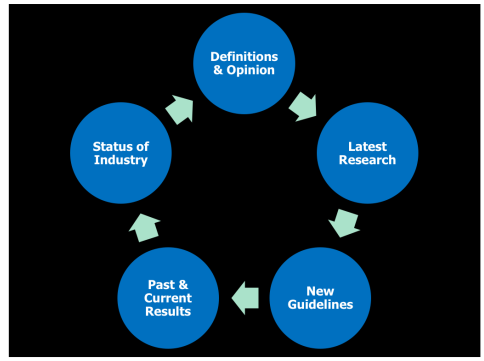
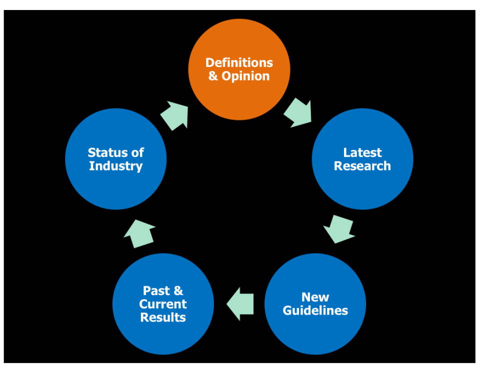
My presentation will focus on new research that is specific to the cotton system. However, I'm going to try to broaden the theme somewhat to better draw in everyone in attendance, because there are hopefully some fundamental lessons that we can learn from and that may have impact on how we think about and even do our work in our respective professions.

Invited presentation, AzCPA, Desert Ag Conference, Chandler, AZ; 30 min.; 0.6 CEU

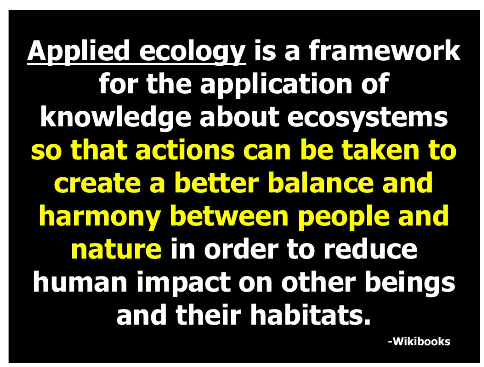


I have a bit of a circular outline for my comments today, and I will touch on each of these areas including the newest research that we are doing.



However, I'd like to place the spotlight first on some definitions and opinions about those definitions. I'm at risk starting my talk this way — there's rarely a perfect definition of anything. But I think it is important to introduce these definitions as a way to stimulate dialog about where our industry is and what it is we're all trying to do.

For me, when asked, I tell people I work in Integrated Pest Management (IPM). Unfortunately, that's not a term that is well understood among lay audiences, nor is it one that translates well even in scientific circles. As a result, I often clarify by saying that I work in "Applied Ecology". People recognize "ecology" as something probably good and "applied" communicates that I'm working with purpose, for the benefit and use of others.



So, what then is applied ecology? Here is a fairly standard definition that can be found on the web. Notice the emphasis on creating a better balance and harmony between people and nature.

Applied Ecology/Introduction. (2017, July 31). *Wikibooks, The Free Textbook Project*. Retrieved 23:38, May 8, 2018 from https://en.wikibooks.org/w/index.php?title=Applied_Ecology/Introduction&oldid=3252771.

Balance and harmony is something we certainly did not have in the agricultural industry of Arizona in the early 1990s! We know from bitter experience just how unstable a system can be, when a new species of whitefly invaded our borders.

This was the scene we were facing when the invasive B-biotype (or Silverleaf Whitefly) came to Arizona. The numerical pressure was overwhelming and impacting not only agricultural areas, but also Arizona's largest city, Phoenix, as seen here on the campus of our local South Mountain Community College. The urban friction caused was substantial, where residents had to wear masks just to jog or ride a bike in the fall of 1992. Anyone that lived through this period of time remembers just what this can do to our production and protection systems.

