

The Role of Ambrosia and Bark Beetles in Sudden Oak Death

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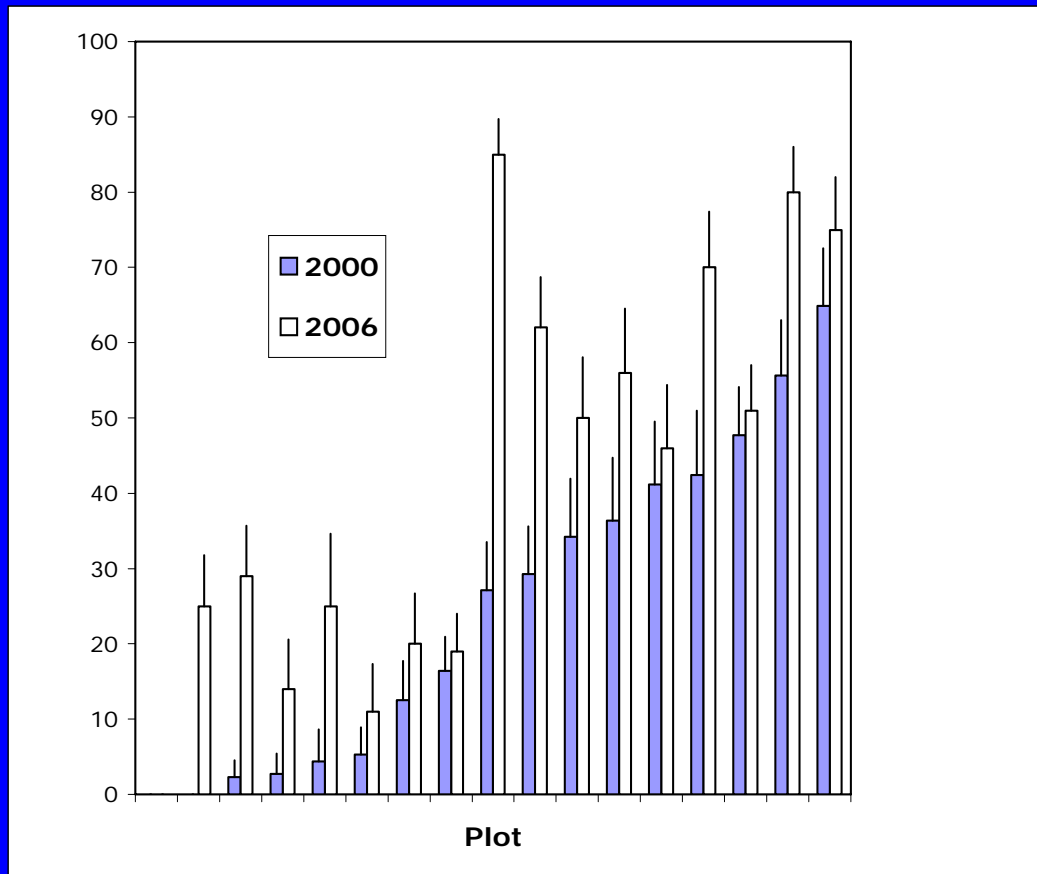
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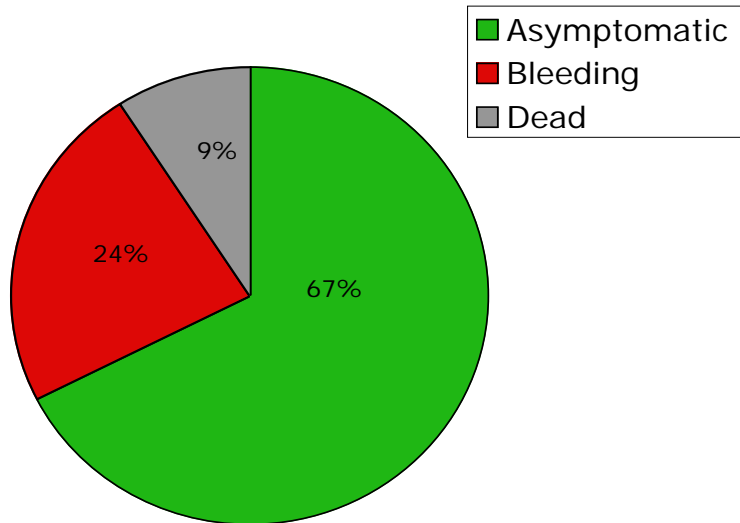
Beetle tunneling can kill a *P. ramorum*-infected coast live oak without evidence of decay fungi



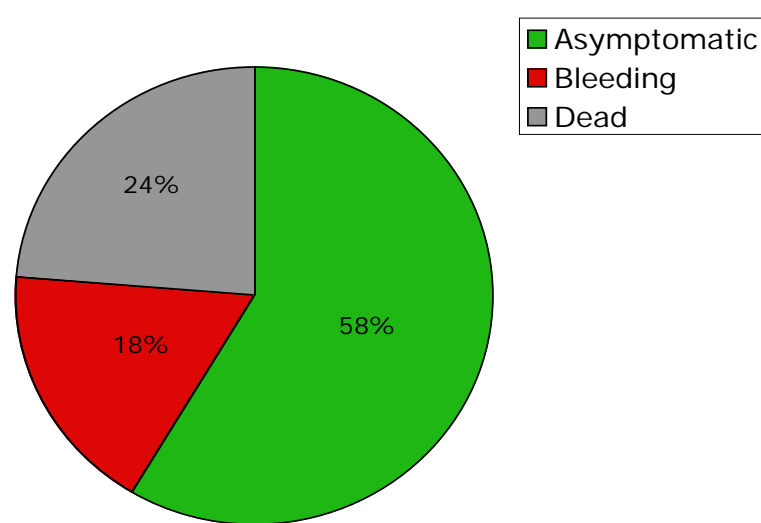
The total impact (infected + dead) of SOD on coast live oaks in Marin County increased in every plot from 2000 to 2006.



