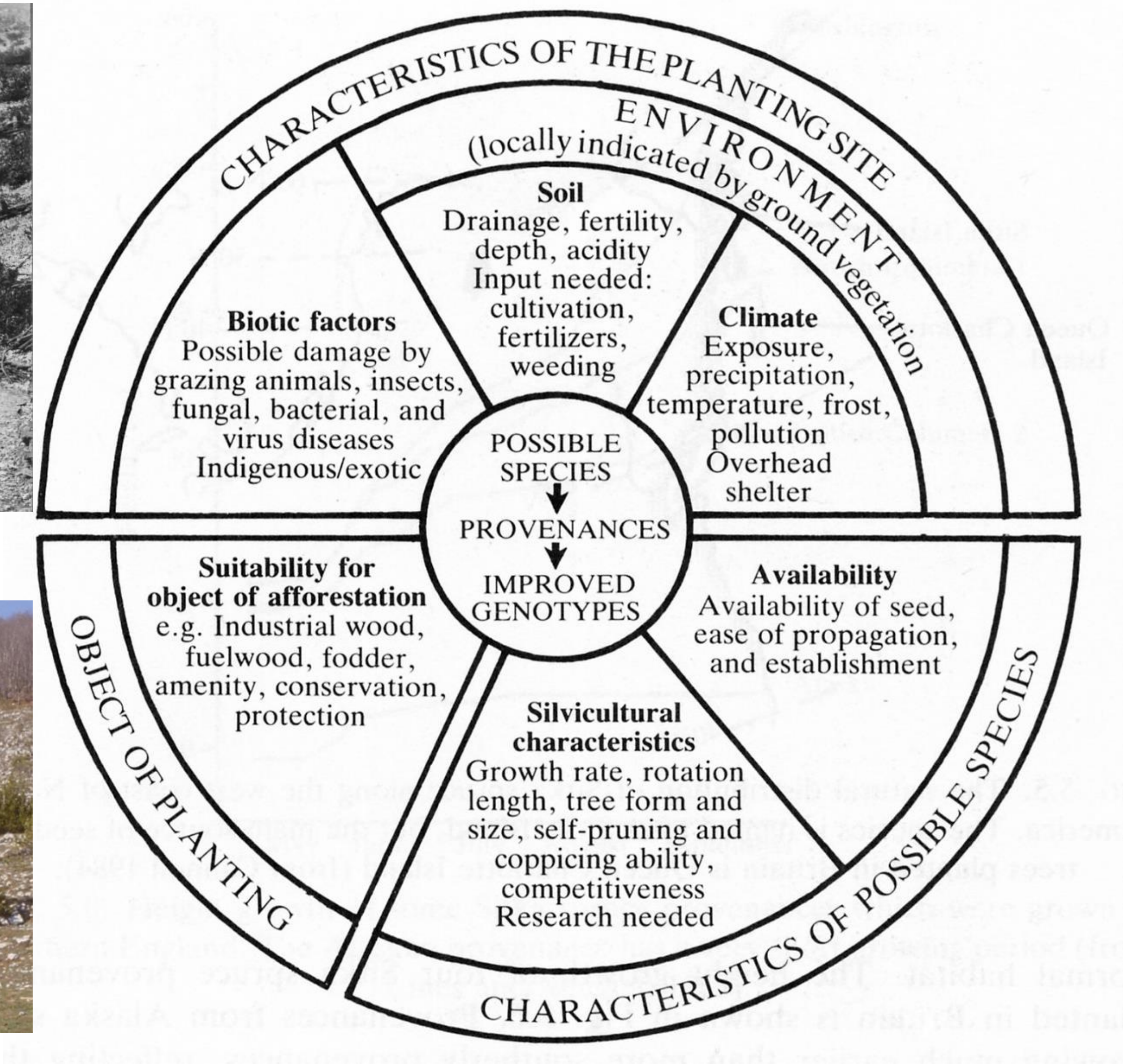


Figure 3.22 Timing insecticide treatments against *Rhyacionia frustrana* on young radiata pine in California, USA. Male moths were caught in pheromone-baited traps deployed part way through the extended flight period of the overwintering generation (P). This first flight has no distinct beginning in the mild climate. The first moths caught in the F1–F3 generations (▼) were used as the 'biofix' point for the start of day degree (DD) accumulation and peak moth counts (▲) as the end point. This corresponded to 575 DD (horizontal bar). Peak egg hatch occurred an additional 111 DD after peak flight and this was the optimum time for insecticide treatment. The timing of treatment following the first flight (P) was based on accumulation of 111 DD after the peak trap catch (↓) (from Malinoski and Paine 1988).

