Invasion dynamics and the role of urban-ag spillover by the Asian citrus psyllid

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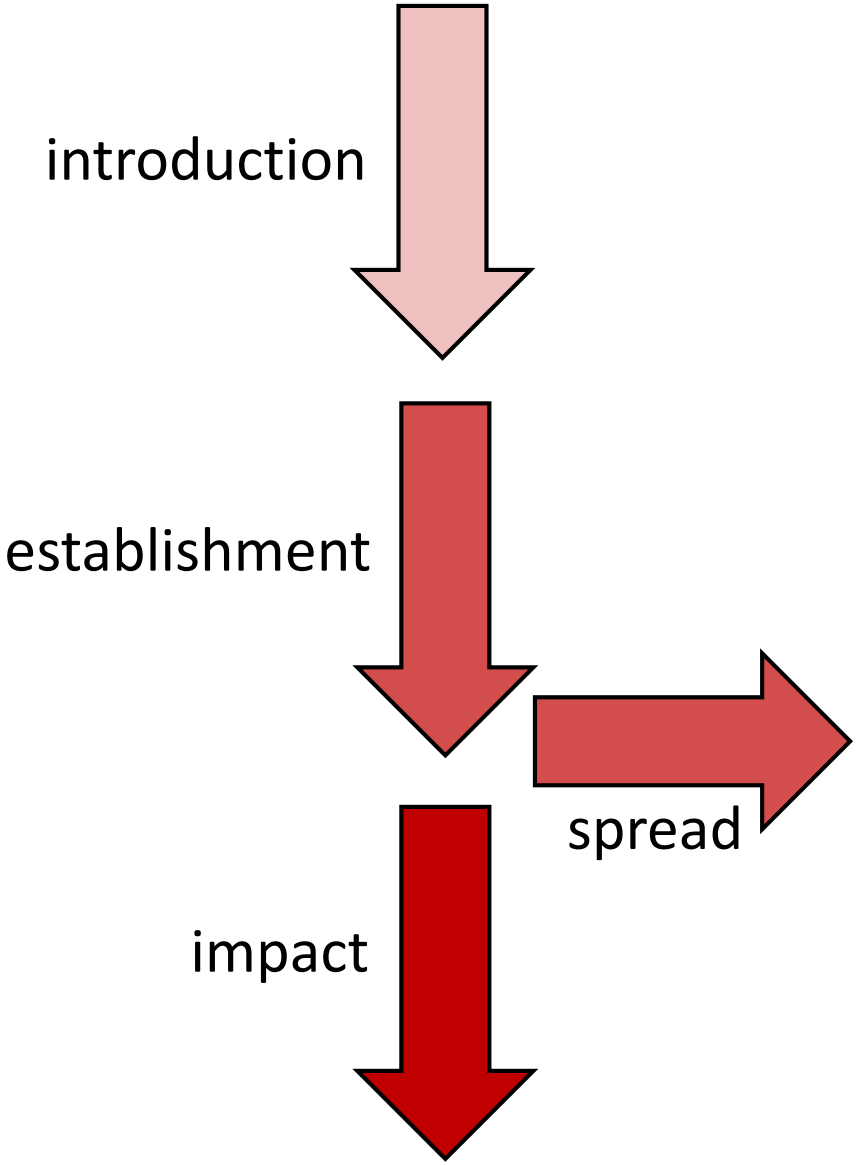
Stages of biological invasions



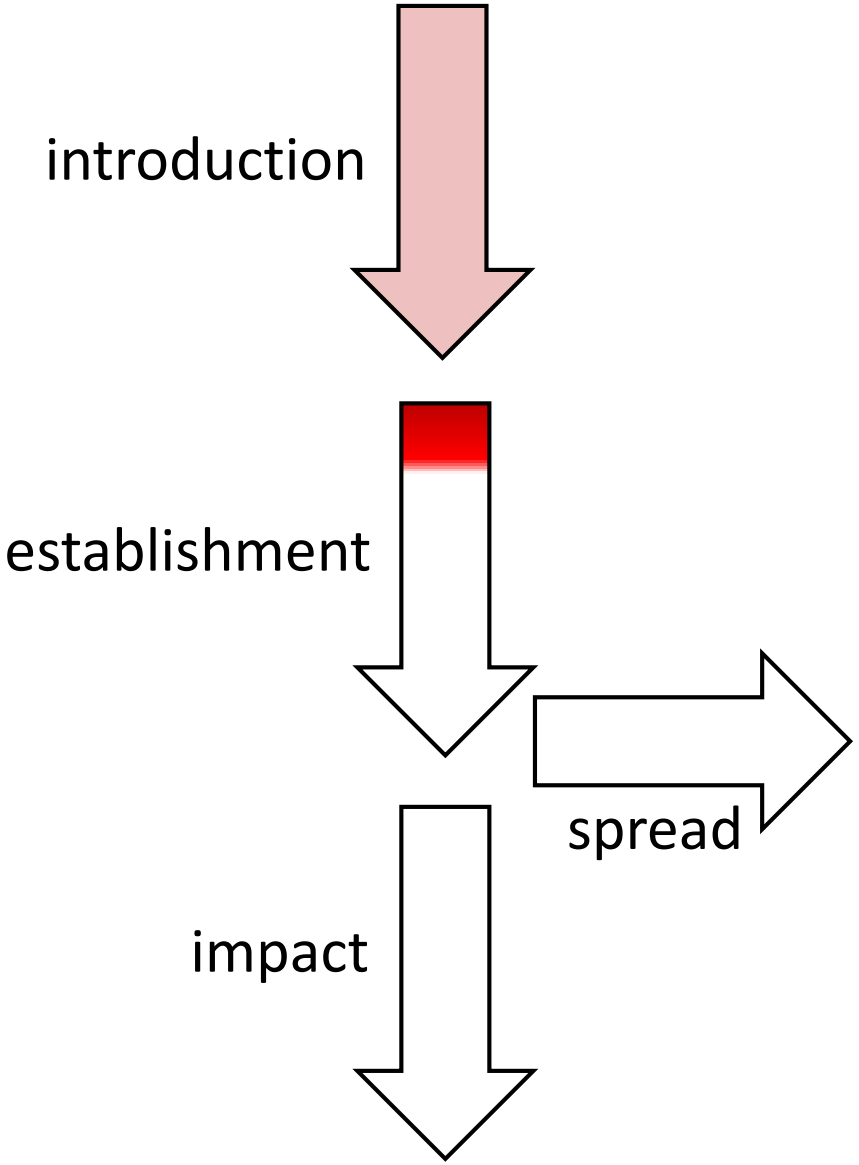
In California, 8 to 10 exotic arthropods introduced each year

~20% become invasive

Three (or 4) categories of stages are involved in biological invasions

Each stage introduces unique hurdles for an invader's success

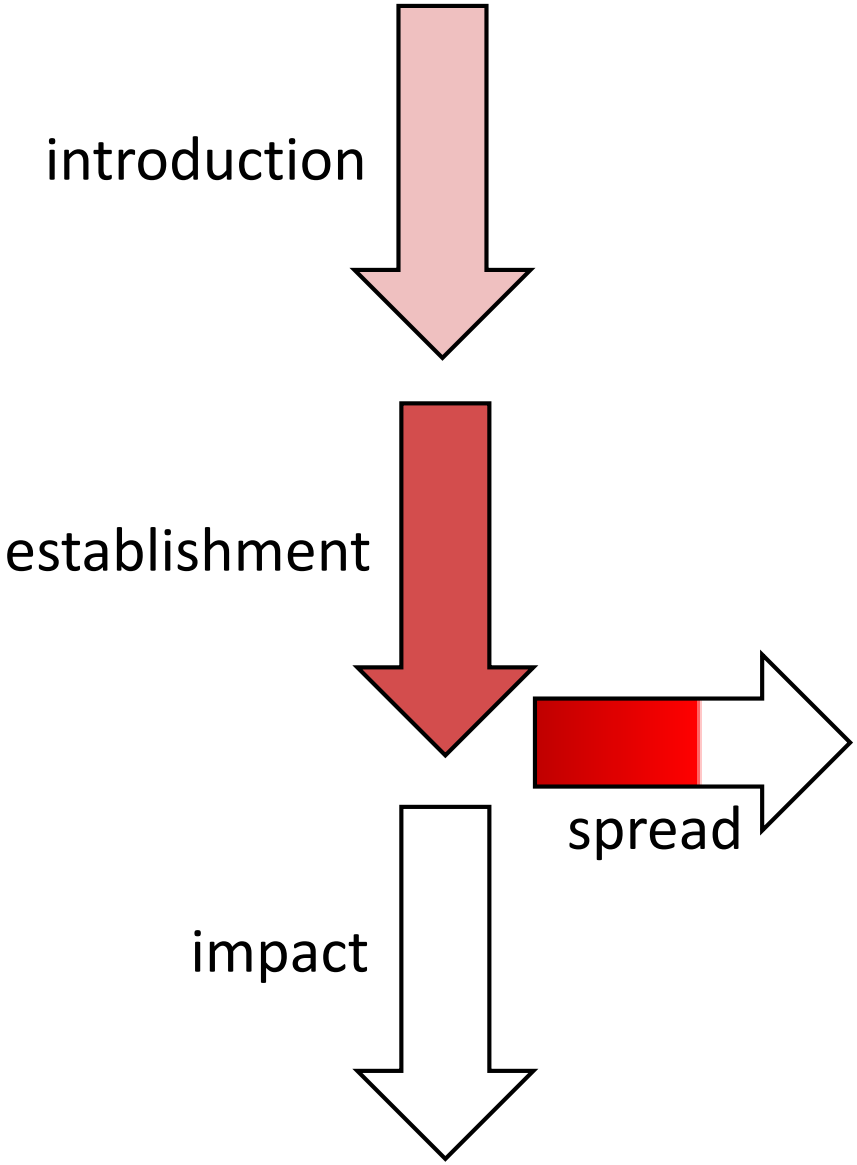
Stages of biological invasions



Most exotics probably fail to become widely established

- introduced into unfavorable area
- early detection and aggressive control eradicated red palm weevil

