Changes in Arthropod Communities Catalyzed by Aphid Invasions

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Aphids benefit from conventional agriculture

Aphids:

- disperse widely, colonize rapidly
- explosive reproductive potential

(asexual reproduction with ‘telescoping’ of generations)

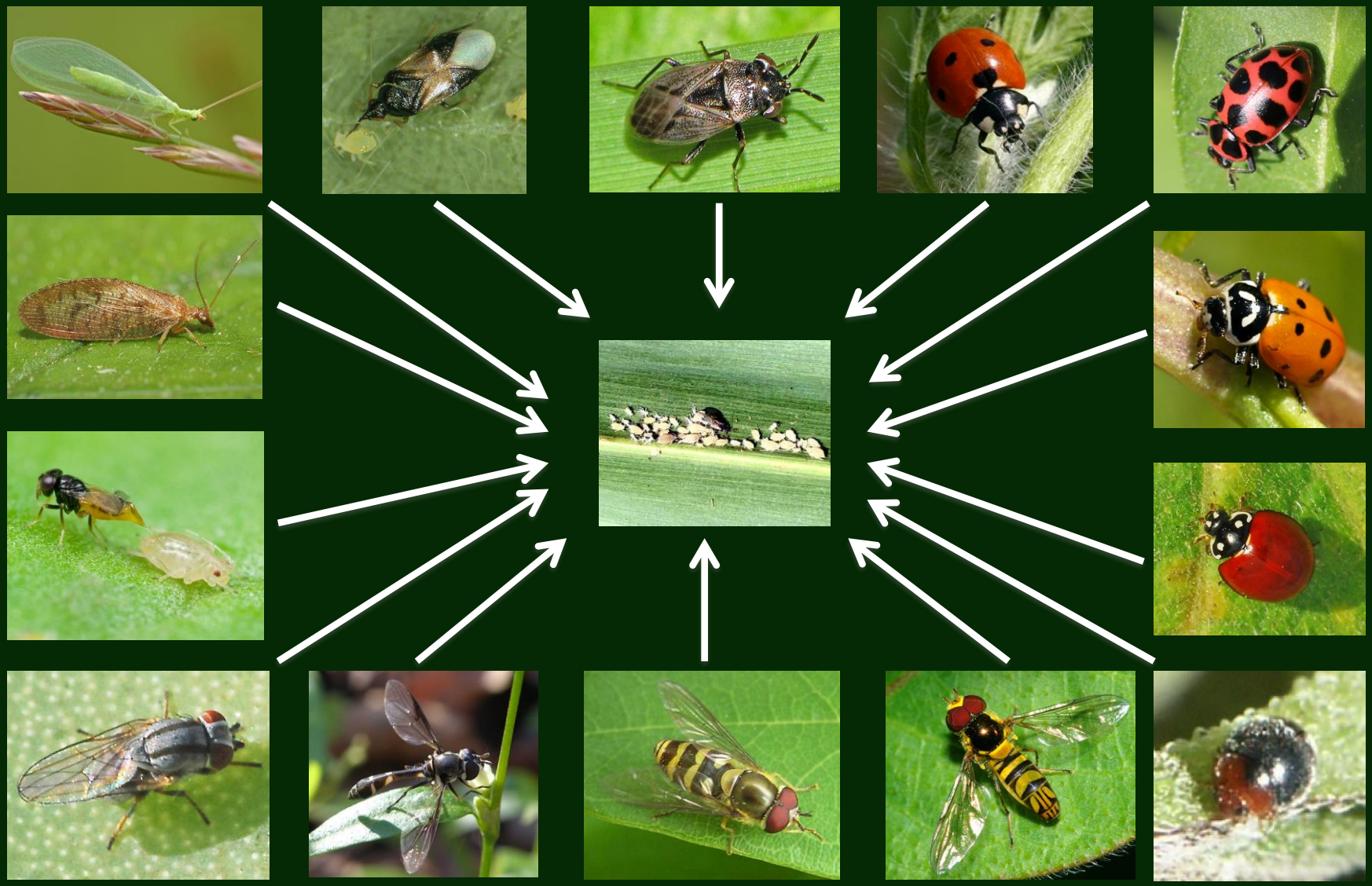
Conventional cereal and field crops:

- genetically uniform plants
- grown in vast, synchronous monocultures

Agroecosystems highly susceptible to aphids!

And yet, most aphid species remain under good biocontrol...