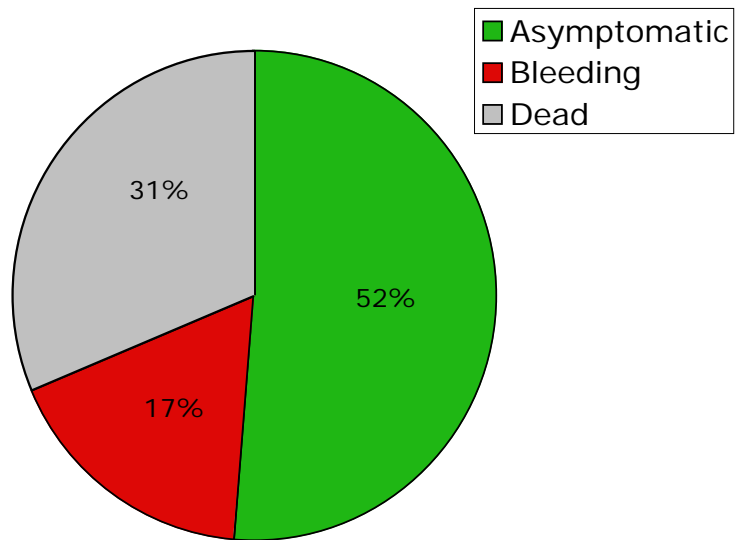
2000 Coast Live Oak



2003 Coast Live Oak

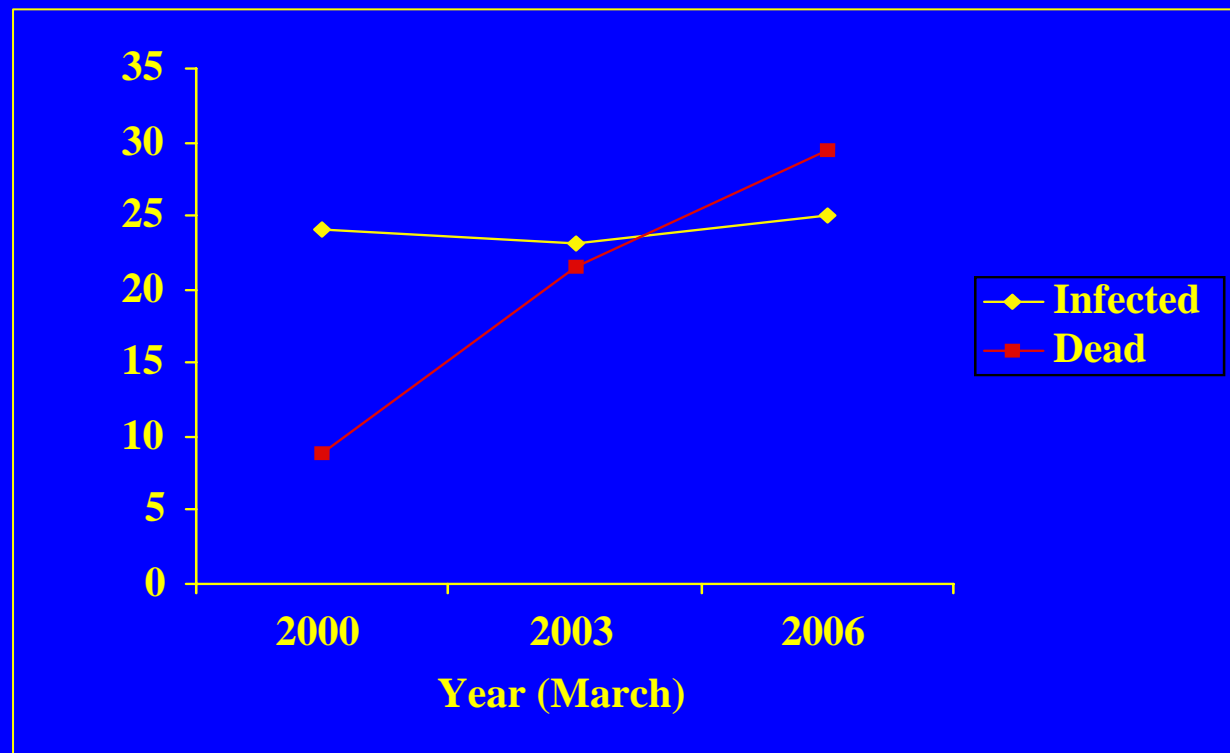


2006 Coast Live Oak

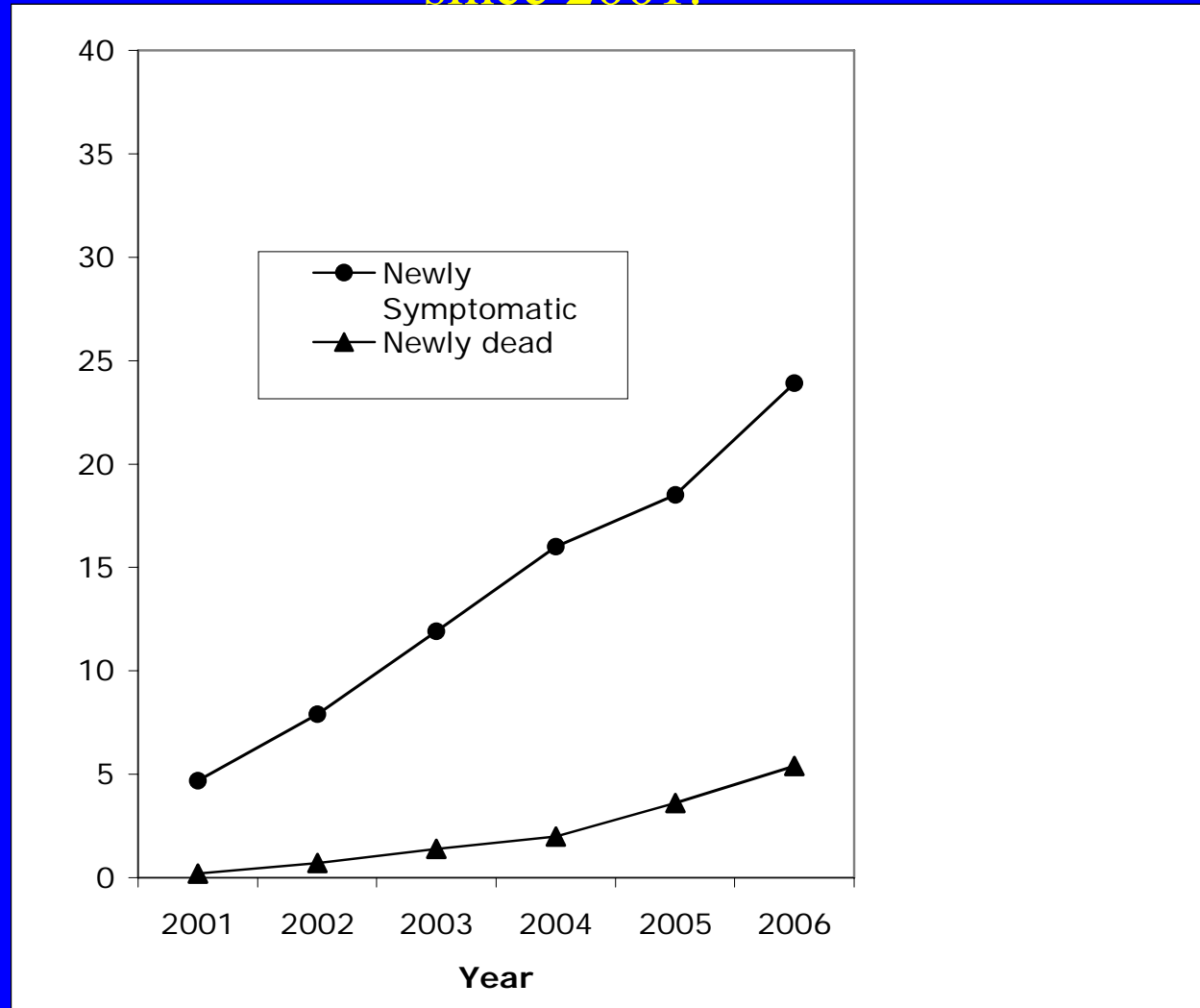


Coast live oak infection levels have remained relatively steady as mortality has increased in 20 Marin County disease progression plots, 2000 to 2006.

Infected trees are shown as percentages of living, and dead as percentages of total numbers of trees.