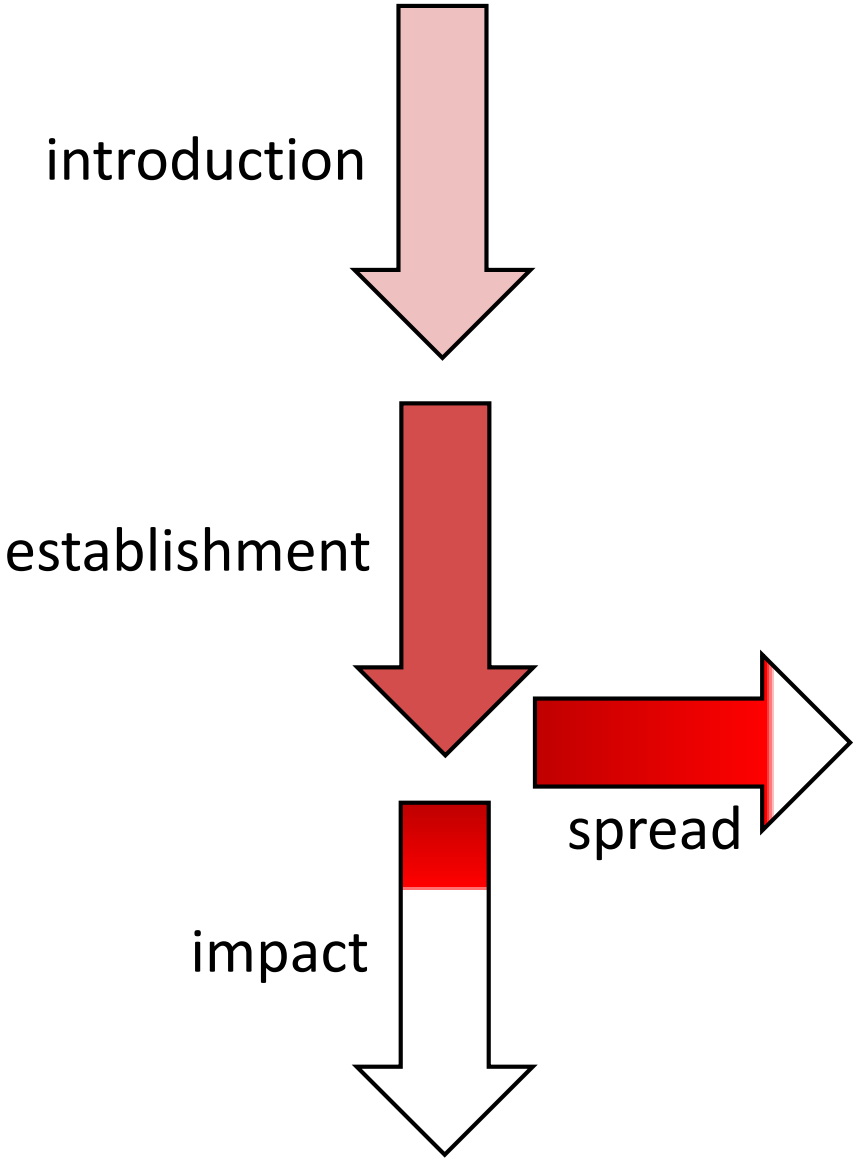
Stages of biological invasions



Some exotics can become widespread without causing major damage

- BMSB has not been associated with major damage (so far)

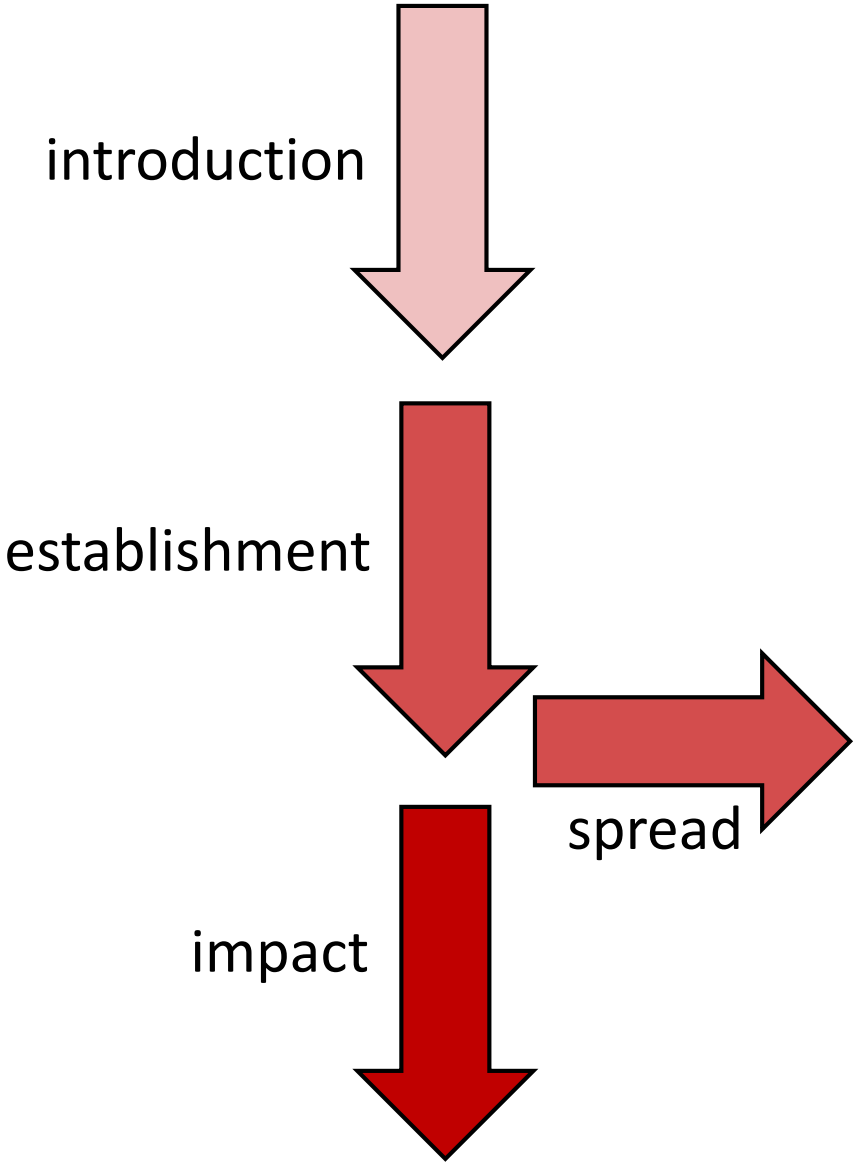
Stages of biological invasions



Some exotics can become widespread without causing major damage

- LBAM impact has been constrained by high “biotic resistance”

Stages of biological invasions



Without effective barriers, early detection, or management some exotics cause major impacts

- human activities often contribute to invader success

Recent invasive insects in California

Biological invasions are often associated with cities

“Urban invaders” threaten garden and landscape flora

Also put nearby ag areas at risk in the event of spillover

- lots of urban-ag interface in CA

Management in urban areas important, challenging

Asian citrus psyllid (*Diaphorina citri*)

Native to Southern, Southeast Asia

Highly invasive in the Americas

Attacks all varieties of citrus and some relatives (Rutaceae)

- dynamics tied to flush cycles

Feeding can damage new shoots

Transmits bacteria (Candidatus *Liberibacter* spp.) associated with huanglongbing disease

Huanglongbing (Citrus greening)

Delayed symptom onset

Earliest symptoms include blotchy, irregular yellowing of leaves

Fruit don’t develop properly; small, deformed, poor flavor

Lack of tree vigor, stunting; excessive fruit drop

Tree mortality in as little as 5 years

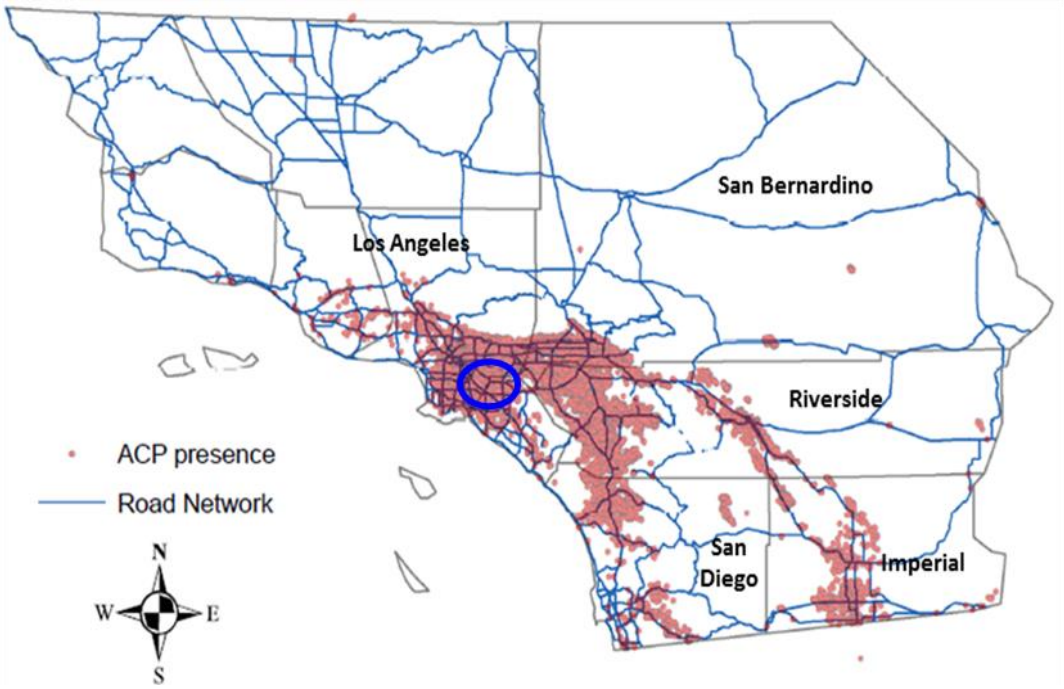
ACP invasion in California

ACP was found in residential San Diego in 2008. It then spread throughout Southern California

- widespread in urban and suburban areas

HLB first documented in 2012

- 1600+ total cases
- thus far, restricted to residential areas



Attempts to mitigate the impact of ACP and HLB

1. Statewide monitoring for ACP and HLB
   - residential and commercial trapping; inspections of nurseries
   - “high risk” disease surveys

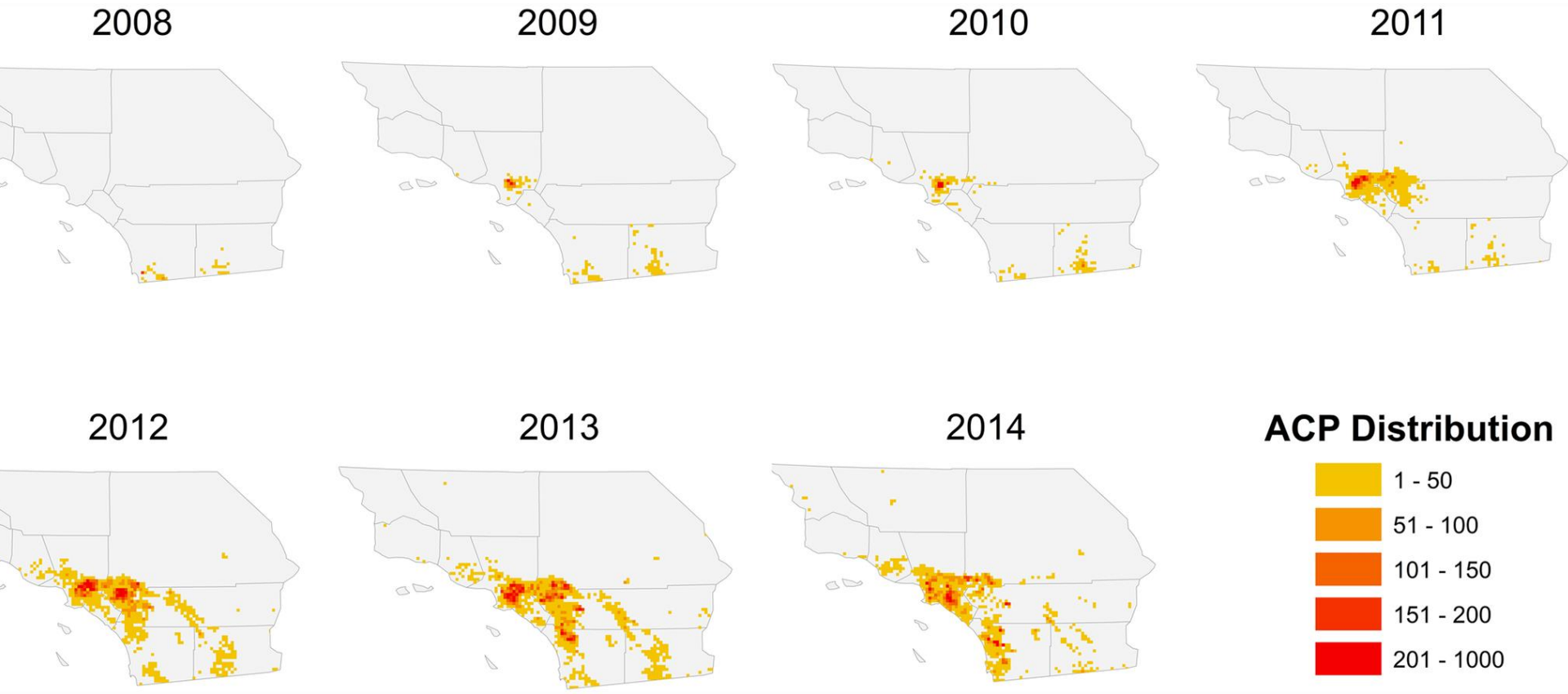
2. Quarantine zones established around infested areas
   - restrictions on nursery shipments