Successful biological control of aphids requires the timely arrival of diverse natural enemies in sufficiently large numbers



Aphid invasions have three phases

1. Epidemic Phase

   High populations cause heavy economic losses over a broad geographic region

2. Attenuation Phase

   Infestations become more sporadic and limited in scope; geographic range may contract

3. Endemic phase

   Economic infestations become rare – usually associated with some disruption of biological control

An aphid invasion triggers ecological cascades

-> temporary and permanent changes in the arthropod communty

VERTICAL TROPHIC IMPACTS

Large numbers of aphids mean lots of food for generalist predators
> numerical responses > big predator populations

The most preadapted natural enemies increase in abundance

HORIZONTAL TROPHIC IMPACTS

Large numbers of aphids divert predator attention from other prey
> aphids easy, profitable prey > secondary pests escape control

The importance of population size

Population size determines:

- the range of existing genetic variation
- the mutation rate

Both are critical determinants of evolutionary rate, and potential for evolutionary change in any population

Just as population bottlenecks constrain evolution, population explosions create evolutionary opportunities for adaptive radiation into new niches

Harmonia axyridis illustrates the potential of the Coccinellidae for evolutionary change and ecological niche expansion

Now occurs worldwide, but regional populations have evolved very different behaviors and ecological associations

Within North America alone, the ecological niches utilized by *H. axyridis* have changed dramatically over the past 20 years, and often in response to aphid invasions

Harmonia axyridis was present in Florida in the mid 1990s,
but not a presence in citrus until the invasion of *Toxoptera citricida*

Large populations of *T. citricida* subsided in 3-4 years,
but *H. axyridis* remained a dominant coccinellid in citrus groves

Subsequently, *H. axyridis* responded quickly to the arrival of Asian citrus psyllid following its invasion in 2000

Soybean aphid, *Aphis glycines*

Discovered in Illinois in 2000

Why did it take *A. glycines* to attract *H. axyridis* into soybean?

Similarly, although present on the High Plains since the 1990s
H. axyridis was absent from sorghum
- despite the presence of various aphid species

Field of grain sorghum destroyed by *Melanaphis sacchari* (NE Mexico, 2013)

Combine header covered with *Melanaphis sacchari*

Following the invasion of sugarcane aphid (SCA), *Melanaphis sacchari, H. axyridis* populations exploded in Kansas sorghum fields (2014-2016)

As SCA populations subsided (2017), *H. axyridis* (and other predators) again colonized sorghum fields in large numbers – even with SCA absent

In 2018, insect populations reverted to pre-SCA invasion levels, with very few aphids or natural enemies

Native aphid predators also exhibited numerical responses to SCA

Harmonia axyridis remains absent from wheat and alfalfa on the High Plains, despite abundant aphid prey

Aphis craccivora

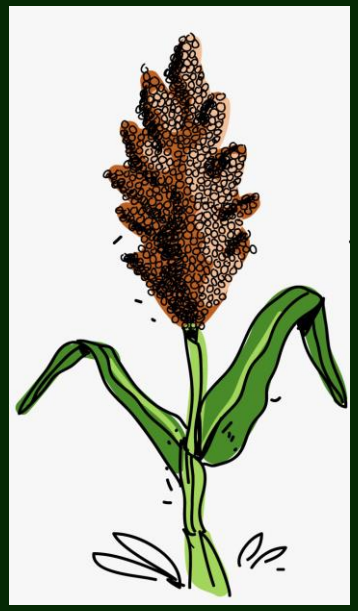
BUT: *H. axyridis* has colonized alfalfa in Chile, dominating native coccinellids

Therioaphis maculata

Acyrthosiphum kondoi

Acyrthosiphum pisum

Generalist predators can be innately attracted to certain plants, independent of the presence of prey, but how does this response evolve?