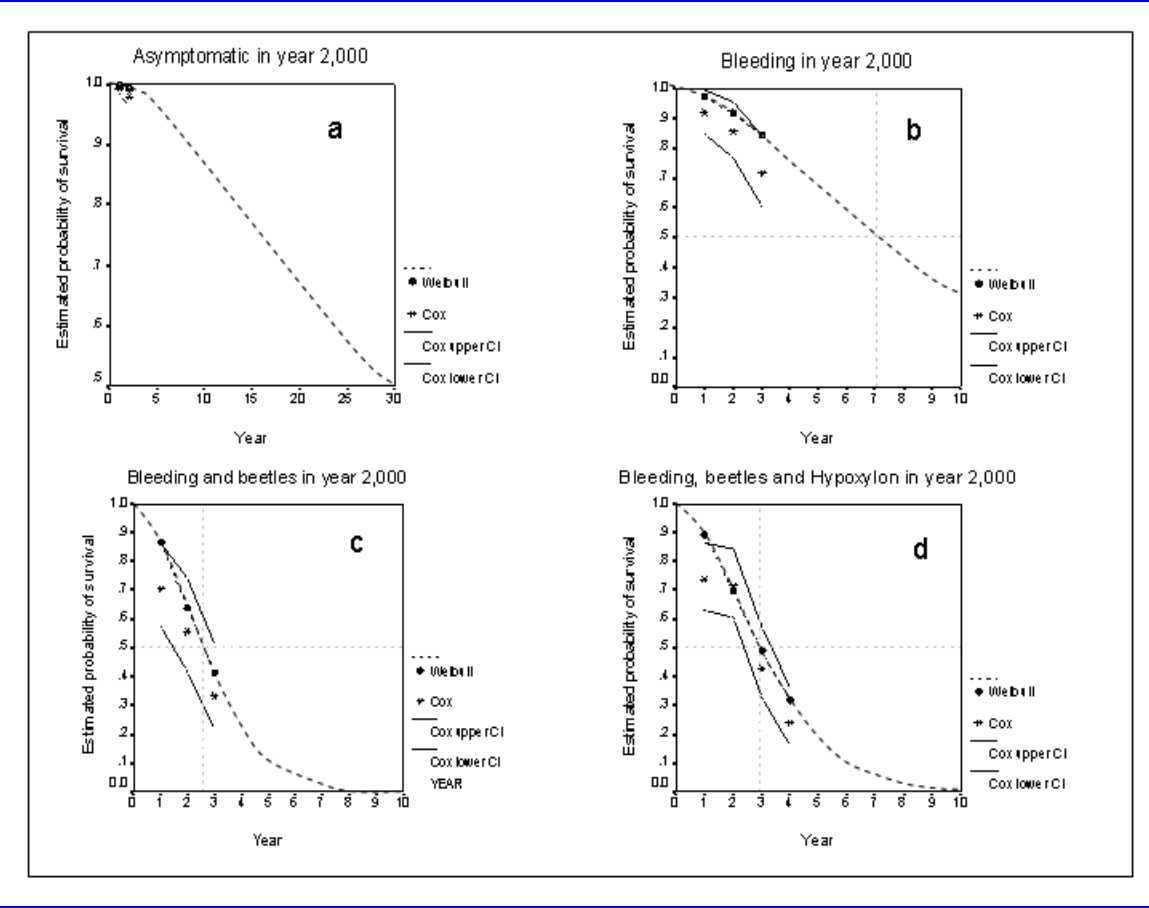


The cumulative incidence of new infections and mortality among coast live oaks in Marin County has increased steadily since 2001.



Weibull regression analysis found considerable differences in median survival of coast live oaks in 4 different cohorts : Asymptomatic (1), Bleeding only (2), Bleeding with Beetles (3), and Bleeding with Beetles and *Hypoxylon* (4).

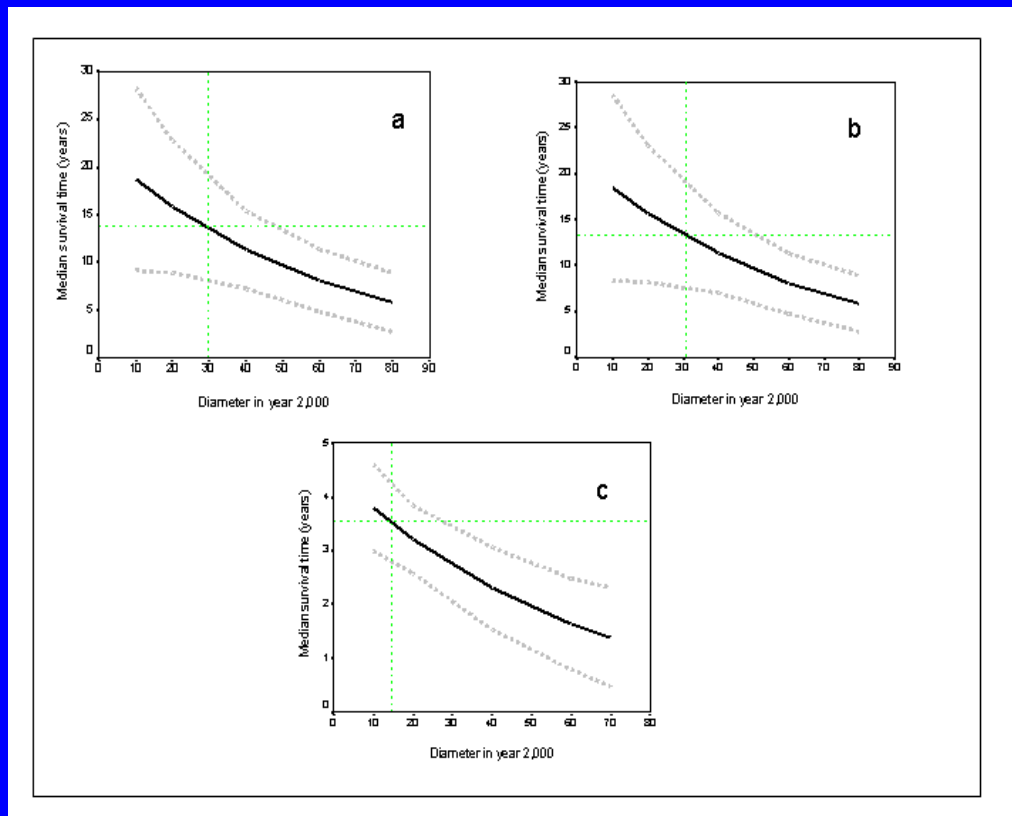
Category (disease status)	Survival (years ± SE)
1	29.5 (8.4)
2	7 (1.2)
3	2.6 (0.3)
4	2.9 (0.3)



Health analysis: For both coast live oaks and tanoaks, stem diameter (dbh) predicts duration in an asymptomatic condition: as dbh increases, probability of infection increases.

Dbh in 2000 (cm)	10	20	40	80 (oak) 70 (tanoak)
Coast live oak	18.7	15.9	11.4	5.8
Tanoak	3.8	3.2	2.3	1.4

Weibull health analysis:
Figs. a and b are coast live oak in China Camp and MMWD, respectively; c is tanoak. The green line defines the mean for each population.



Why are the roles of bark and ambrosia beetles of interest?