3. Treatments of residential citrus

4. Biological control

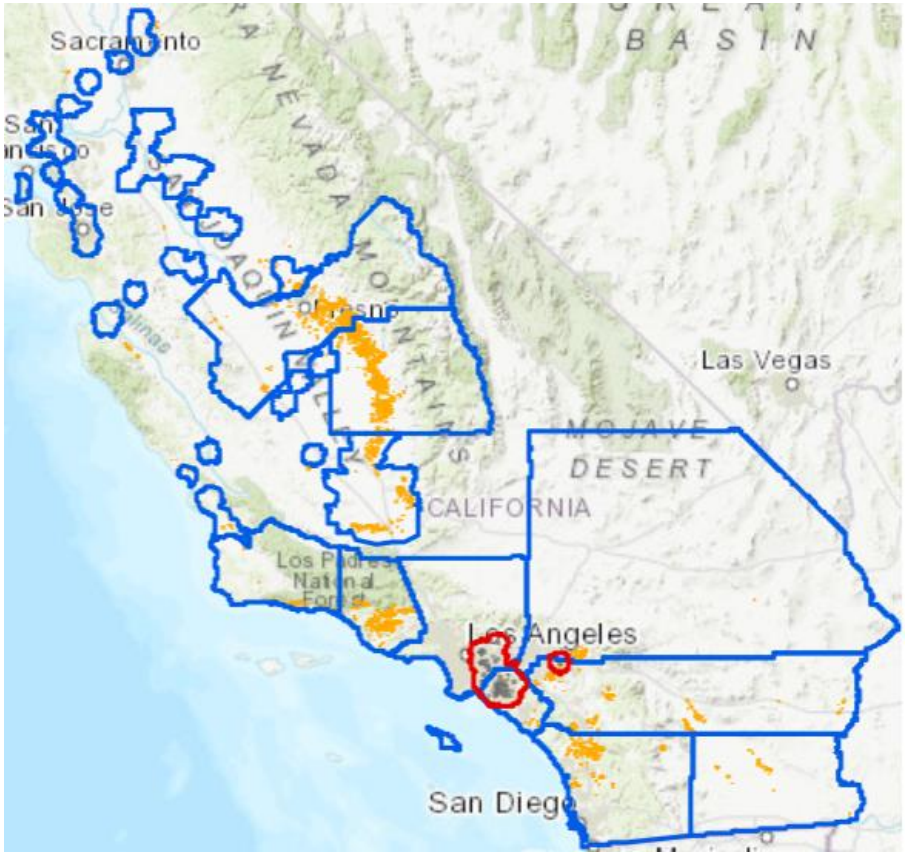
5. Area-wide treatments of commercial citrus; restrictions on fruit movement

Despite management efforts ACP has become widespread



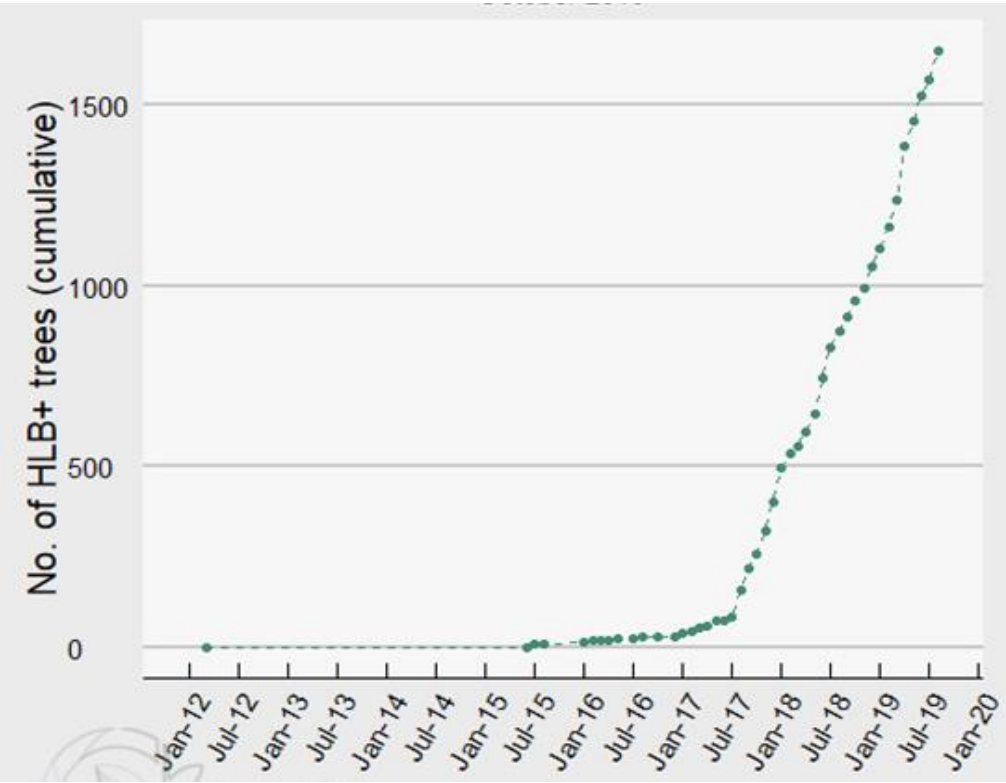
- ubiquitous in residential S. CA; common in groves

Despite management efforts ACP has become widespread



- locally abundant further north, particularly in residential areas

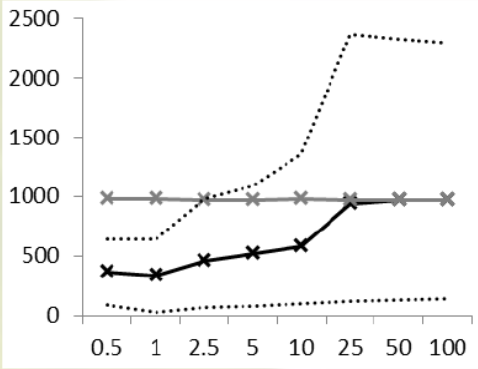
Huanglongbing has continued to spread in Southern California

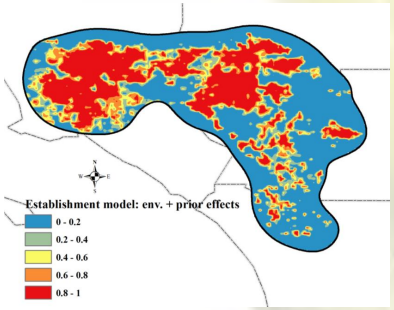


- >1600 infected trees removed, >260 infected ACP detected
- no detections (yet) in commercial citrus

What can we learn from the ACP trapping program?

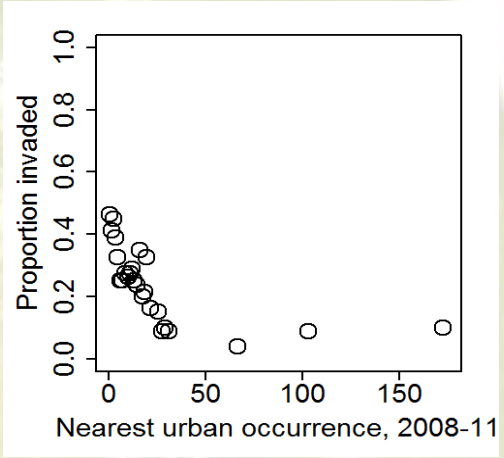
1. Spatiotemporal patterns of ACP occurrence and spread





