

***Phoresy Rates and Spore Loads of An
Exotic Pathogen, Fusarium circinatum, on
Native Bark Beetles Induce Resistance to
F. circinatum in Natural Monterey Pine Forest***

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Conifer Defenses Against Insects and Pathogens

- *Systemic Induced Resistance (SIR)*: Infection by a pathogen resulting in greater resistance to subsequent challenge by the same pathogen
- Tree Mortality = f (host resistance threshold X colonization density)
 - Trees are able to resist colonization below a “*critical threshold*”
 - “*Critical threshold*” is a quantitative measure of tree resistance to a known dose of the pathogen
 - Beyond this threshold, trees’ resistance is rapidly reduced

Critical Variables for Beetle Colonization Resulting in Tree Mortality

- Tree susceptibility or resistance depends on
 - Number of beetles with spores
 - Number of spores on beetles
 - Number of beetles through time and space
 - Density of attacks by beetles
 - Total inoculum vectored into host

Exotic pitch canker affects many native conifer species in California

- *Pitch canker is:*
 - A tree disease caused by an exotic fungus (***Fusarium circinatum***)
 - First identified in California in 1986
 - It was most likely introduced from FL
- Most widely impacted tree species is Monterey pine
- Many other pine species (12), and Douglas-fir, are also infected in nature

Single branch tip infection-Multiple branch tip infection-Canopy dieback-Topkill-Canker development-Tree mortality



*The fungus produces a honey-colored discoloration (**lesion**) on the phloem and an outer sapwood*



Many beetle species are associated with *F. circinatum*

- Engraver Beetles (*Ips* spp.): *I. mexicanus* and *I. plastographus*- main stem and large branches
- Twig Beetles (*Pityophthorus* spp.): *P. setosus* and *P. carmeli*- main stem, branches and cones
- Vector and/or create wounds

Monterey pine resistance: Evidence from field observations and experiments

- 1-2 % of native tree populations show natural resistance (***no infection***) to *F. circinatum**
- This variation can be quantified by measuring lesion length following mechanical inoculations

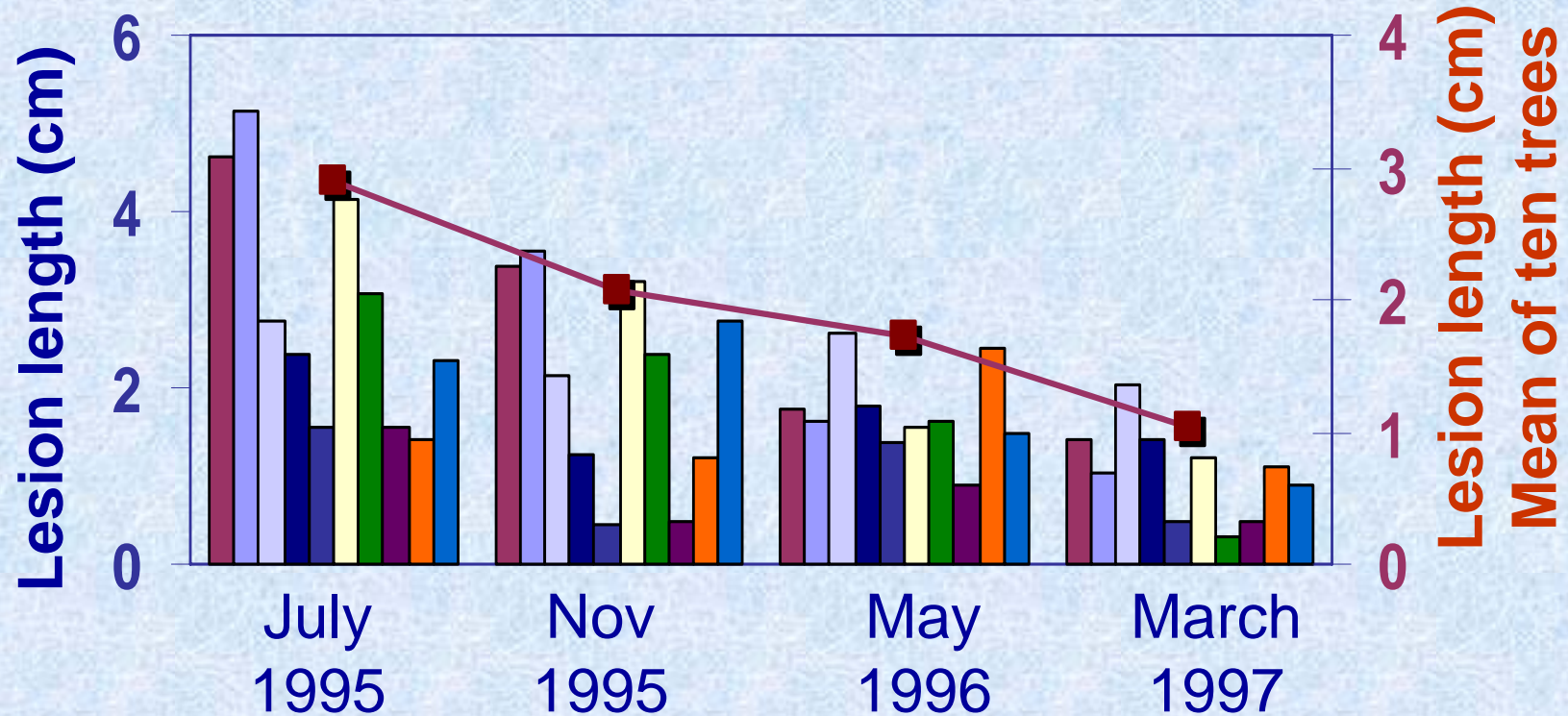
**Storer et al. (2002): For Sci. 48:694-700*