Early attacks are only found within the margins of cankers

>95% of dead, infected trees were attacked by beetles while alive

Beetle-attacked live trees have accelerated rates of structural failure

These beetles are not reported to attack trees that appear to be vigorous

Beetle attacks on infected trees appear to be significantly associated with decreased survival

Experimental design

Coast live oaks were inoculated with *P. ramorum* in July 2002

Insecticide (0.2% Permethrin) was applied in August 2002

and March & August 2003

Sticky traps were placed on the insecticide-treated inoculated and mock-inoculated (wounded) trees in March 2003

Insecticide			No Insecticide		
Inoculated	Wounded	Control	Inoculated	Wounded	Control
40	20	20	40	20	20

Inoculation study results

80% of inoculated trees developed bleeding within 1 year

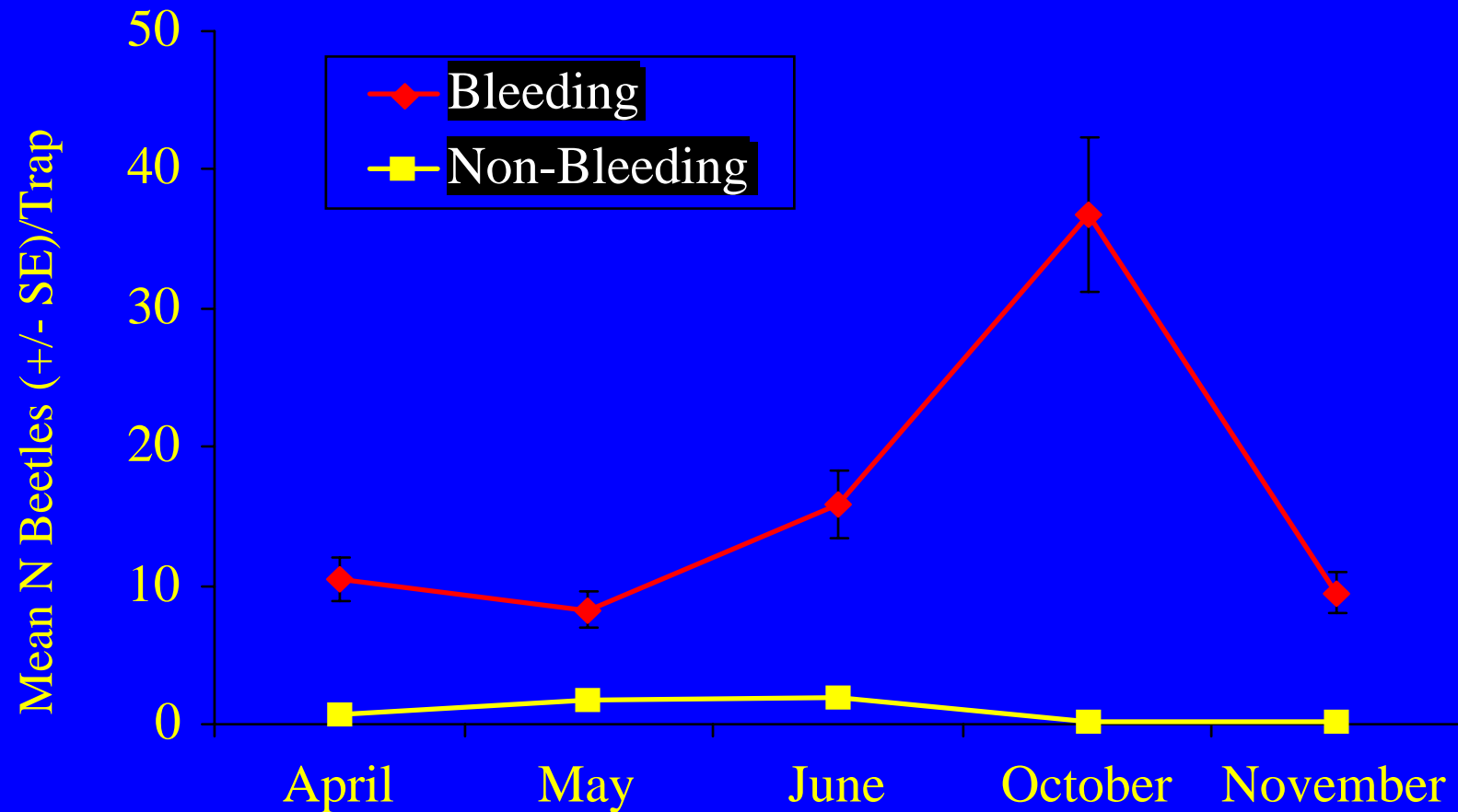
97% of all beetles were trapped on inoculated trees