Vern Stern was an observer of "balance and harmony" as well. He and his colleagues more than 50 years ago were contending with terrible outbreaks of spotted alfalfa aphid in alfalfa during the 1950s. This was a time dominated by cheap and effective, but broad spectrum insecticides like DDT used in many crops. It was also a time when "womb to tomb" spraying was the prevailing strategy for insect control. Vern proposed a rather radical idea for the time, the so-called "Integrated Control Concept".

Integrated Control (IC)

"*Applied pest control which combines and integrates biological and chemical control.* Chemical control is used as necessary and in a manner which is least disruptive to biological control."

Stern, Smith, van den Bosch & Hagen 1959, Hilgardia

At its heart, Stern's ICC boils down to this…

Again, in a backdrop of womb to tomb spraying, the idea that one would harness and even combine biological and chemical controls was quite novel. This was the precursor to the modern Integrated Pest Management concept that we rely on today.

While the ICC did not require it, emphasis turned to reducing pesticide use, and this theme has persisted through the early development of IPM on into the views of many that work in IPM even today.

IPM, Federal Definition

"Integrated Pest Management, or IPM, is a long-standing, science-based, decision-making process that identifies and reduces risks from pests and pest management related strategies."

Almost 15 years ago now, however, a "new" federal definition of IPM was introduced. It certainly is not the longest or most detailed definition. Yet, it is quite comprehensive and quite expansive, relative to past definitions. In fact, the change is significant enough to constitute a new paradigm…

This shift is important, because it takes emphasis away from "pesticide reduction" and places it squarely on "risk reduction". Why is this important? Because pesticides are not the chemical tools of old. Many are not the broadly toxic, broad spectrum post-World War tools that carried with them a number of non-target and off-target effects. Pesticides have, in fact, changed in significant ways. Where we were once spraying pounds and gallons per acre of these materials, and often times repeatedly, we now use grams and ounces very sparingly throughout most of agriculture.

It also was less a process-based definition that so many of us had grown accustomed to — IPM = a combination of tactics — moving more to an outcome-based definition. We can all agree generally that risk reduction is a good thing.

Risk reduction can come in many forms and is a universally understood concept. The federal definition of IPM identifies it as a risk reduction strategy that will limit risks to people, property, resources (economic and otherwise), and the environment, from the pests as well as the full complement of pest management practices that might be deployed against that pest.

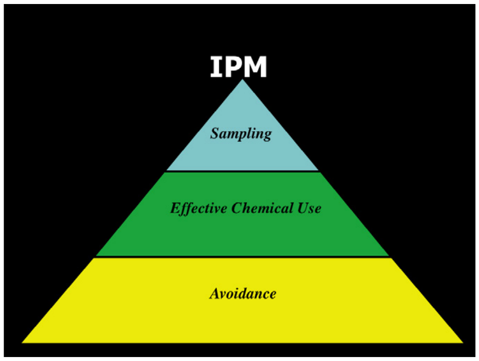
Is IPM applied ecology then?

Well as you might imagine, not all scientists through history have been in agreement on this point. Even today, there are fine points of debate among scientists.

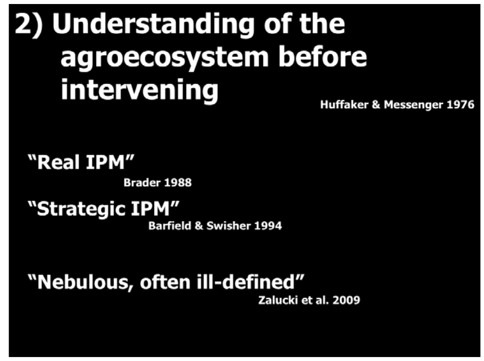
Zalucki et al. (2015), like many before him, recognize two broad schools of thought regarding what IPM "really" is in practice. The 1st school of thought has its roots in writings that date back to the 1940s and suggest "responsible use of pesticides". While everyone might agree that this is an important goal, is this all that IPM is?

Critics of IPM through history and from this school of thought have suggested major limitations of IPM…

And, while some of these are from writings now 25–35 years old, as recently as 2009, Zalucki was still critical of how IPM is practiced, "Sample, spray and pray".