Mechanical inoculations induce lesion*



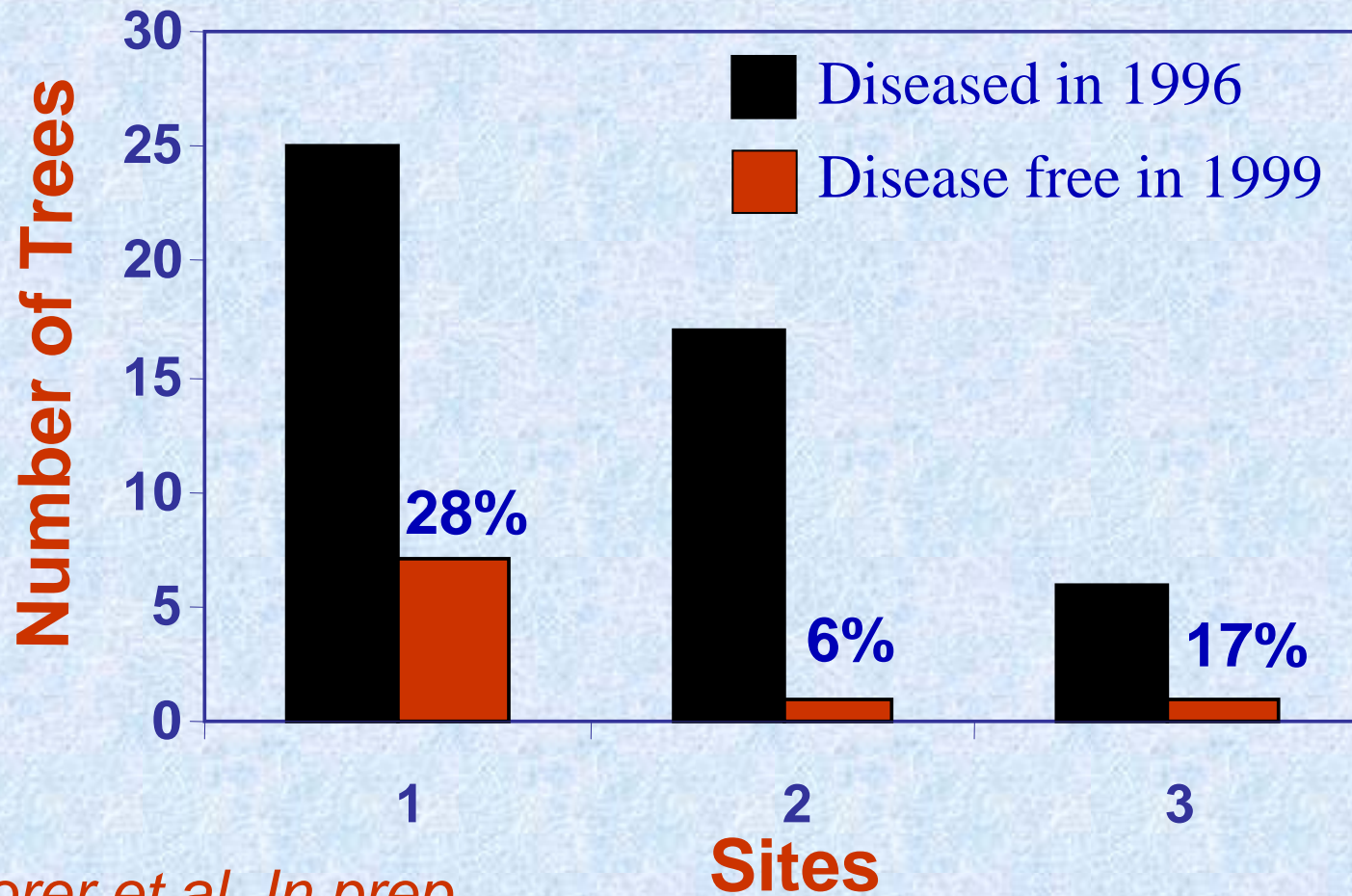
****Gordon et al. (1998): Plant Pathol. 47:706-711***