2. Habitat suitability modeling of ACP in residential citrus

3. What factors are driving ACP invasion of commercial groves?



CDFA geodatabase of ACP records

+ initiated in 2008, prior to ACP establishment

+ “statewide” program in residential and commercial citrus

+ 10,000s to 100,000s of georeferenced records

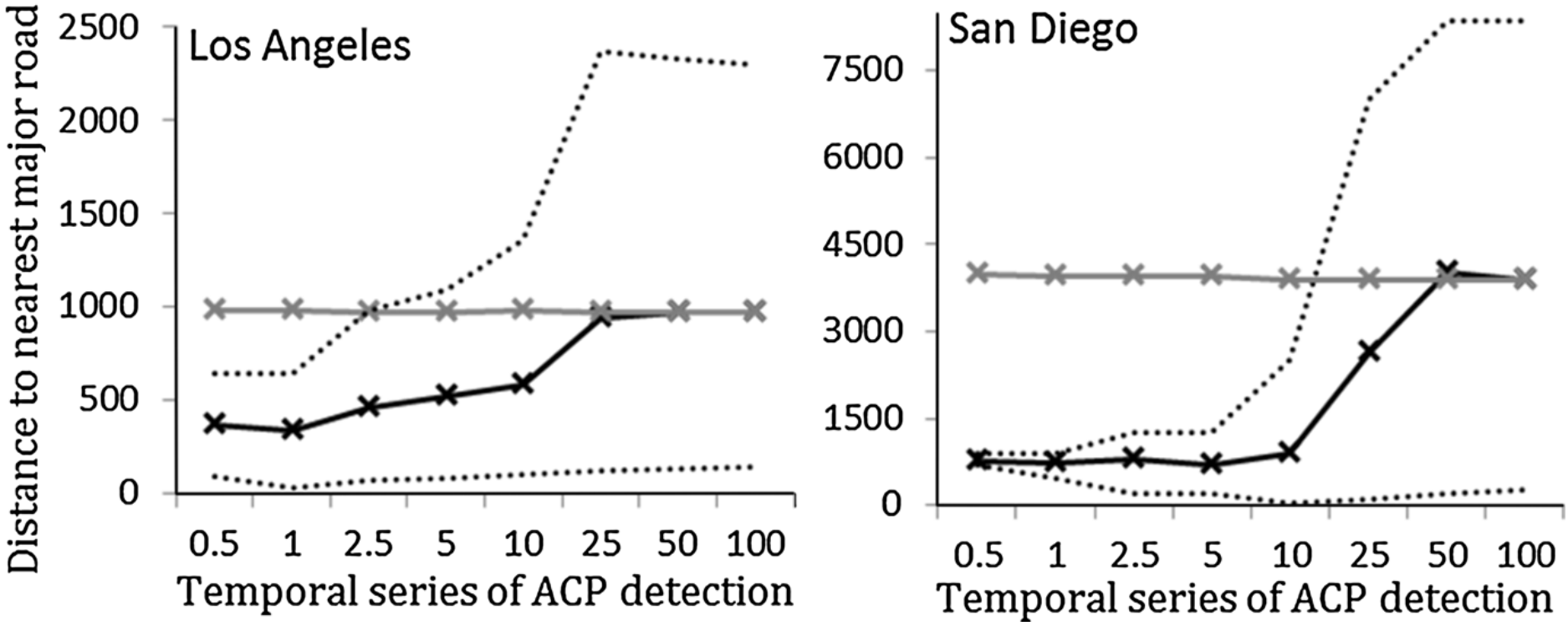
- trapping effort inconsistent

- absences not reported for residential traps

- inconsistent recording of presence vs. number per trap

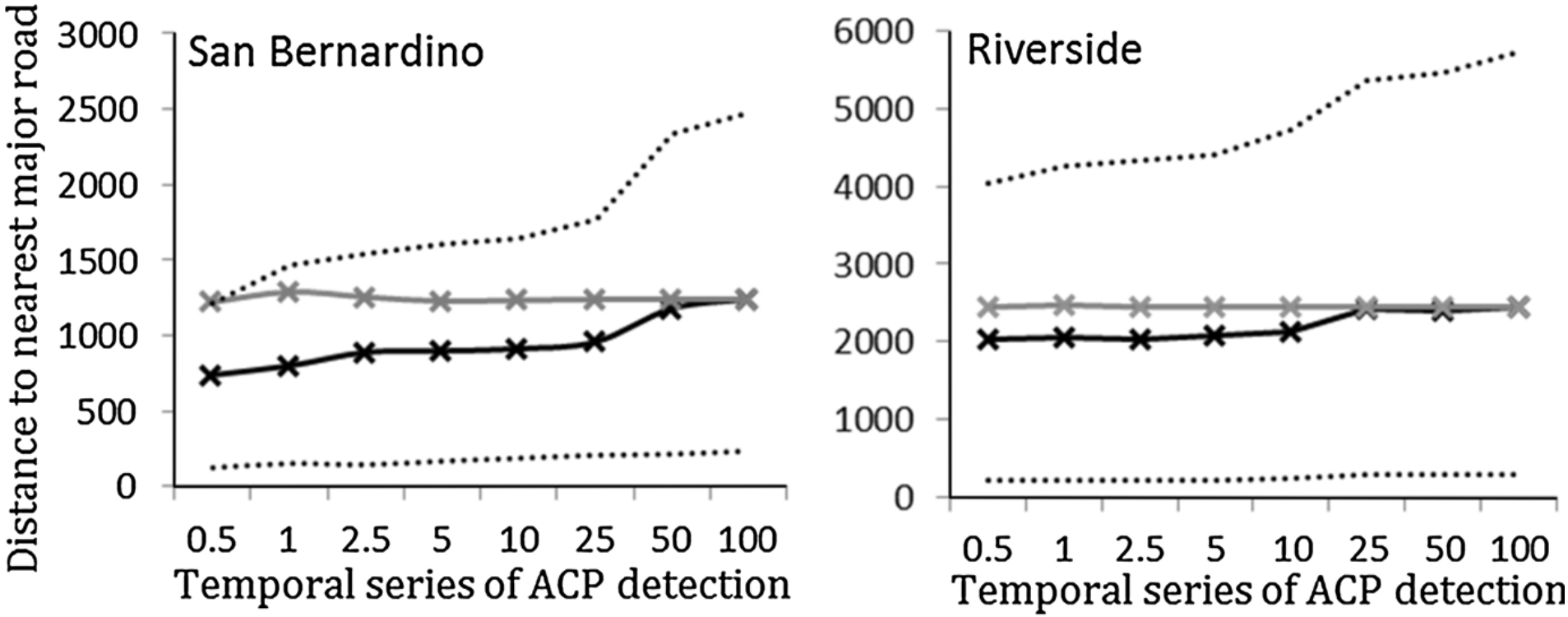
1. Spatiotemporal patterns - invasion pathway

- in SD, LA earliest ACP finds disproportionately near major transportation corridors



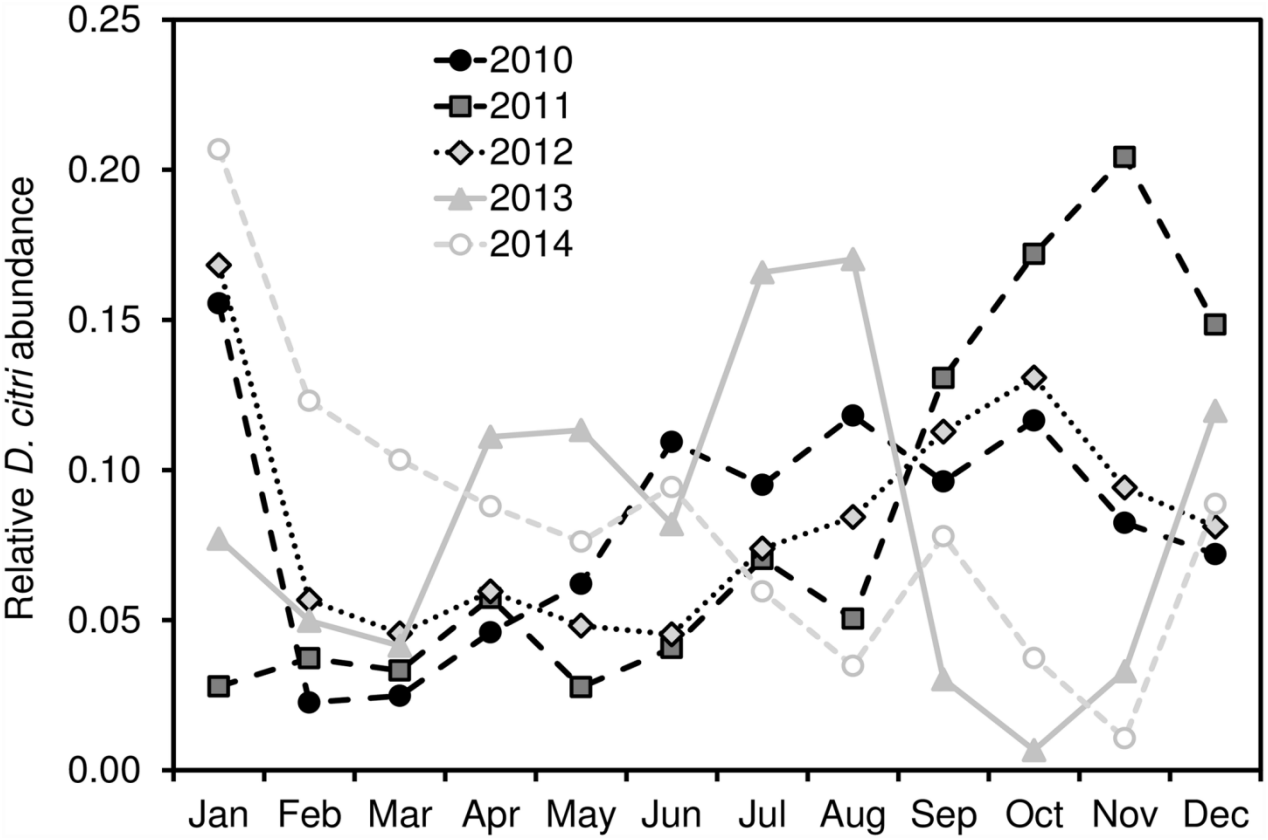
- indicative of human-assisted spread?

- in SB, RIV earliest ACP finds aren't associated with transportation corridors



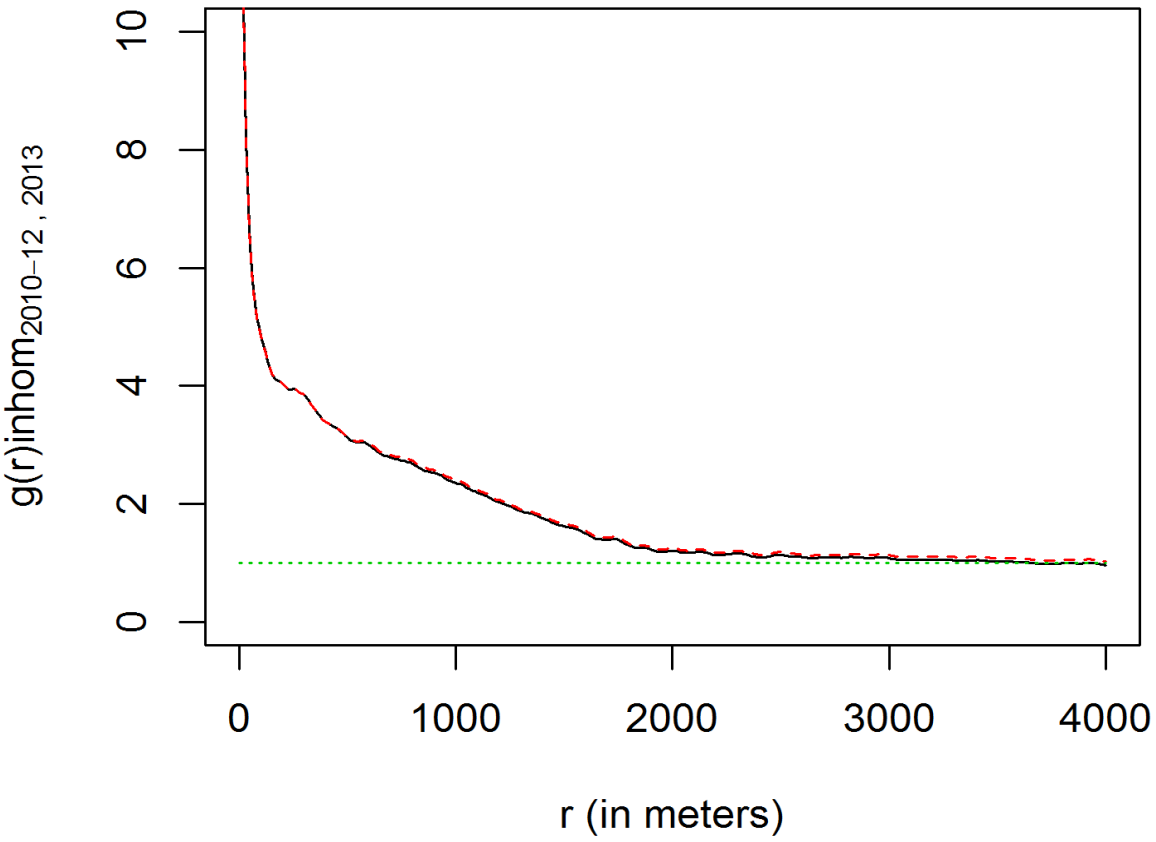
- more consistent with substantial natural spread