Generalist parasitoids can also form new host associations quite quickly

Lysiphlebus testaceipes – a highly polyphagous aphid parasitoid

Highly indiscriminate oviposition behavior predapts it to attack novel hosts

This behavior also results in a lot of lost fitness through ‘egg sink’ effects

Lysiphlebus testaceipes

Immediately began attacking brown citrus aphid upon its arrival in Florida

Survival in the new host was initially very low

Successful development took about 5 years to evolve

Lysiphlebus testaceipes – a different story in *Melanaphis sacchari*

The SCA was readily attacked, but there was no sign of any eclosion or parasitoid development in dissected aphids

Hamilonella defensa or some other protective endosymbiont seemed implicated

After several years, a number of independent reports of successful mummification (Georgia, Texas and Mexico)

SCA colony with *Scymnus* larvae, aphelinid and braconid mummies (Texas gulf coast)

Five different braconid genera now reported attacking SCA in Mexico

Aphelinus nigritus

A native species that had not been seen on cereal aphids previously

A. nigritus responded quickly to SCA and became abundant in sorghum fields

In 2018, it was found mummifying greenbugs in wheat in Oklahoma for the first time

Large populations facilitate rapid evolutionary and ecological change

Aphelinus certus

A case of ‘fortuitous’ biological control

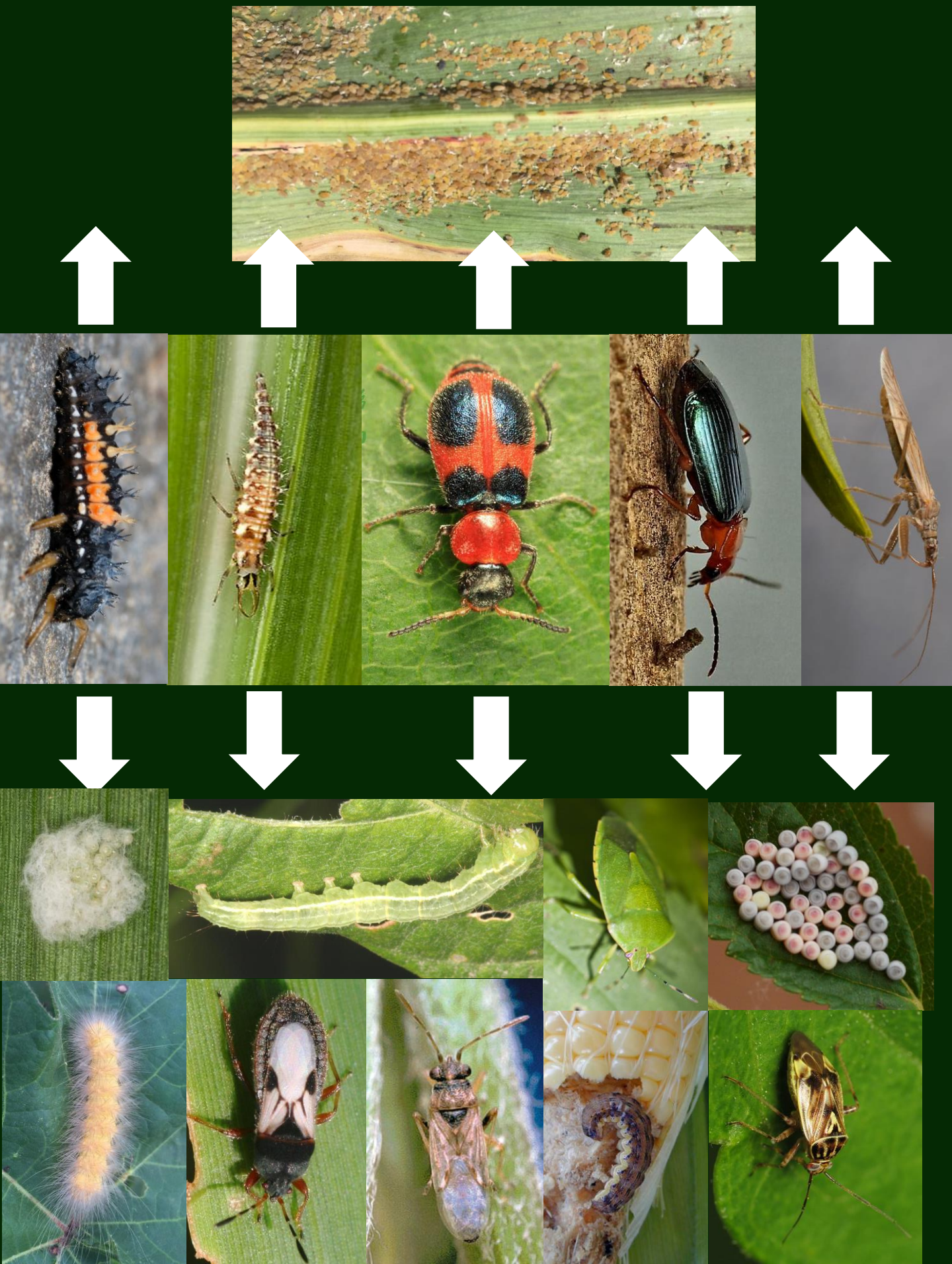
A non-native parasitoid that ‘piggy-backed’ on the soybean aphid invasion to gain a foot-hold in North America