Repeated inoculations reduce susceptibility of trees to *F. circinatum**



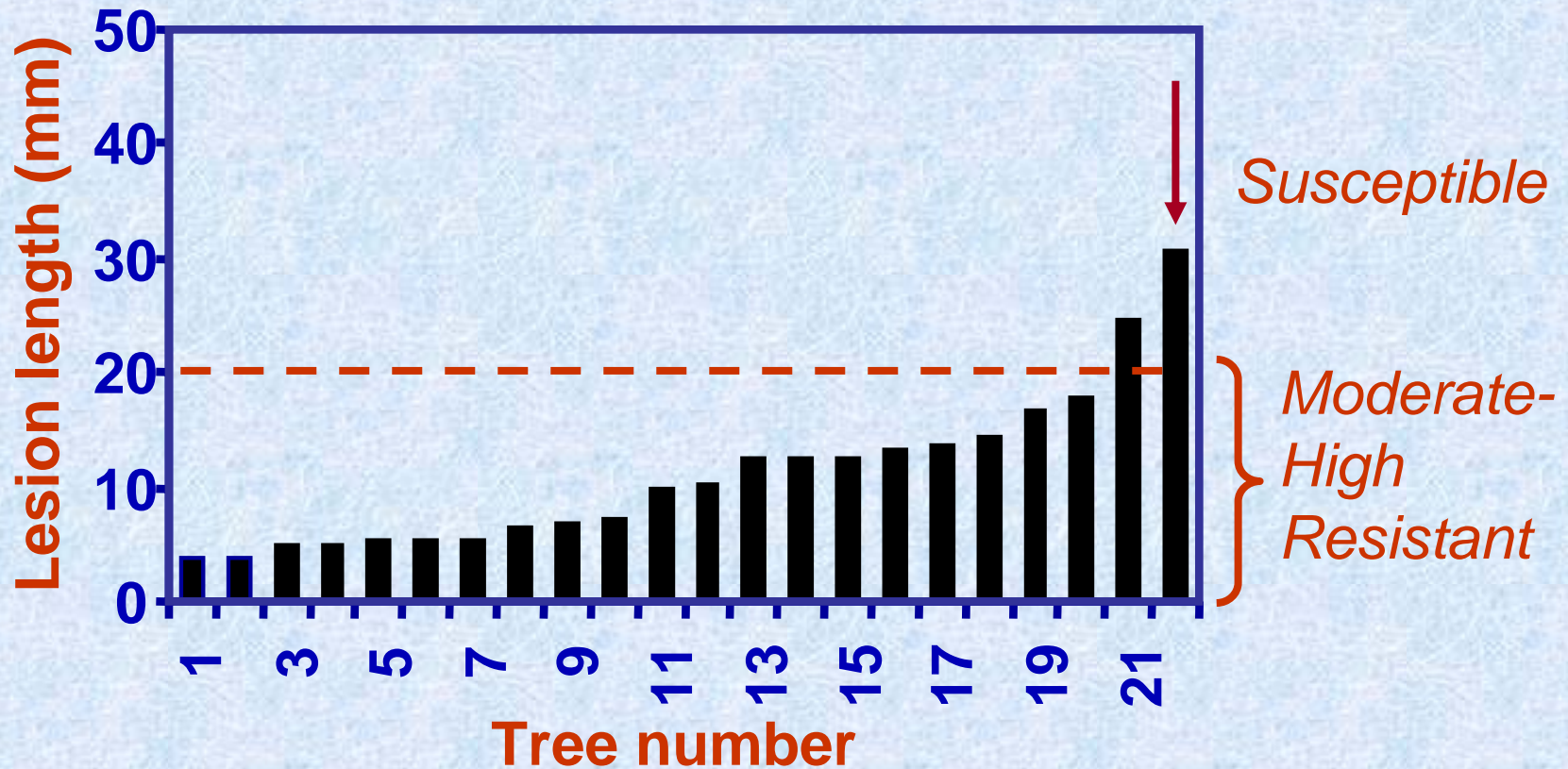
**Bonello et al. (2001): For. Path. 31: 99-106*