Seasonality in ACP in residential areas



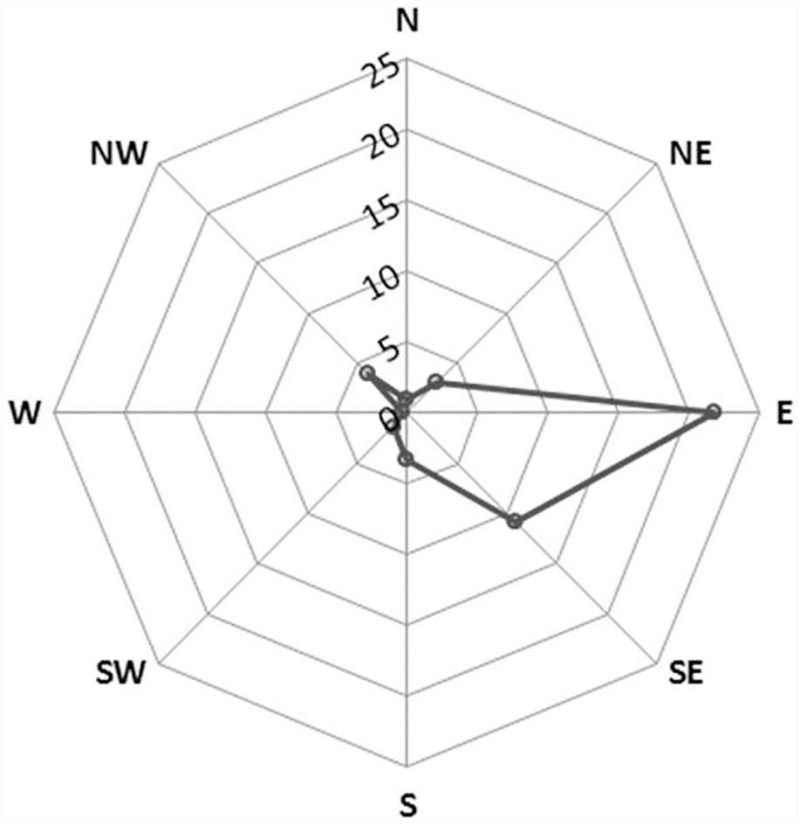
- ACP detections highly variable
- inconsistent with typical flush cycles in commercial citrus

Spatial autocorrelation as an indicator of ACP movement



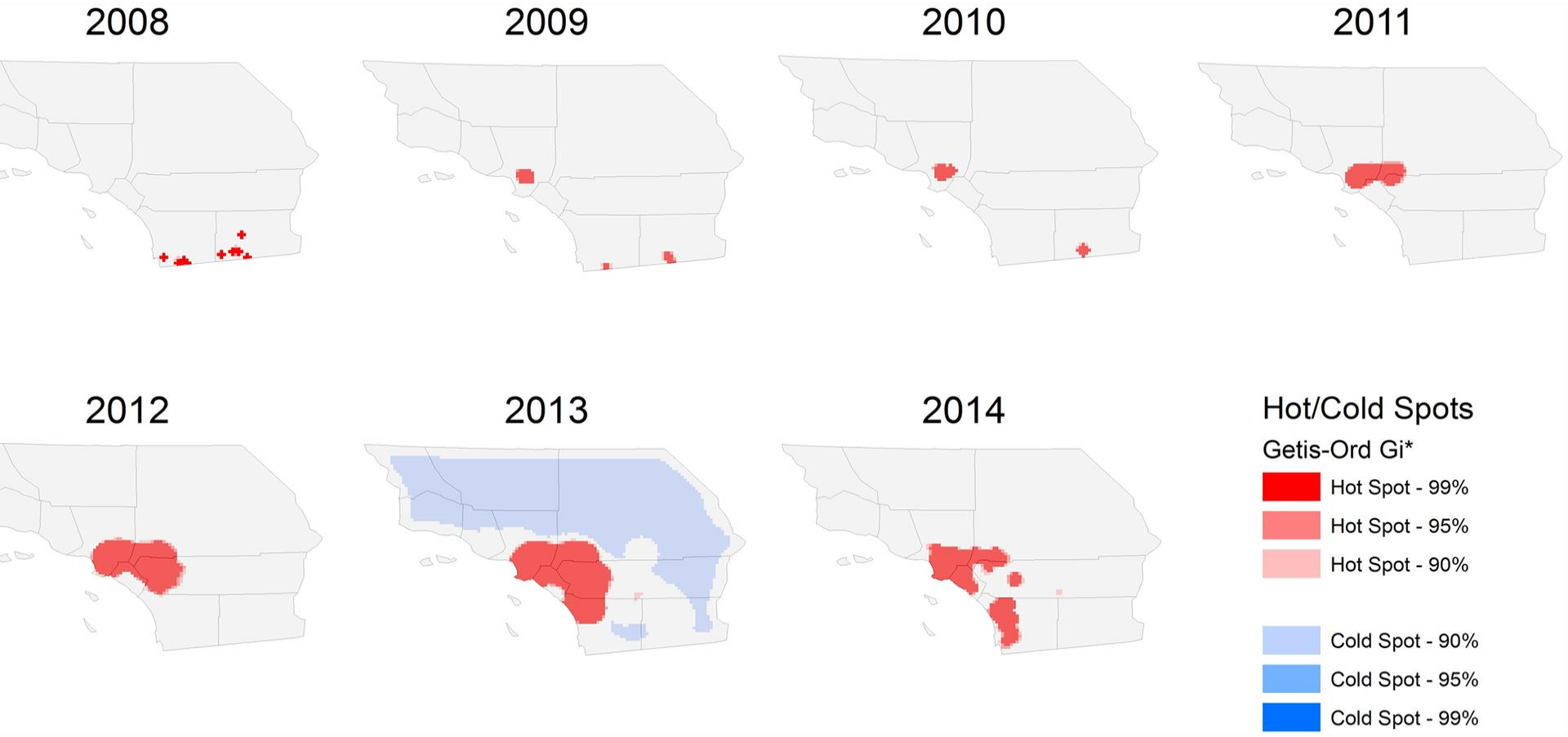
- significant correlation up to ~2 km
- vast majority of ACP movement under ~500 m

Asymmetry in ACP movement



- for LA region, ACP spread predominantly to the E and SE (toward SB and RIV)

Hot spot analysis



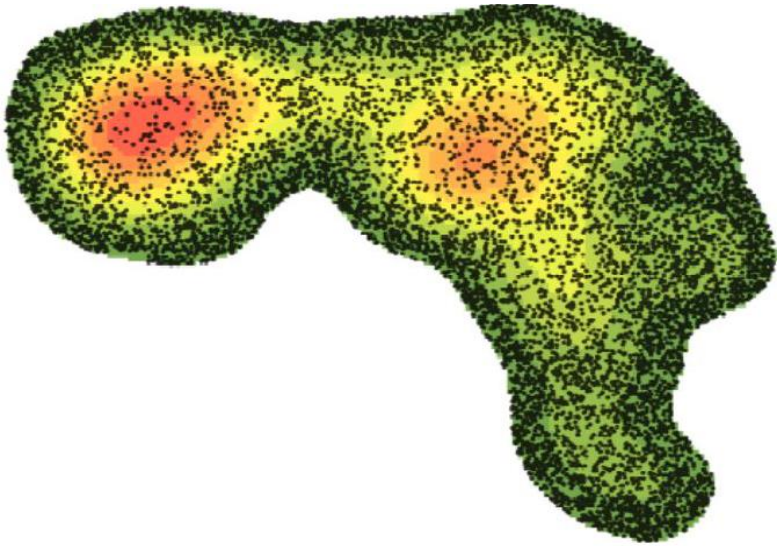
- ACP detections strongly clustered, centered in urban areas
- asymmetric expansion of hot spots over time (to SE)

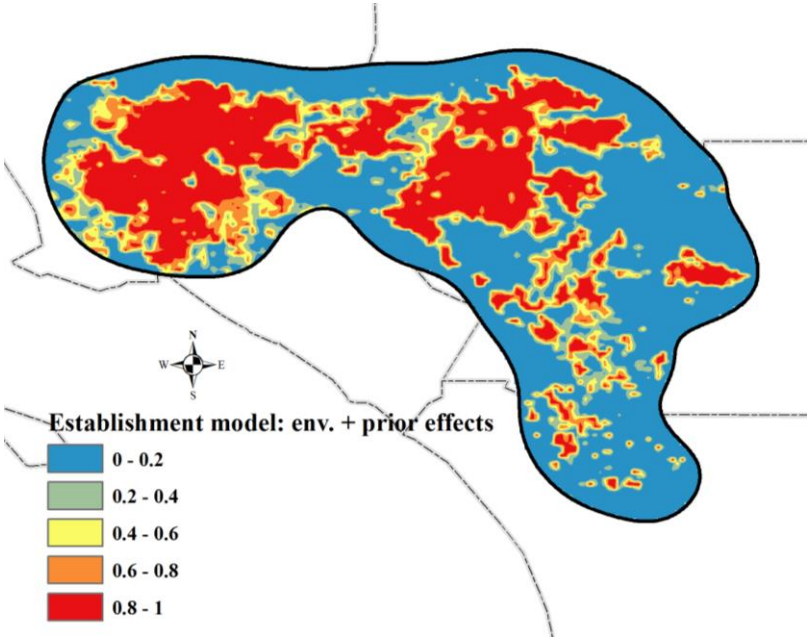
2. Habitat suitability modeling

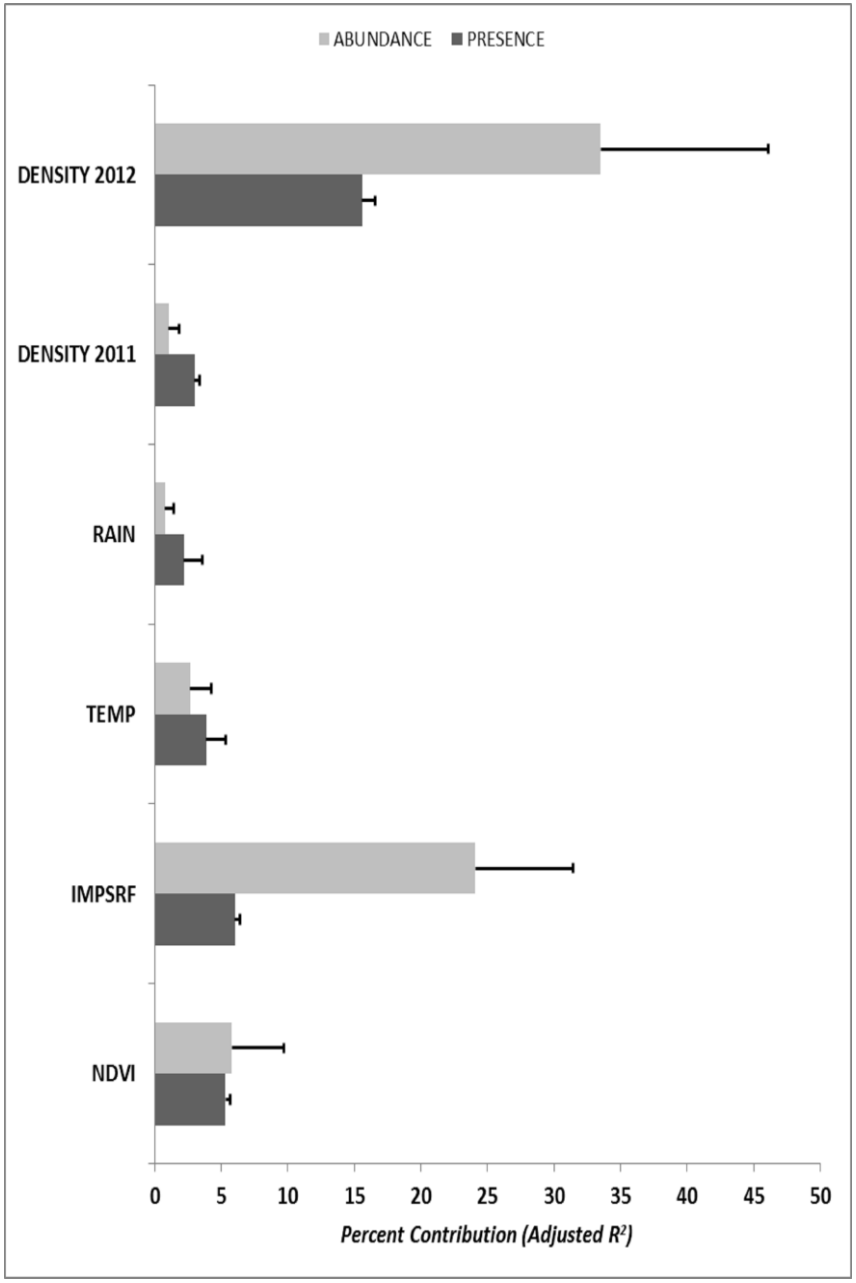
Los Angeles ACP hot spot

GAM models on ACP occurrence, cumulative abundance in 2013

- spatially weighted pseudo-absences
- NDVI, % impervious surface, mean temp., mean rainfall, winter rain
- lagged ”neighborhood” effect
- 60:40 training and testing datasets