Insecticide delayed beetle attacks for up to 2 months, but did not prevent them

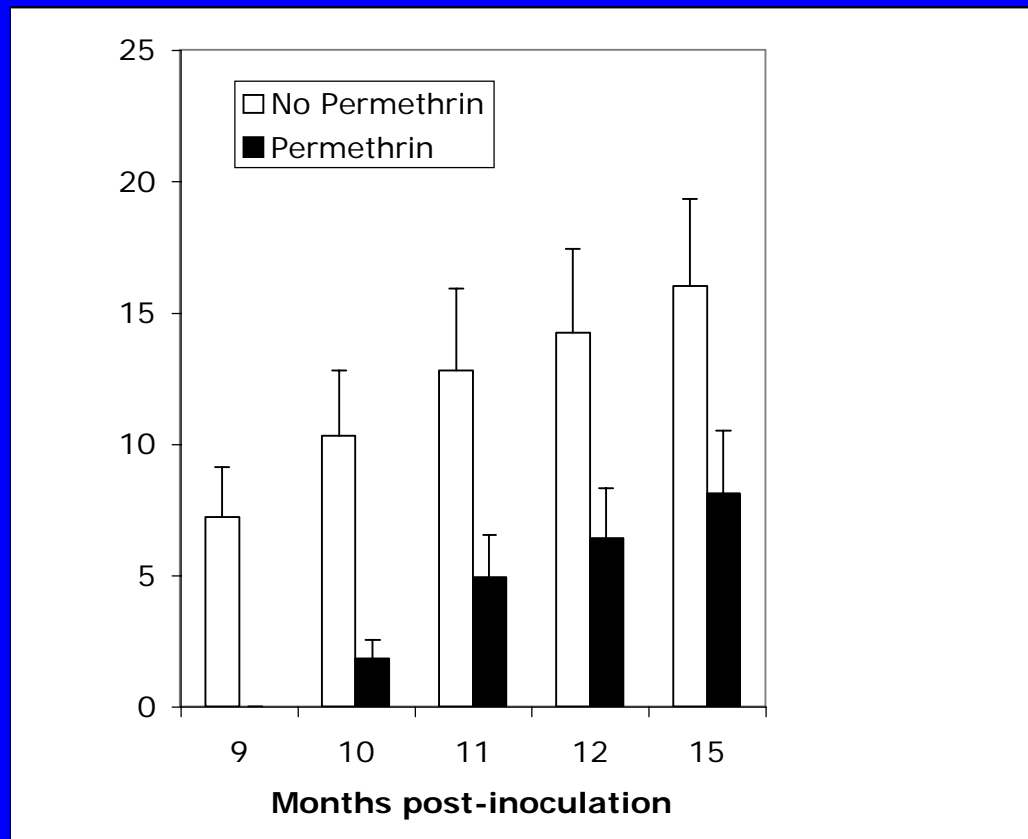
Bleeding cankers measured 9 months after inoculation ranged in size from 0.008 m² to 1.13 m²

7 saprotrophic beetle species were trapped: *Monarthrum scutellare*, *M. dentigerum*, *Xyleborus californicus*, *Xyleborinus saxeseni*, *Gnathotrichus pilosus*, *Pseudopityophthorus pubipennis* (bark beetle) (all Cucurlionidae, Scolitinae), *Scobicia declivis* (Bostrichidae)

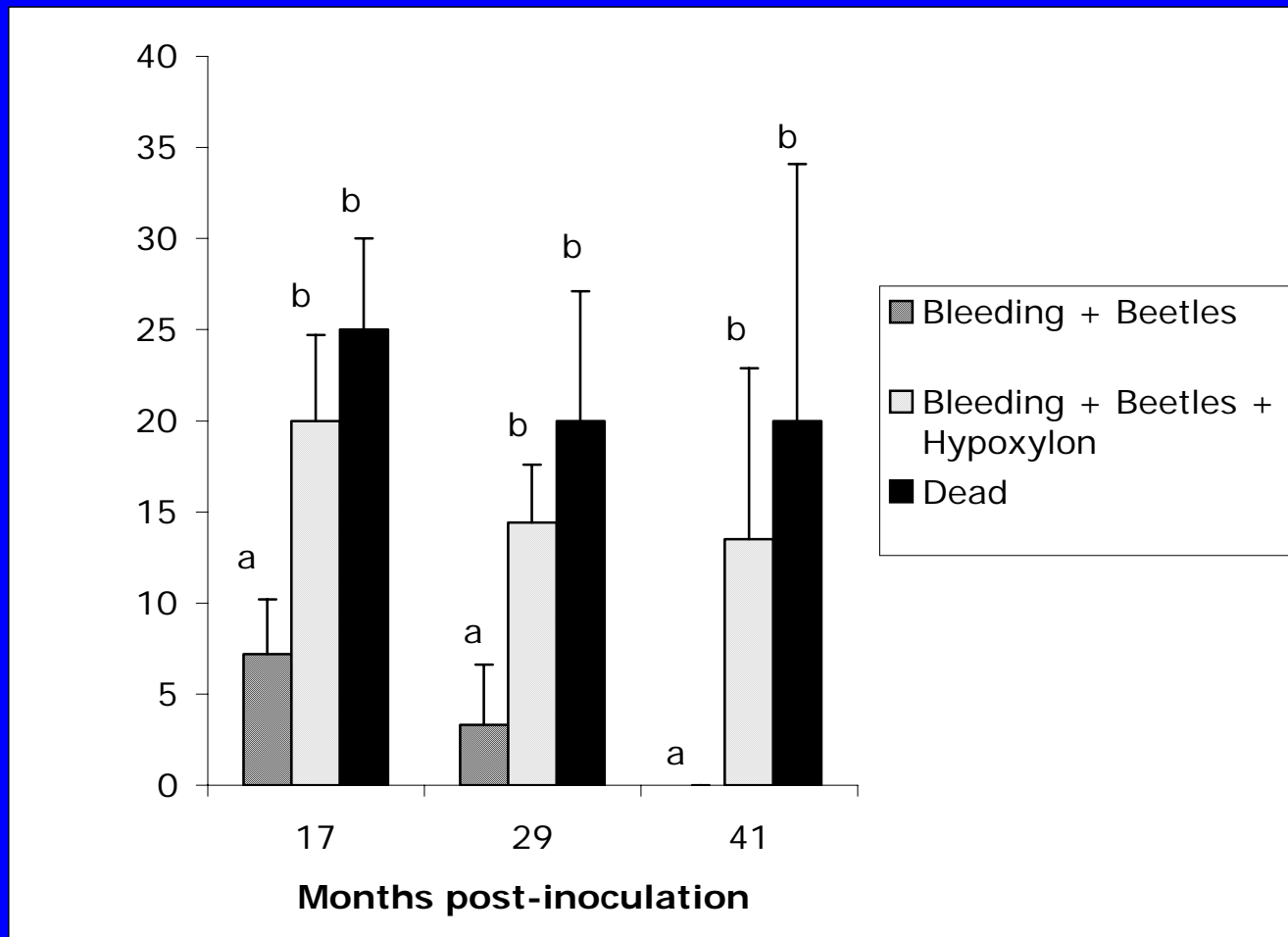
Total Number of Bark, Ambrosia & Powderpost Beetles Trapped at Bleeding & Non-Bleeding Trees