2. The role of silviculture

Species selection



The role of silviculture

Thinning

Pinus nigra

Ips sexdentatus

Tree vigour and resistance

The role of silviculture

Wind-felling

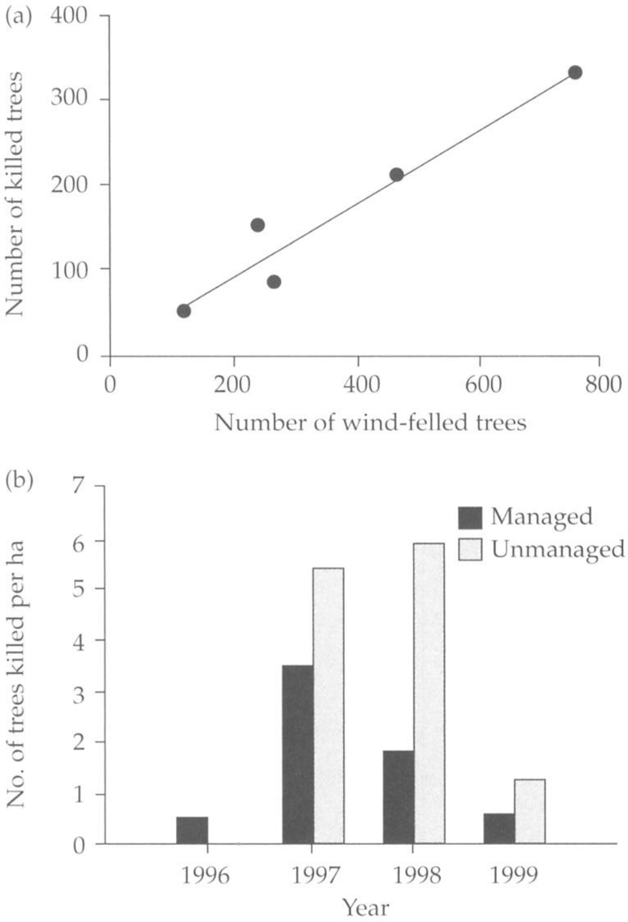


Figure 4.20 The effect of stand management after windblow on the number of Norway spruce trees killed by *Ips typographus* in southern Sweden. (a) In the area affected by the storm, there was a linear relationship between the number of windblown trees and the number of trees killed by *I. typographus.* (b) In managed stands, fallen trees were removed before the summer but left in place in the unmanaged ones with the result that twice as many trees were killed by beetles in these stands over a 4-year period (from Schroeder and Lindelöw 2002).