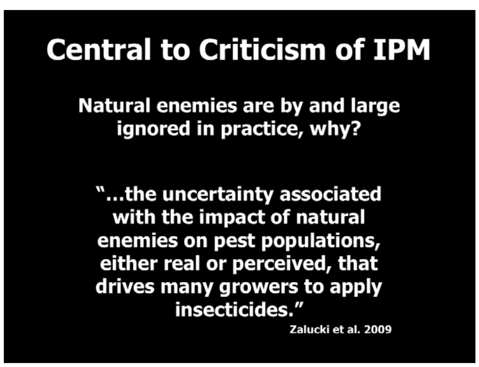
Anyone that attends our Extension meetings where I am speaking knows that I have shown pyramid representations of IPM just like this. While very reminiscent of "Sample, spray, and…", there should be a very broad set of avoidance and prevention practices creating the foundation to any IPM strategy.



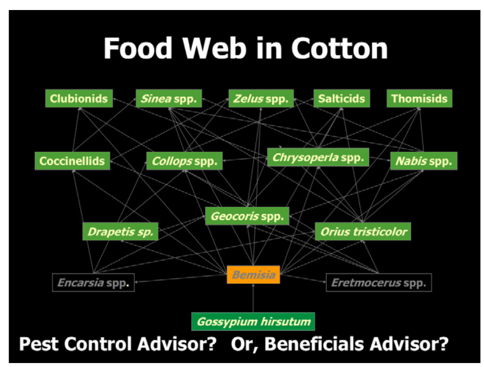
The 2nd school of thought, which surfaced shortly after IPM was so-named, suggested that understanding the agroecosystem prior to intervening with pesticides or other control inputs was at the heart of IPM.

This approach is considered more strategic and consistent with the academic vision for IPM.

However, Zalucki has suggested that this "understanding" is all-too nebulous and often ill-defined. What does it really mean to understand the agroecosystem? And, how much understanding is needed before practical application of IPM is possible?

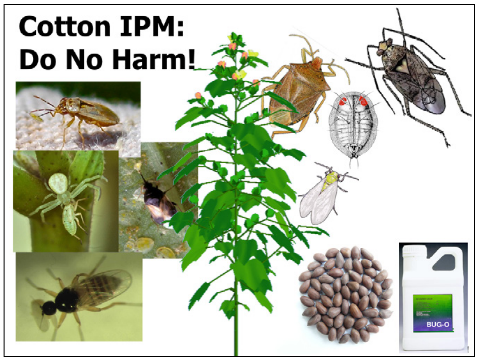


Central to Zalucki's and many others' criticisms of IPM as it is actually practiced is that natural enemies are all but ignored, in large measure because of the uncertainty associated with their impact on pest populations. This is what drives growers to the easier and often more effective or at least immediate insecticides.

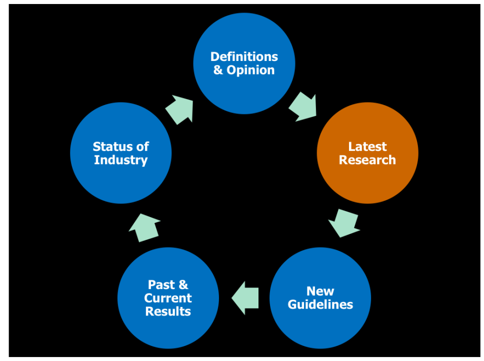


This is the challenge that faces cotton pest managers today in Arizona. Cotton is an agroecosystem rich with generalist predator fauna that feed on whiteflies, other pests, and even each other. And, these dozen species shown here are representative of yet another dozen or more present in the system. How is it that we gain enough insight into just this part of the agroecosystem in order to better manage pests? And, is managing pests what we should be doing principally any more? With all the interests in bees and other pollinators, perhaps Pest Control Advisors should start thinking about and marketing themselves as Beneficials Advisors!

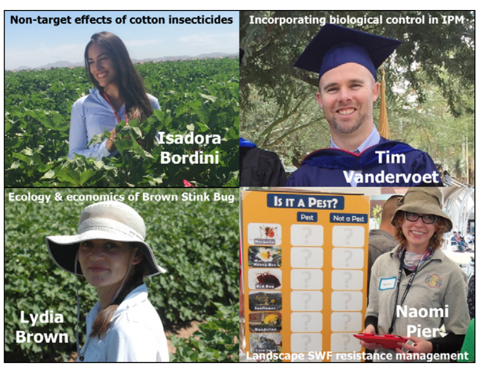
This is the challenge for the next generation of pest managers.