Remission (=recovery from infection) of trees from pitch canker infection is frequently observed in planted trees



**Storer et al. In prep.*

Most trees in remission are less susceptible to subsequent pitch canker infection



**Gordon et al. In prep.*

Hypothesis

Natural occurrence of induced resistance (*SIR*) in Monterey pines may be influenced by the amount of inoculum introduced into trees by feeding and/or tunneling activities of various bark beetle species

Objectives

- To determine the relative importance of each of the known subcortical insects associated with *F. circinatum*
- To determine how phoresy rate (*proportion of insects with propagules in a population*) and spore load (*number of spores carried by an individual*) on bark beetles relate to risk of disease transmission and tree resistance

Methodology

- Beetles trapped and reared from *F. circinatum*-infected hosts were used.
- They were examined for the presence of *F. circinatum*.
- *Percent phoresy rate* and *mean numbers of spores* carried by individual beetles were calculated.

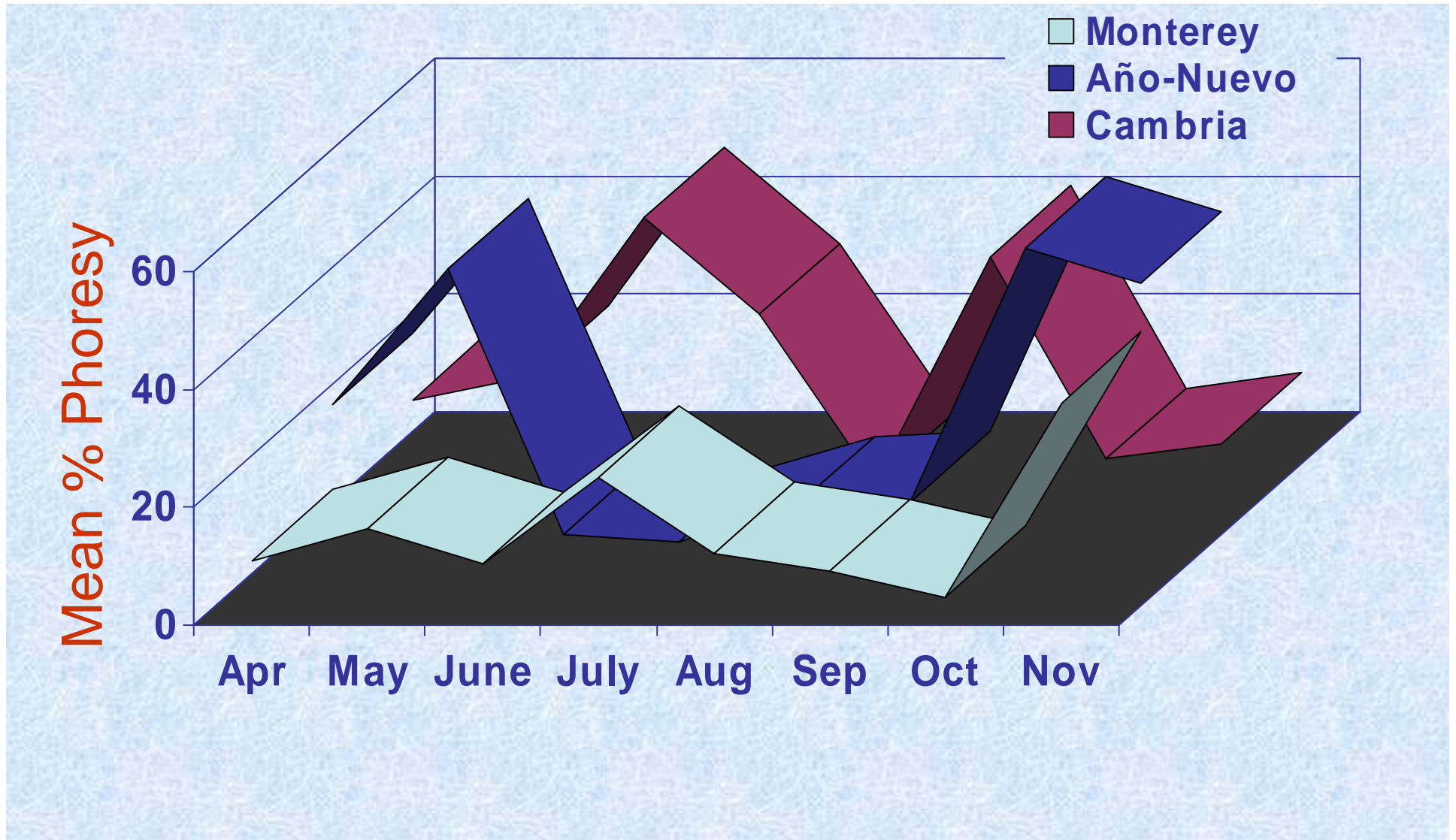


Each colony represents one spore of *F. circinatum*

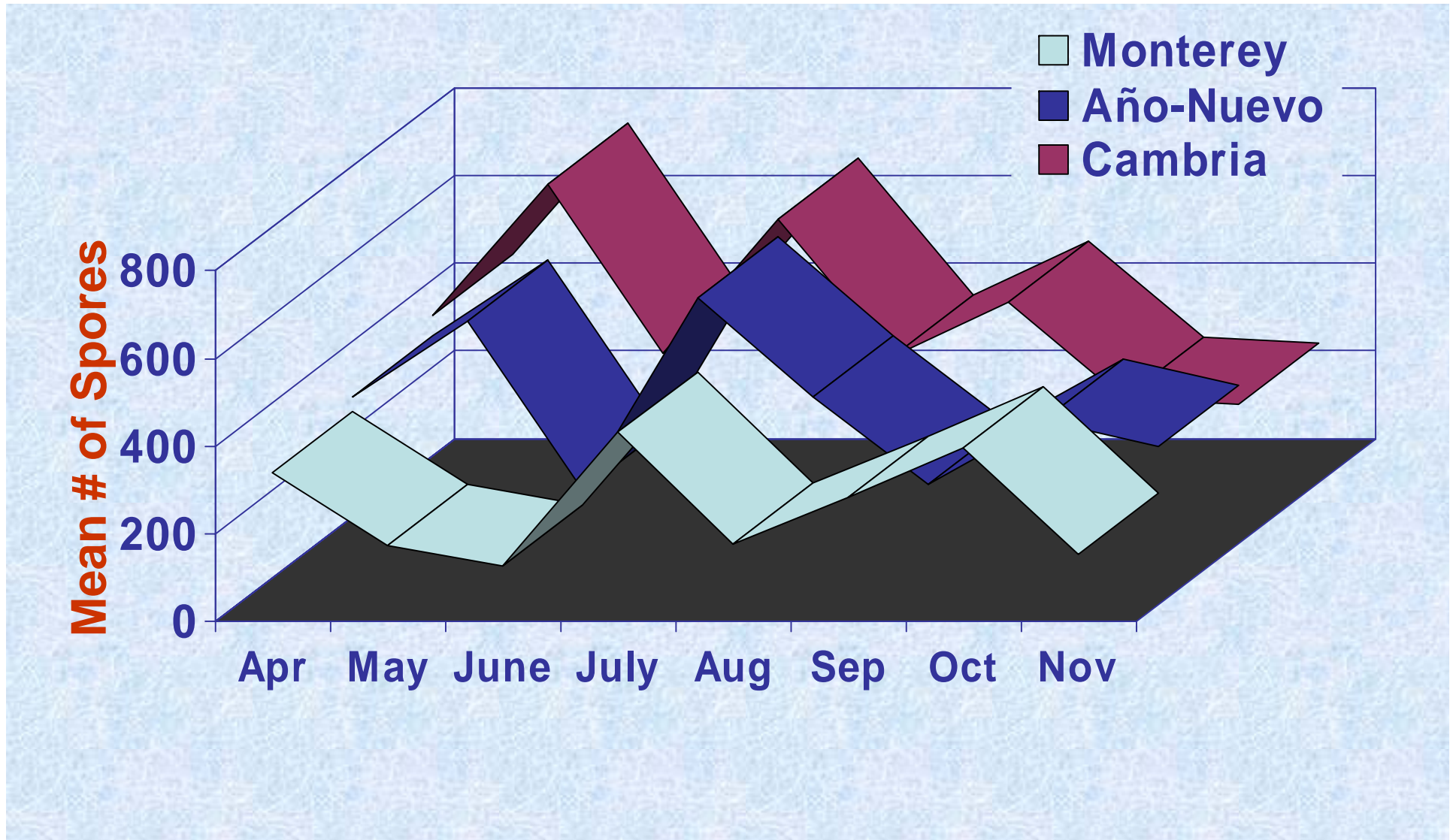
Percent phoresy rate and spore numbers varied by beetle species