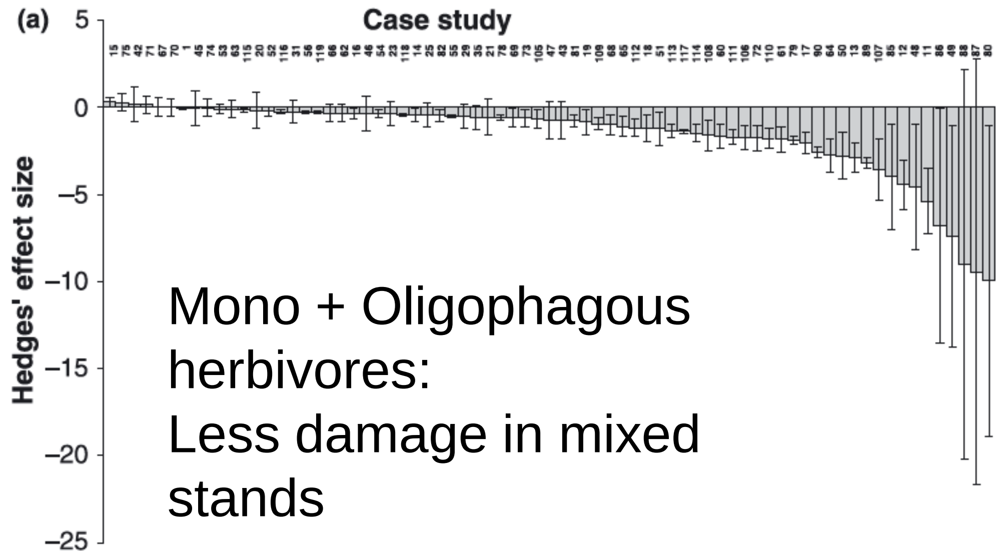
Natural and managed forests

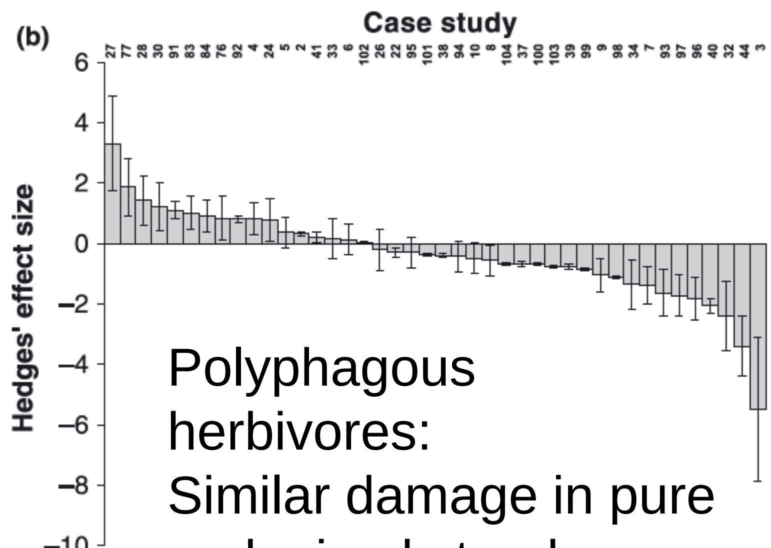
Pure stand

Mixed stand

Natural and managed forests: diversity = stability? The results of a meta-analysis of 119 studies on the impact of forest pests in pure and mixed stands (Jactel & Brockerhoff 2007)

Effect size: damage in mixed – damage in pure stands





Natural and managed forests

Hypothesis ➔ the stand diversity

in single-species forests, plant resources are more easily located by insect herbivores due to

- **absence of physical barriers**
- **absence of chemical barriers**
- **absence of temporal barriers**
- **absence of generalist parasitoids and predators**

BUT not always, because

- **some species of herbivores are favoured by mixed stands (es. polyphagous species and associational susceptibility)**