Neighborhood effect is the strongest predictor of ACP establishment and impact

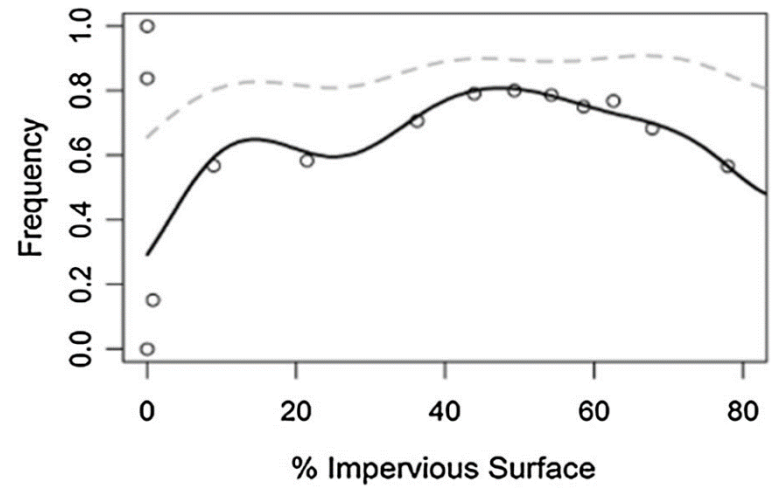
- a lot of small-scale movement

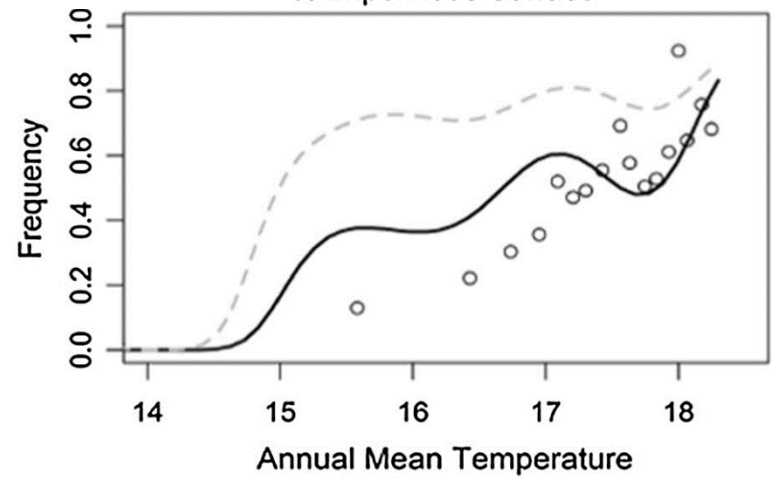
Landscape context is important

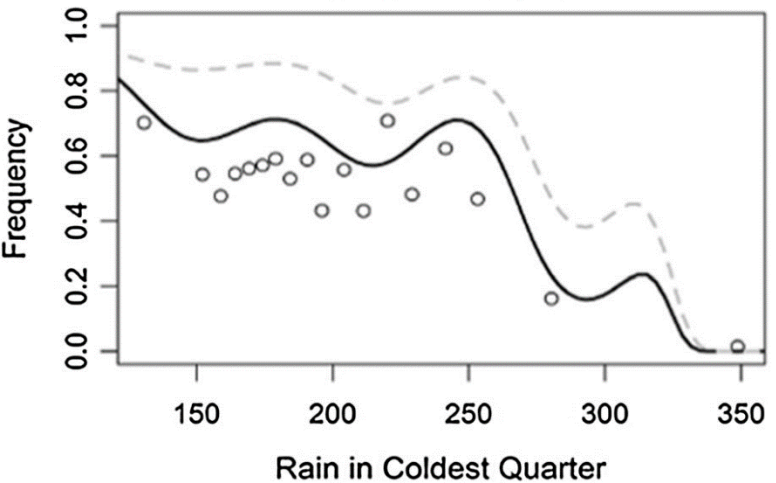
- % impervious surface

Climate is also important

- mean temperature, winter rain







Neighborhood effect is positively associated with establishment and impact

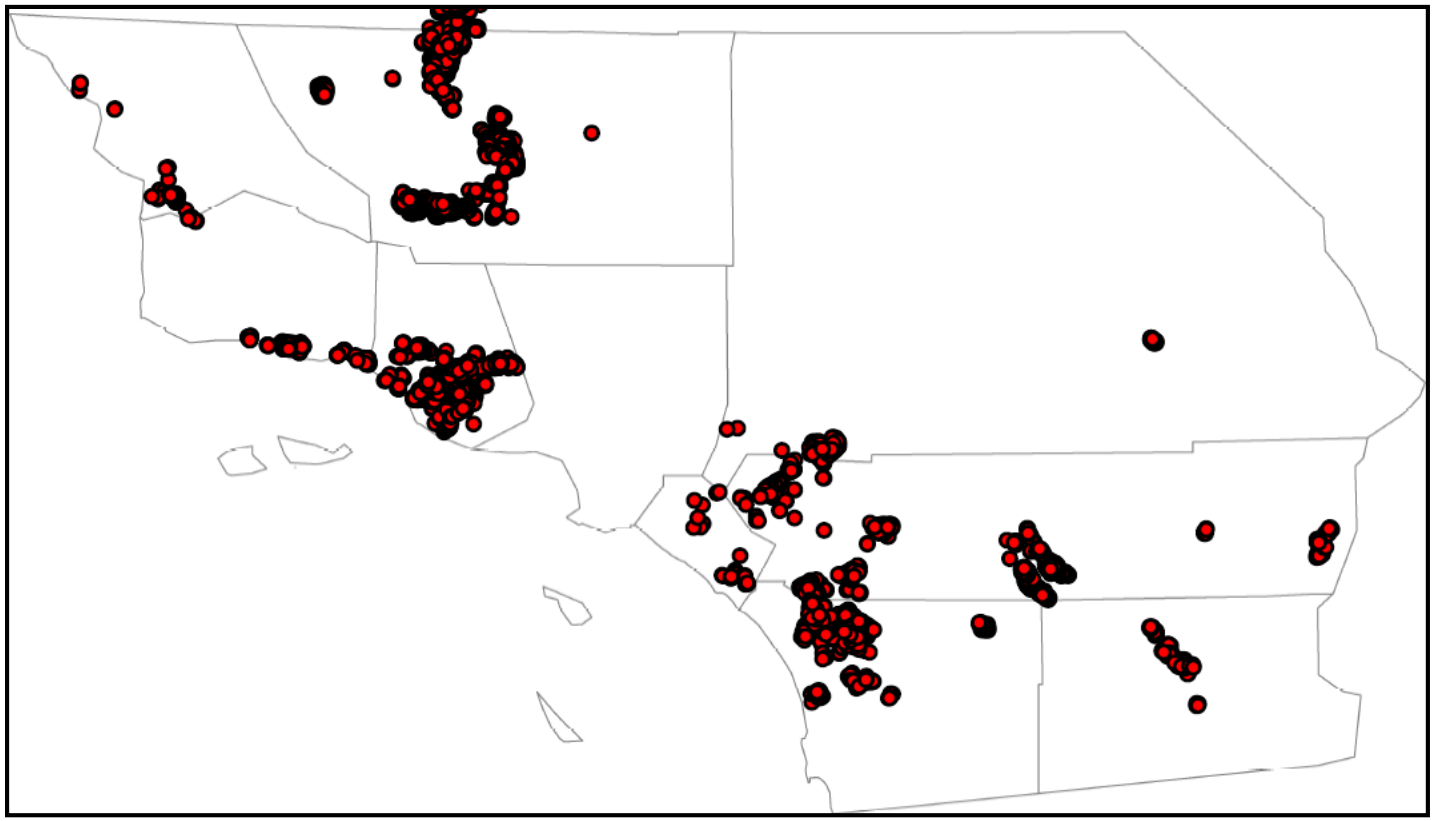
% impervious surface has a hump shaped effect

- highest at intermediate values

Mean temperature is positively associated with ACP

Winter rain is negatively associated with ACP

3. Invasion dynamics in commercial groves



Why are some groves more prone to invasion and frequent ACP detections than others?