A. certus has a relatively broad host range in the Aphidinae, and may well broaden its host range in NA over time

Horizontal Trophic Impacts: Predator Diversion

A consequence of optimal foraging theory:
Generalist predators will focus on the most profitable prey

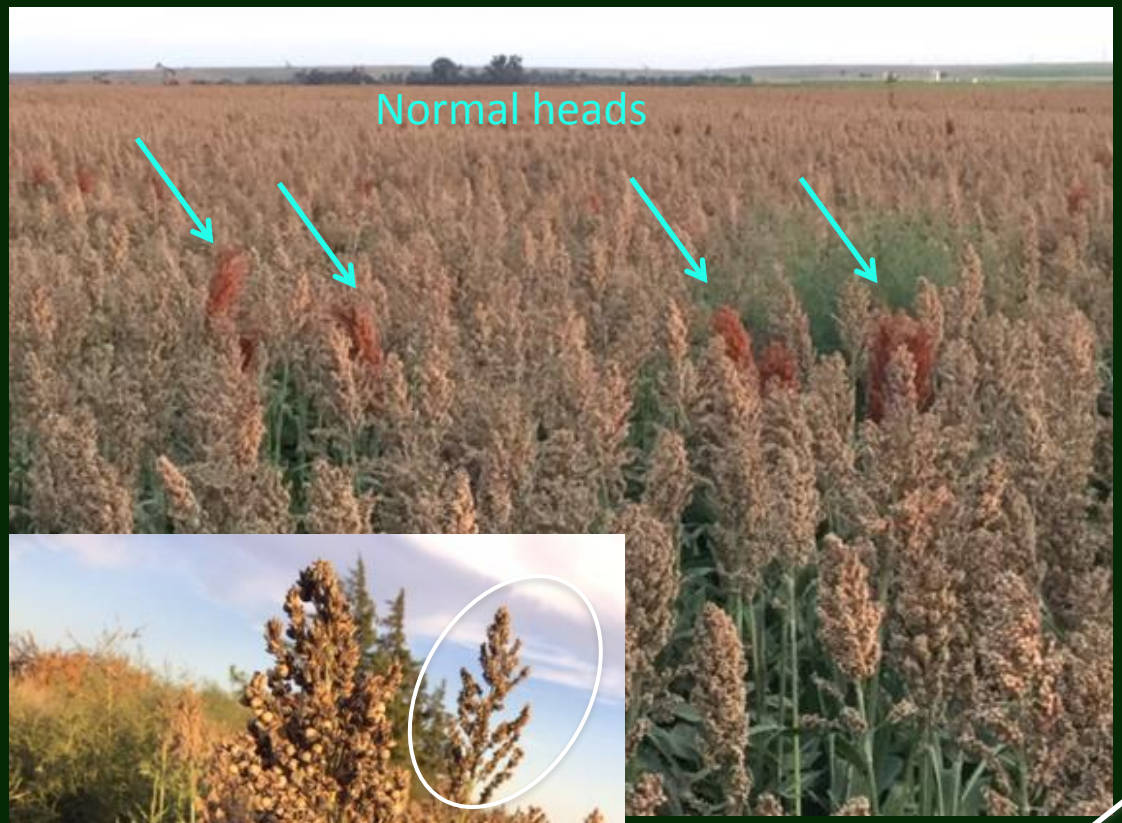
Combine headers with
Melanaphis sacchari



Adult lygus bugs can enter sorghum and damage milk-stage grain after displacement from other fields

Lygus bug

False chinch bug



Blasted grain

Sorghum field in 2016 with 50-60% yield loss
due to feeding by false chinch bugs and Lygus bugs
Predators controlled the SCA in this field!

Conclusions

Aphid invasions create ecological cascades that can have both temporary and permanent impacts on arthropod communities

An abundance of prey results in large natural enemy populations, creating evolutionary opprtunities for these species

Most horizontal trophic impacts result from predator diversion, and will be temporary, subsiding with the outbreak aphid populations

Novel predator-prey and parasitoid-host relationships once formed, are likely to be permanent

A series of successful generations in a crop can potentially result in natural enemies evolving novel plant associations, although how this occurs remains obscure