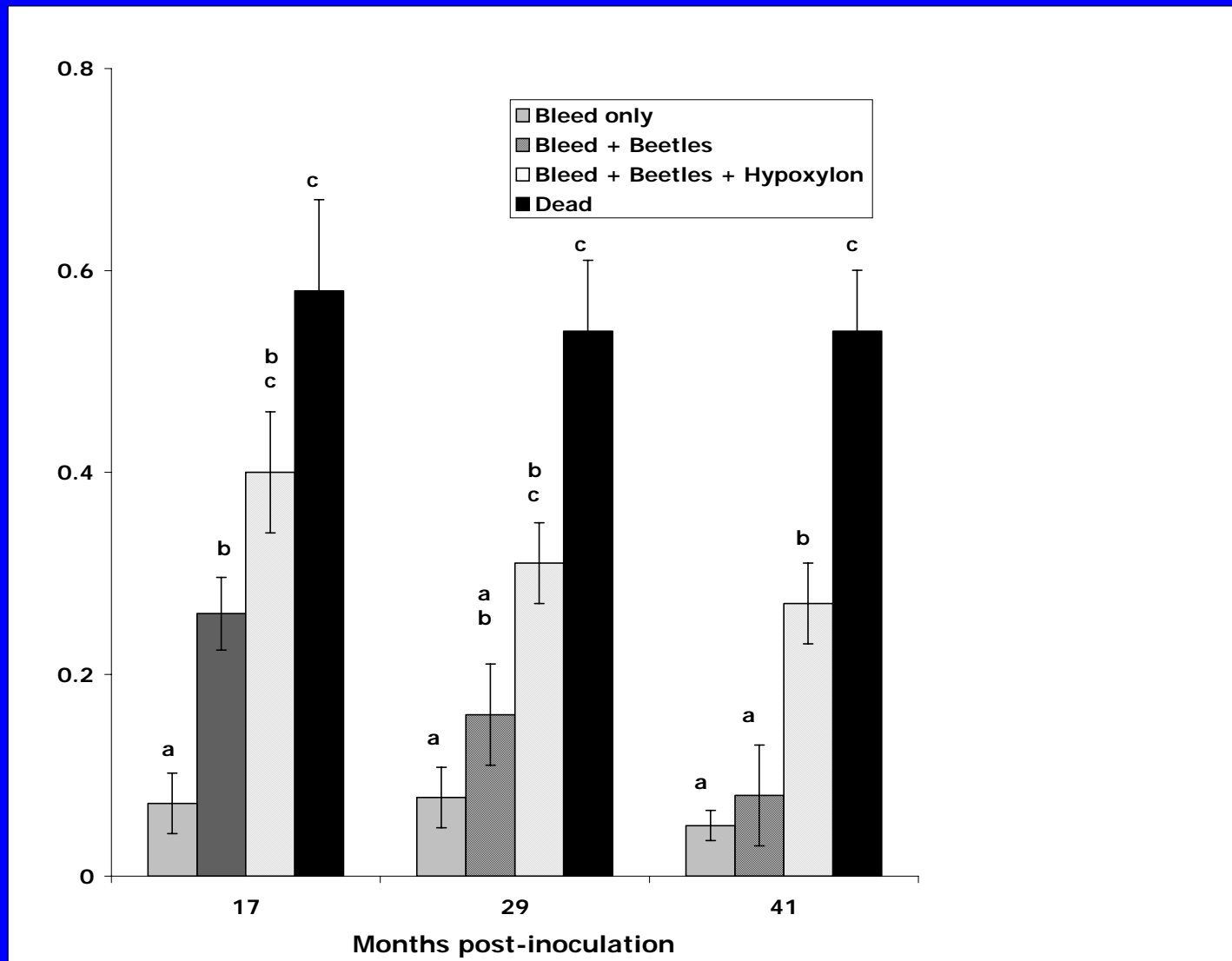
Beetle attacks on insecticide-treated trees were consistently lower than on untreated trees. This has not resulted in differential mortality (yet?).