The problem of the scale: from stand to landscape

Natural and managed forests in the Alps

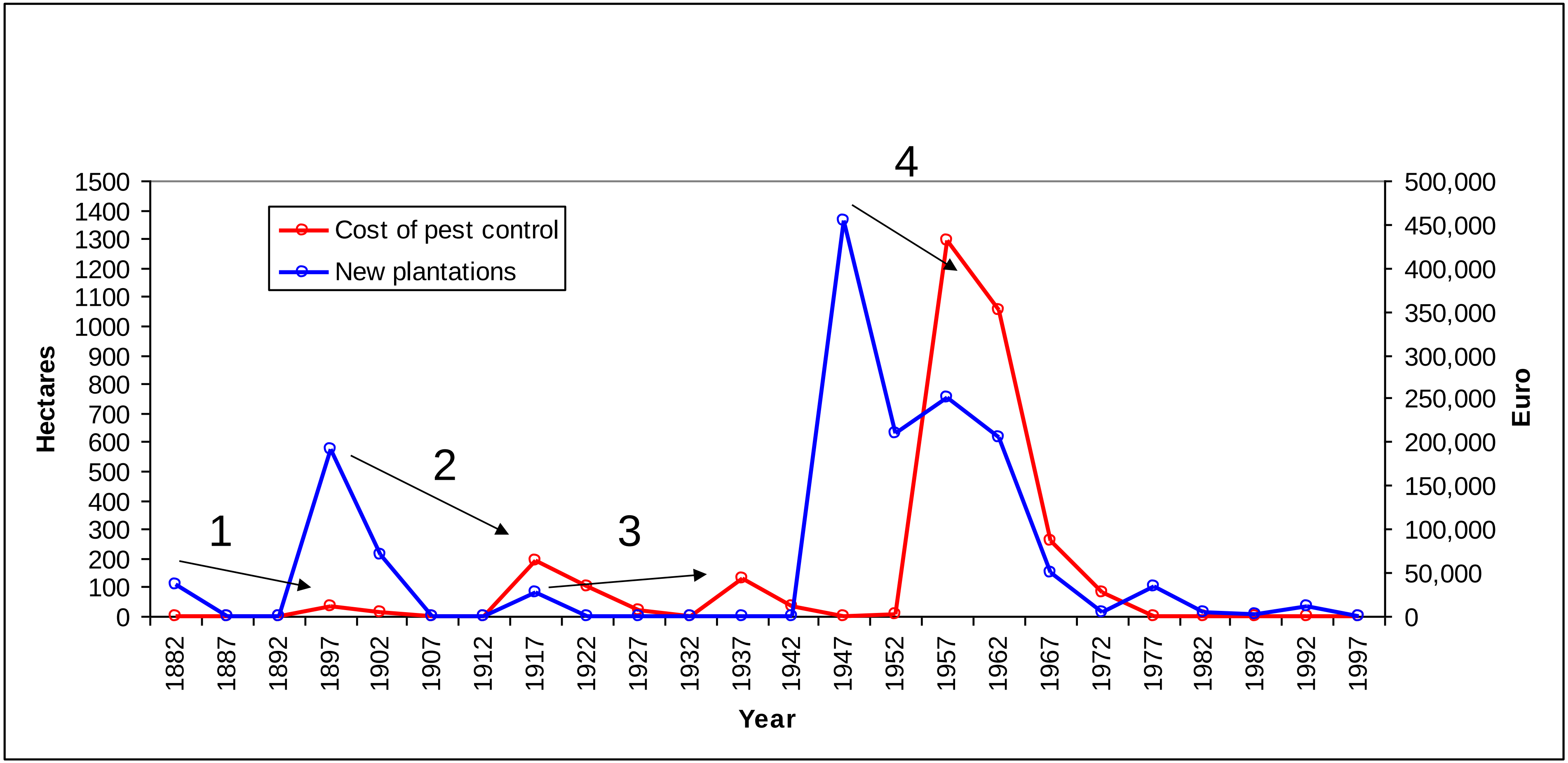
Pinus nigra

Thaumetopoea pityocampa, pine processionary moth

Plantations in Trieste Karst: history and pest control

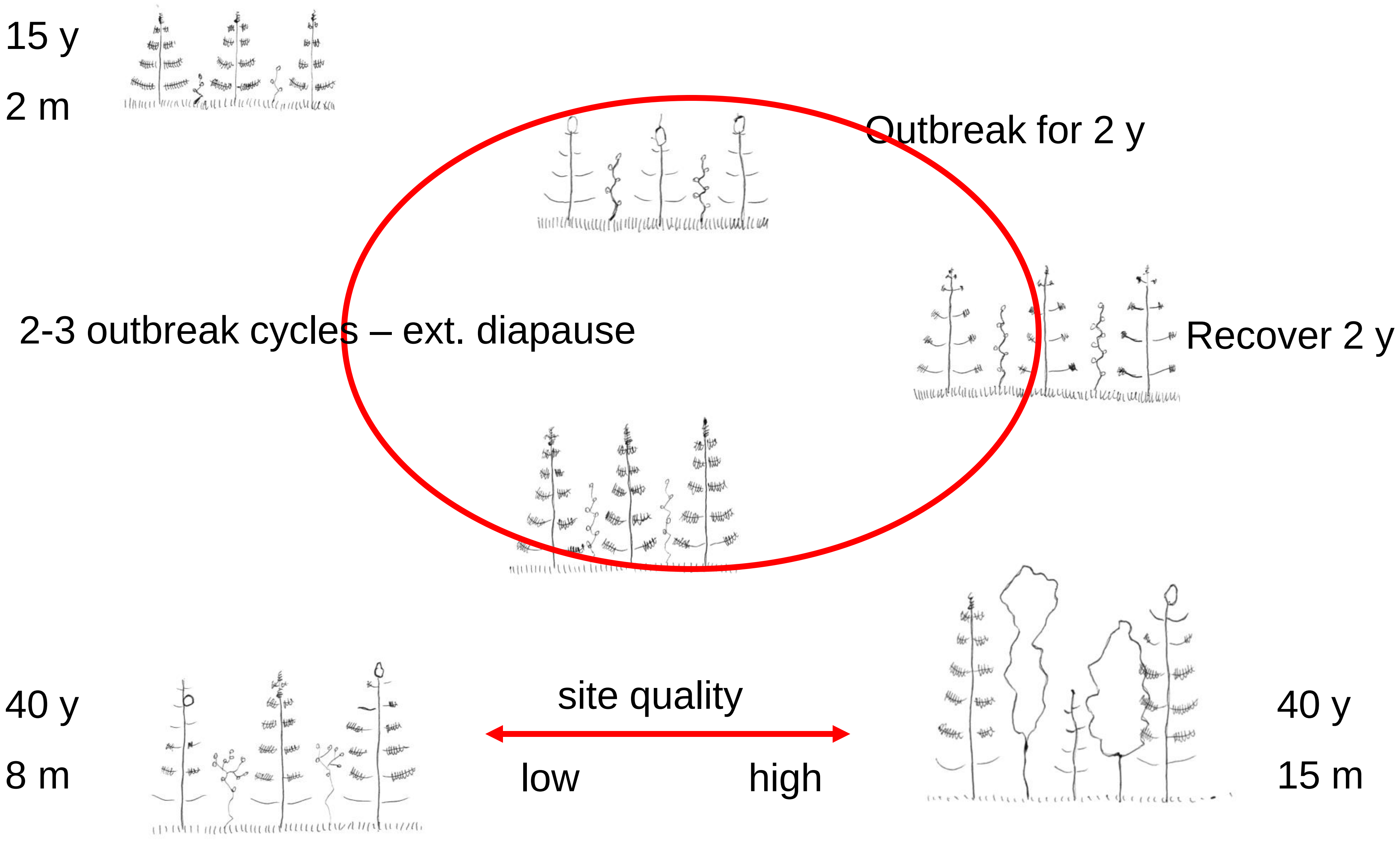
- 1360 hectares left
- 1400 hectares lost or trasformed
- Control through manual removal of nests

Pine processionary moth in Trieste Karst: plantation history and pest control



15 years gap between plantation and maximum cost of control (2006 value)

Dynamics of pine processionary moth and evolution of the plantations



Semiochemicals

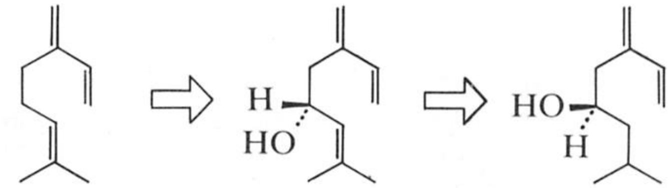
Chemical compounds that transfer information among insects.