<i>Insect spp.</i>	<i>Mean % Phoresy</i>	<i>Mean No spores /Beetle</i>
<i>Ips mexicanus</i>	20.7	329.6
<i>Ips plastographus</i>	21.9	312.5
<i>Pityophthorus setosus</i>		
<i>Trapped</i>	2.3	13
<i>Reared</i>	56.0	38.9
<i>Pityophthorus carmeli</i>		
<i>Trapped</i>	3.3	20
<i>Reared</i>	57.0	66.5

Seasonal phoresy of F. circinatum isolated from I. mexicanus varied by location and time




Seasonal no of spores of F. circinatum isolated from I. mexicanus varied by location and time



Transmission Experiments: Caging live beetles on branches of Monterey pines

- Live beetles treated with a spore suspension were caged onto branches
- Treatments: 1) Beetle treated with low dose; 2) Beetle treated with medium dose (3 X low dose); 3) Beetle treated with high dose (10 X medium dose); 4) Inoculation with *F. circinatum*; 5) Mock inoculation; 6) Blank Control
- 3 beetles (1 beetle/branch) per tree
- Replicated 20 times for each of two beetle species
- Percent transmission rate and lesion length were determined six months after

Percent transmission rate and lesion length depend on the number of spores of *F. circinatum* carried by *P. setosus*

Treatments (spore load) 	Branches with Caged <i>P. setosus</i>	
	% Trans. Rate	Mean Lesion Length (mm)
Beetle treated w/low dose (13)	13.3 c	2.9 ± 0.5 c
Beetle treated w/med dose (39)	52.6 b	6.1 ± 0.7 b
Beetle treated w/high dose (390)	88.3 a	11.2 ± 1.0 a
<i>F. circinatum</i> inoculation (250)	100 a	13.6 ± 1.5 a

Demonstrating SIR in Nature

- Different branches on trees with the following treatments were inoculated with *F. circinatum* in May of 2006
 - Beetle treated with low dose (2nd Exposure)
 - Beetle treated with medium dose (3 X low dose) (2nd)
 - Beetle treated with high dose (10 X med dose) (2nd)
 - Inoculation with *F. circinatum* (2nd)
 - Mock inoculation (1st)
 - Blank control (1st)
- Lesion lengths were measured in July of 2006

Induction of SIR by *P. setosus* (Ps)

<i>Treatments</i> (dose)	<i>1st Lesion</i> <i>length</i>	<i>2nd Lesion</i> <i>length</i>	<i>Stat.</i> <i>change</i>	<i>SIR</i> <i>Induc.</i>
<i>Ps w/HD</i>	11.2 ± 1.0	3.9 ± 0.3	↓	Yes
<i>Ps w/MD</i>	6.1 ± 0.7	4.2 ± 0.4	↓	Yes
<i>Ps w/LD</i>	2.9 ± 0.5	19.4 ± 1.1	↑	No
<i>F. circinatum</i> <i>inoculation</i>	13.6 ± 1.5	3.7 ± 0.3	↓	Yes
<i>Mock inoc.</i>	N/A	18.4 ± 1.3		
<i>Control</i>	N/A	21.7 ± 2.3		

HD: High dose, MD: Medium dose, LD: Low dose

Conclusions

- *F. circinatum* is phoretic on many beetle species
- Phoresy rates and spore loads show variation among beetle species by season and native stands
- Phoresy pattern of *F. circinatum* is independent of seasonal abundance of beetles
- Spore loads on beetles are consistently low during fall, and possibly for winter

Infection of Monterey pine by *F. circinatum* is dependent on spore load on beetles

- Transmission rate increases with spore load
- Lesion length increases with spore load
- We demonstrated a lower threshold for **SIR** induction by two species of twig beetles, but the upper threshold value needs to be investigated
- Vectors efficacy of beetles determines host resistance to *Fusarium circinatum*

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***Any
Questions?***