Survival analysis: (time to first ACP detection)

Pr(invaded) ~ Farm + Landscape + Neighbor effects

Farm characteristics:

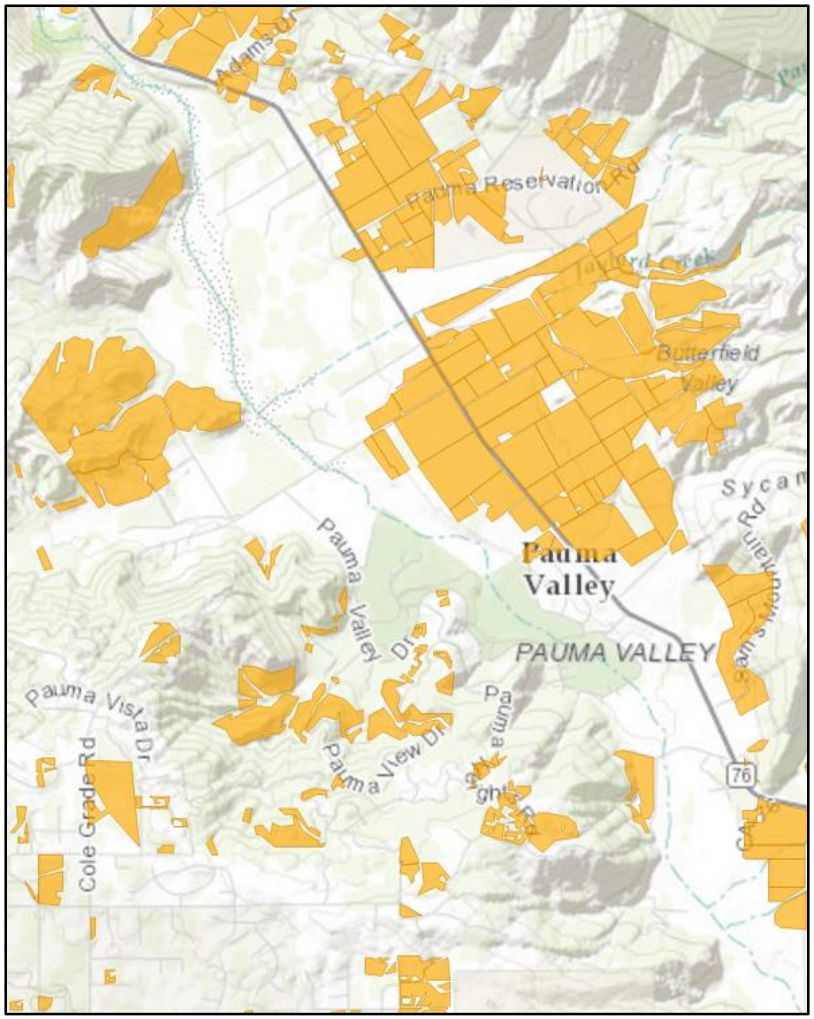
- grove area
- amount of edge
- perforation

Landscape effects:

- distance to major roadways
- urban intensity

Neighbor effects:

- proximity to nearest urban detection
- proximity to grove detection



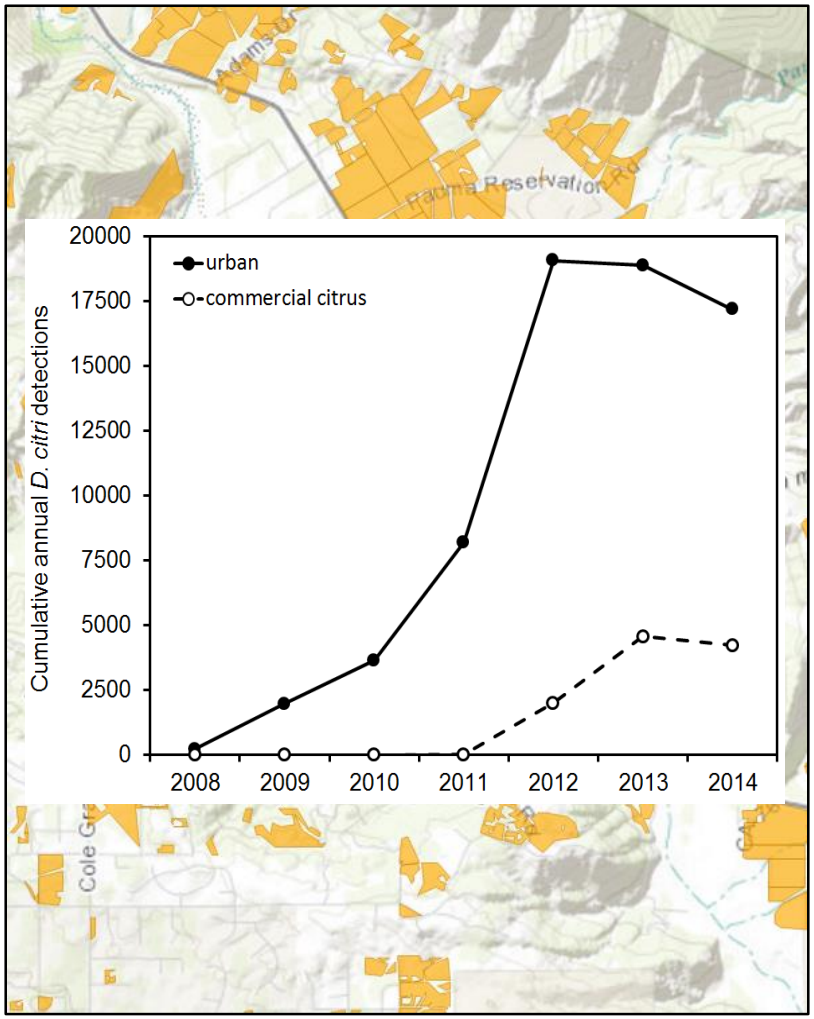
Evaluated neighbor effects over two temporal phases:

urban.early = distance to nearest urban detection, 2008-2011

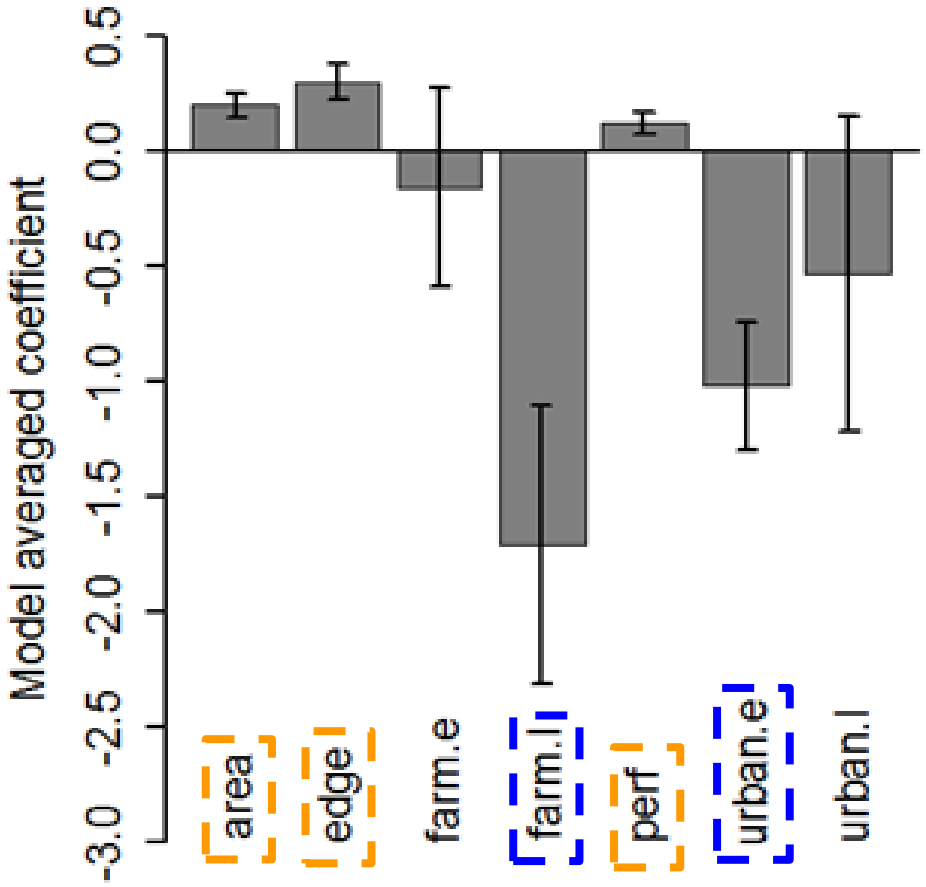
urban.late = distance to nearest urban detection, 2012-2014

farm.early = distance to nearest grove detection, 2011-2012

farm.late = distance to nearest grove detection, 2013-2014



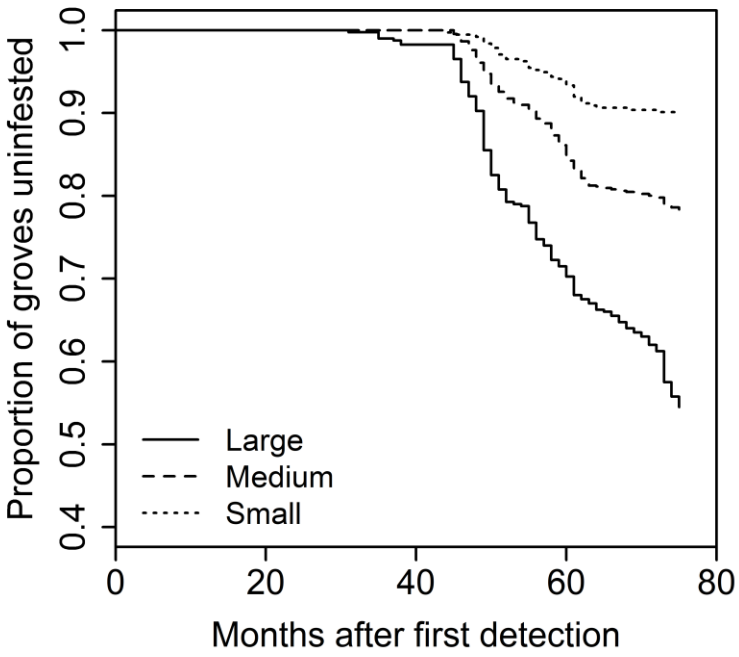
Farm characteristics and some neighbor effects contribute to invasion into commercial citrus

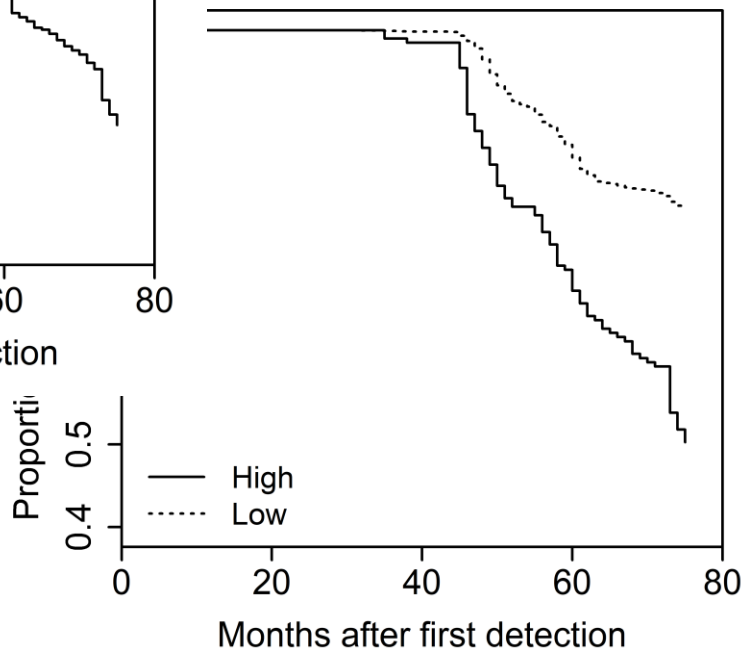


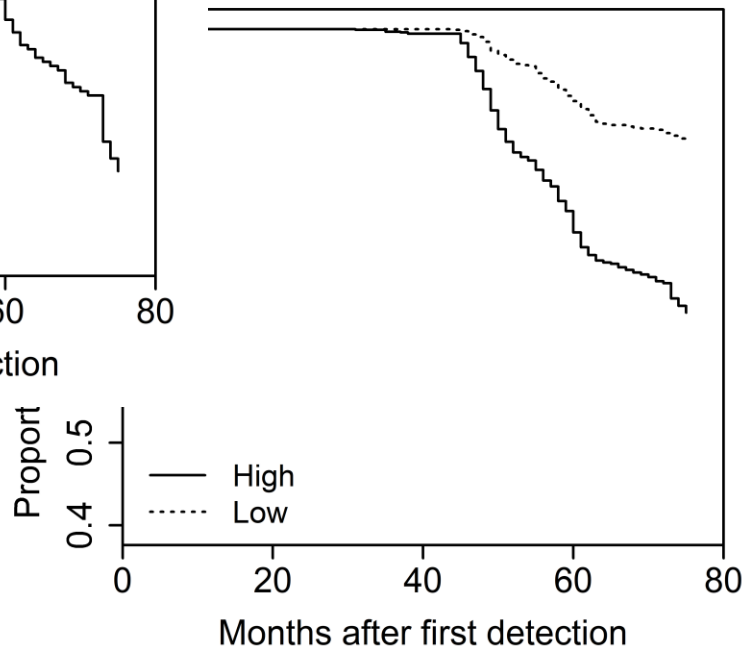
- larger blocks, with more edge, and with more perforated shapes are invaded by ACP at higher rate