Pheromones: intraspecific

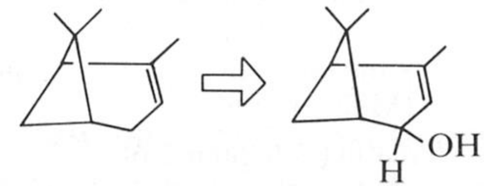
Kairomones: interspecific

(natural enemies)

Repellents: inter- intra-specific



myrcene (+) ipsdienol (−) ipsenol



(−) α – pinene *cis* – verbenol

Applications:

A. Monitoring

B. Mass trapping

C. Mating disruption

D. Deterrence - repellence

Mass trapping

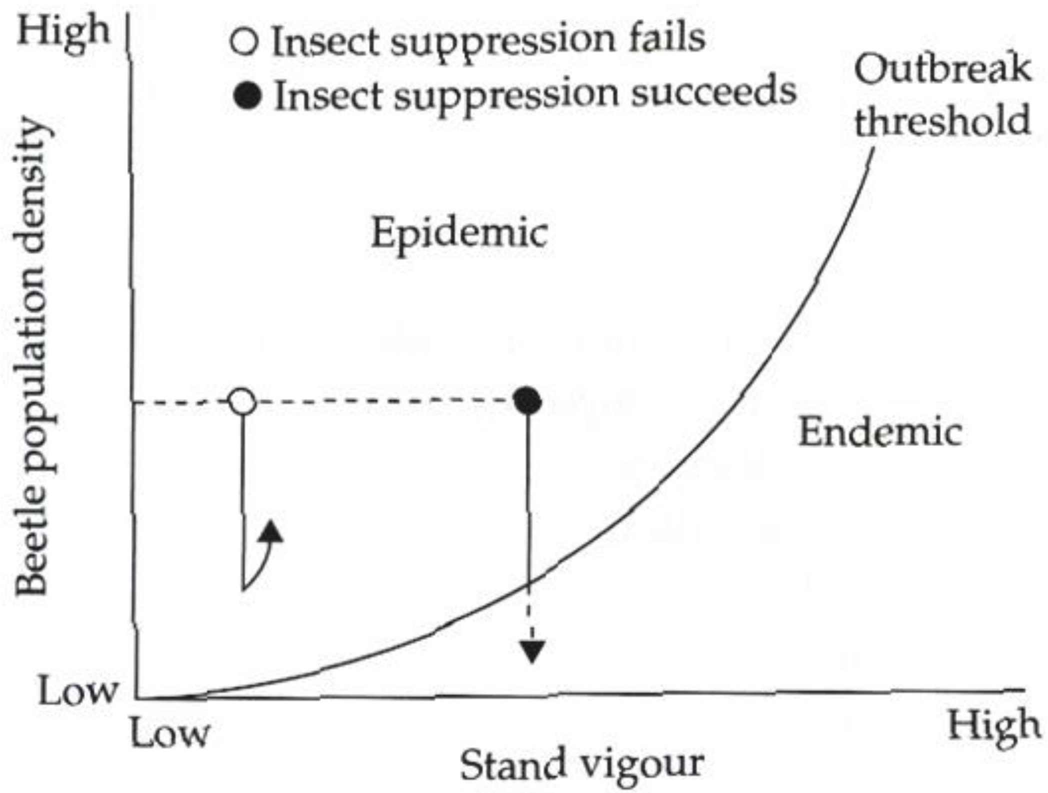


Figure 8.5 The theoretical outbreak threshold for bark beetles in relation to 'stand vigour'. In mass-trapping, or other direct control measures, the aim is to suppress self-sustaining outbreaks by reducing population density below the threshold. This is difficult to achieve when stand vigour is low or when large amounts of windblown material are available for breeding (after Berryman 1978, from Speight and Wainhouse 1989).