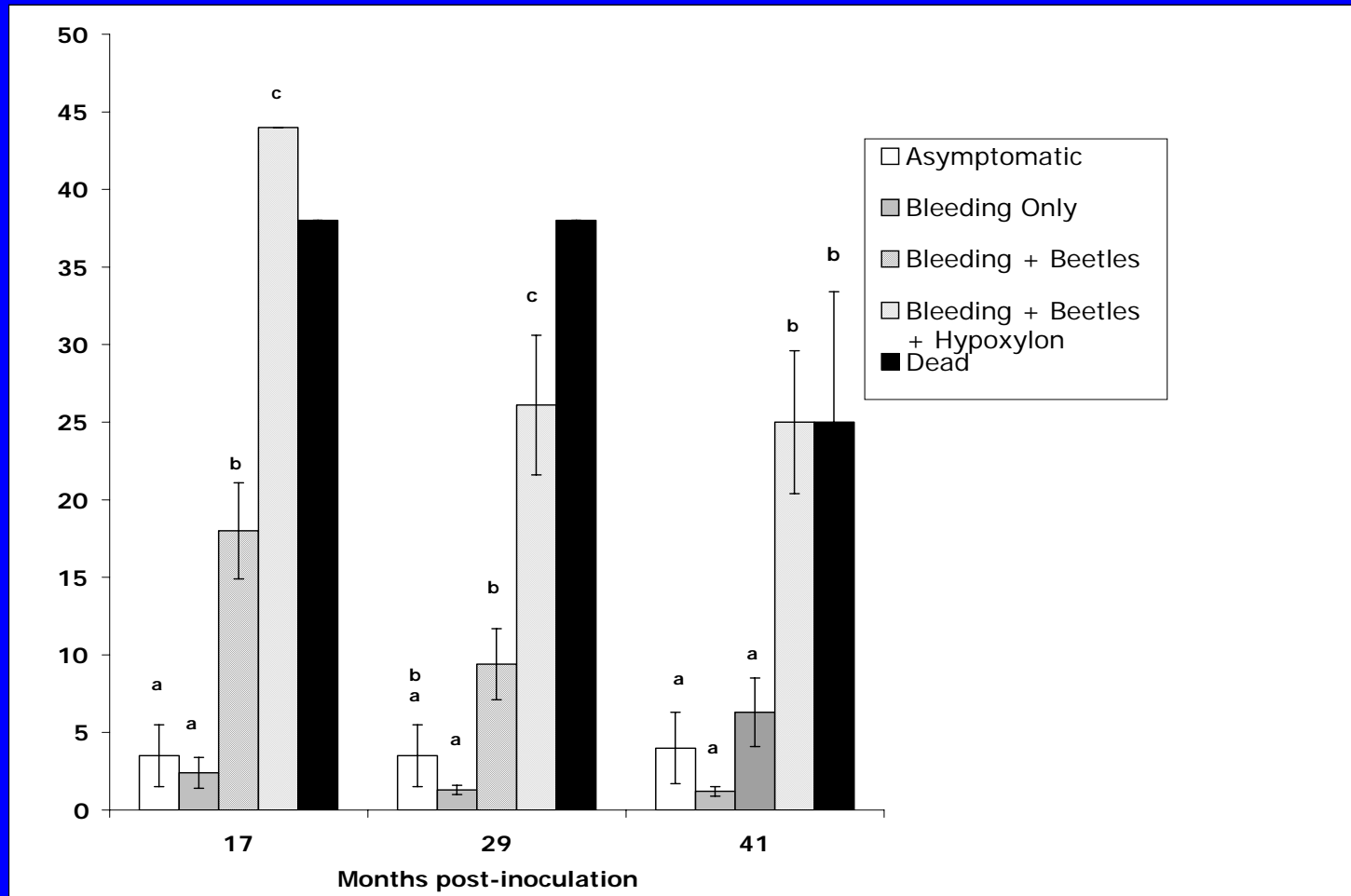
Numbers of beetle attacks on permethrin-free trees in April predicted long-term disease status



Canker size in April predicted long-term disease stage



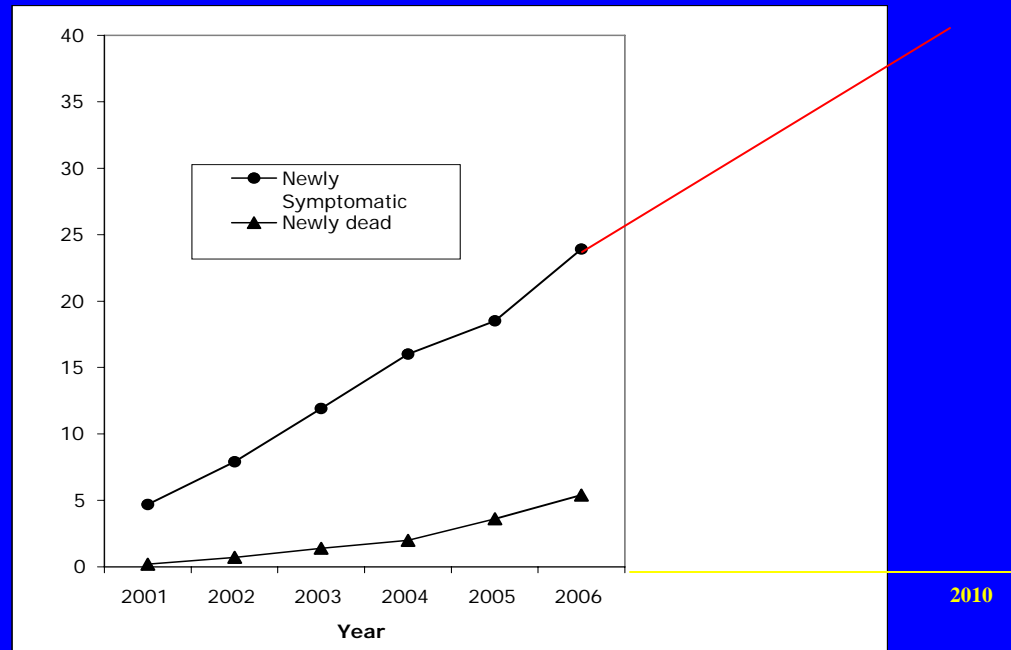
Beetle trap catch in April - before any of the permethrin-treated trees had been attacked - predicted long-term disease stage



Some conclusions and speculations

This pathogen continues to infect new trees and spread within heterogeneous environments

Simple extrapolation from the past 5 years points to significant mortality in the near future, assuming that nothing changes significantly



Some conclusions and speculations

The term resistance may be difficult to define in terms of tree response to this pathogen. An infected coast live oak may be able to limit the extent of canker expansion, but beetle attacks, followed by fungal growth, may shift the balance.

Characteristically saprotrophic beetles are playing new roles in these environments by selectively attacking cankers on infected, but apparently vigorous trees.

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