Farm characteristics

- larger farms, more edge, higher perforation associated with more rapid invasion







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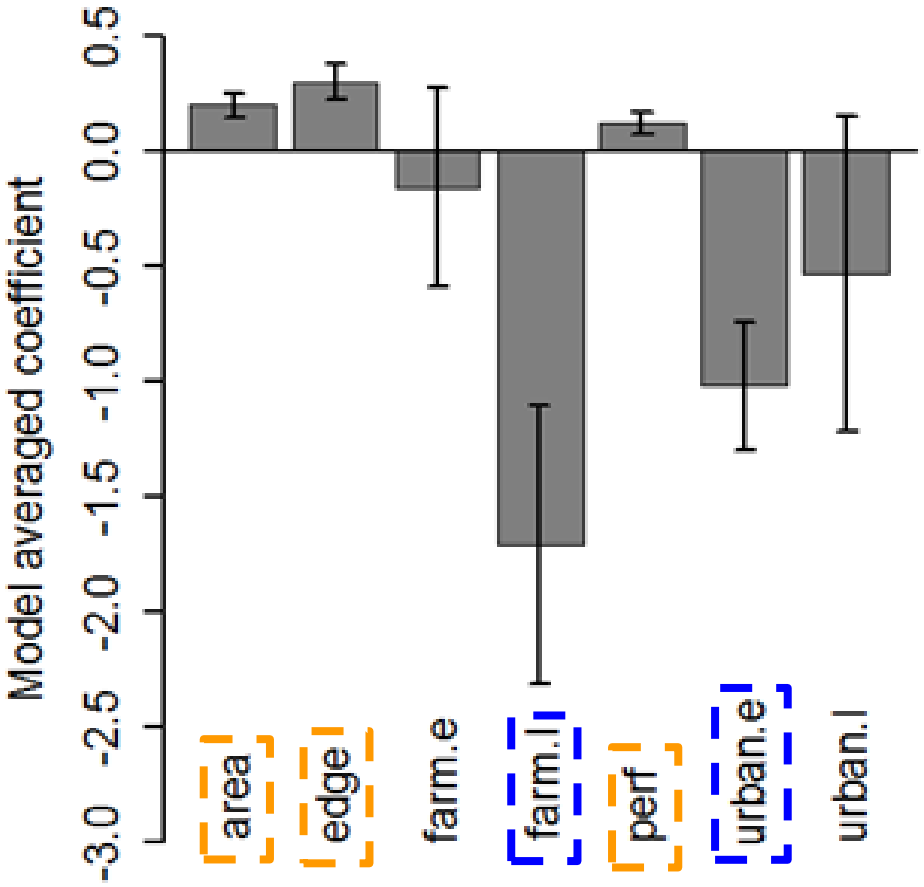
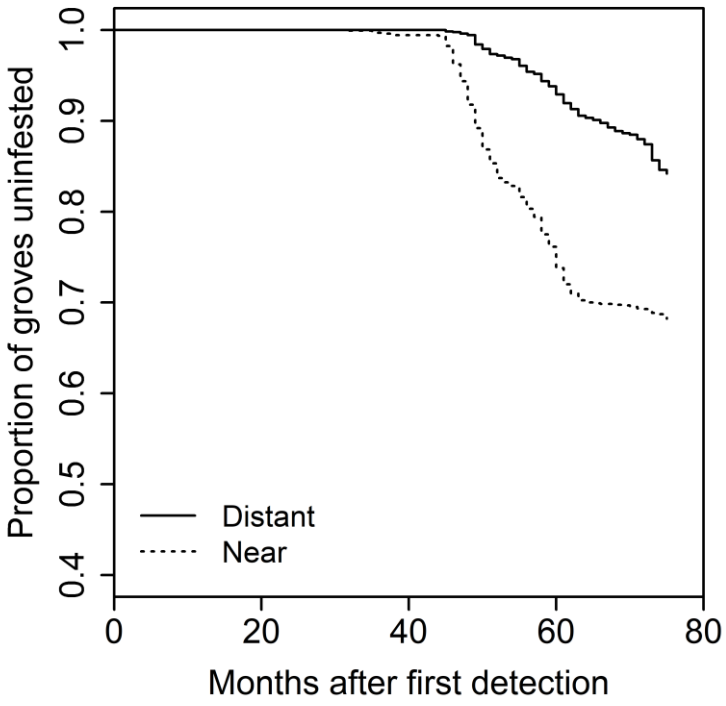
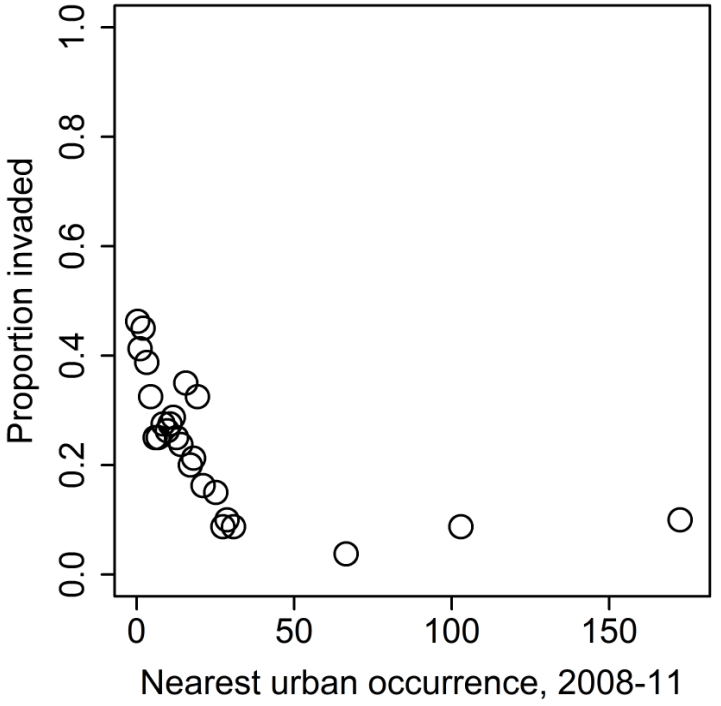


- certain neighbor effects are negatively associated with ACP invasion rate (greater distance = low risk)

Neighbor effects

urban early

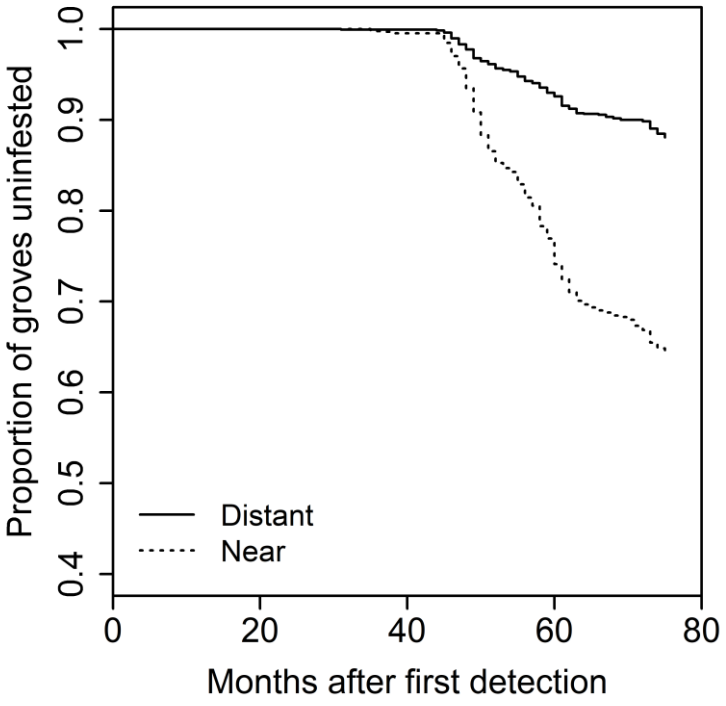


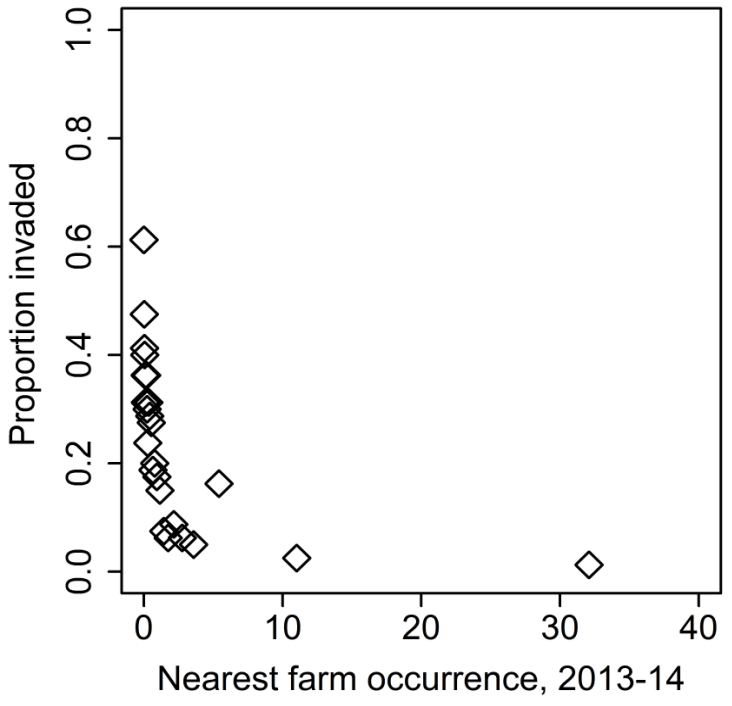


- early on, risk of ACP invasion depends primarily on proximity to nearest urban detection
- invasion kernel is 10s of km

Neighbor effects

farm late





- later on, risk of ACP invasion depends primarily on proximity to nearest farm detection
- invasion kernel < 4 km

Early patterns in ACP detections are consistent with human-assisted spread

- confirms assumption of high risk survey
- likely is still contributing to spread within the state

ACP movement appears to consist of frequent short-distance events, with occasional long distance events

- confirms assumption of high risk survey

ACP has non-random distribution and strongly asymmetric spread

- explained by effects of landscape and climatic variables

Invasion risk partially a function of innate features of citrus groves (area, edge, perforation)

Part of invasion risk depends on landscape context

- urban infestations kicked off grove invasions
- recent invasions primarily from grove-to-grove spread

If the goal is to limit ACP invasion into groves, how important is urban management now in Southern California?

What about management in the Central Valley?

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