Funnel trap

Window trap

Mating disruption

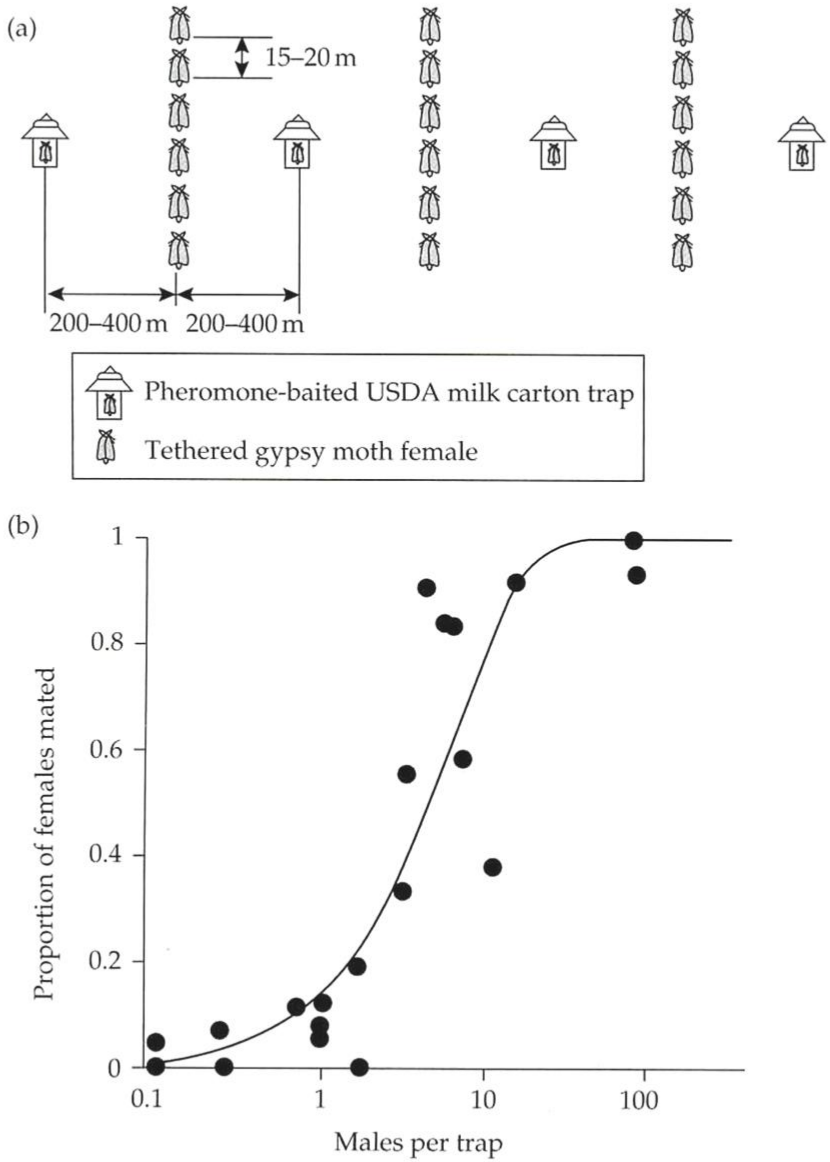
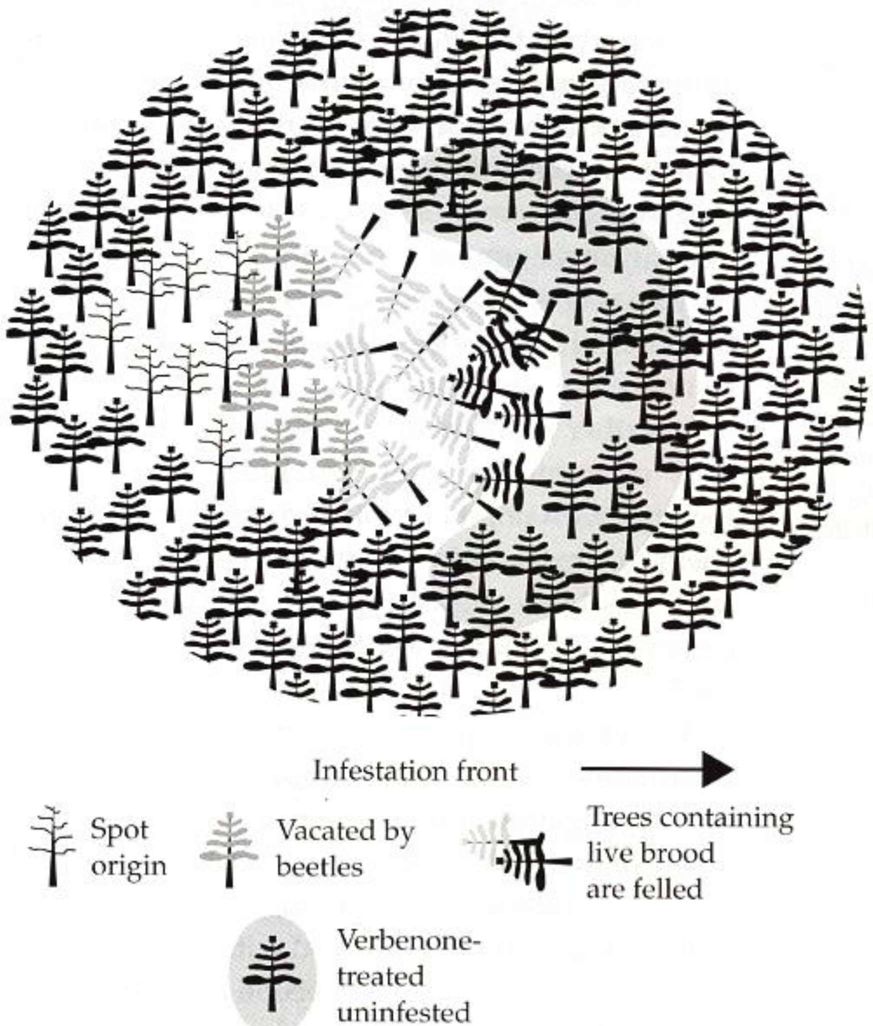


Figure 8.2 (a) Tethered female *Lymantria dispar* used in mating-disruption trials to determine the relationship between mating success and reduction in male captures in pheromone traps. Females were tethered using thread tied to the base of the forewing and attached to the bole of a tree. In experimental plots three rows of females were used, each separated from pheromone traps by at least 200 m. Females, which 'call' for up to 3 days, were dissected to determine mating success. (b) The proportion of female *L. dispar* mated in a low density population in relation to captures of males in pheromone-baited traps based on trials in 2 years together with a fitted model of mating probability. The relationship is influenced by such factors as trap type, pheromone source and population density (from Sharov *et al.* 1995).

Deterrence – repellence

Verbenone and non-host volatiles



Verbenone

+

felling treatment

Figure 8.15 Experimental treatment of spot infestations of *Dendroctonus frontalis* in south-eastern USA. In this example, verbenone treatment of uninfested trees was combined with felling currently infested trees at the front of the infestation (see Table 8.6) (from Clarke *et al.* 1999).

Integrated use: "Push & Pull"

Pheromones