In many ways, the PCA profession mimics the medical profession where their credo, first and foremost, is to do no harm. The human body is a complex ecosystem, too, just as is agricultural ecosystems where a grower and pest manager must simultaneously consider the pests, the technology and the beneficials in their production system.



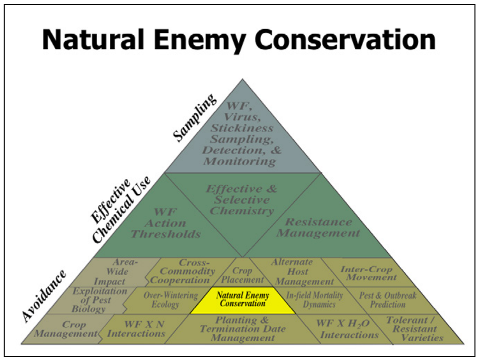
Next, I'd like to review some of our latest research that relates to unraveling the complexity of the cotton IPM system of Arizona.



And, the best way to do this is through an introduction to the graduate students and their work they have done in my laboratory, many of who have been co-advised by my partner in research, Dr. Steve Naranjo from USDA-ARS.

Isadora Bordini & Naomi Pier are currently working on their Masters. Lydia Brown graduated with her Masters and Tim Vandervoet with his Ph.D., both in 2017.

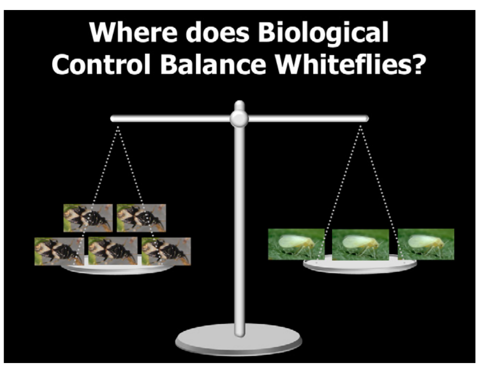
The agricultural disaster in cotton of the early 1990s showed just how disrupted our agroecosystem could be. While devastating at the time, it did fuel interest and innovation in research and Extension to identify and deploy better systems.



It is what ultimately led to the very advanced IPM system we have today that has central to our program of avoidance, natural enemy conservation. Tim recognized that while we depended on conservation biological control, we really needed to know more about this agroecosystem in order to more fully reap the benefits of conservation biological control.

Specifically, it was apparent that we needed a system for measuring the benefits of biological control in cotton.

Photo: Tim and Peter measuring biological control in Mexican cotton field.

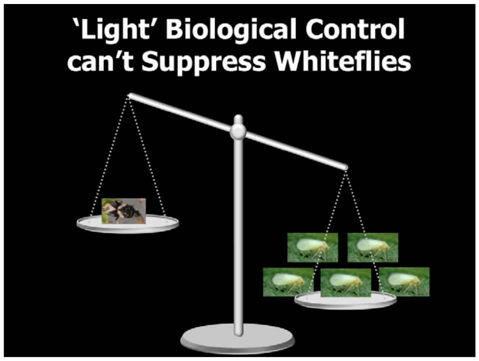


Tim wanted to answer this basic question. Where does biological control balance whiteflies?

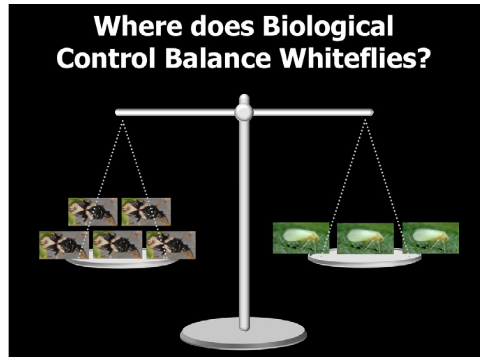
Knowing when things are in balance will also help us understand when things are out of balance. When things are out of balance in our favor, lots of predators relative to whiteflies, sprays could be deferred or potentially eliminated. When things are out of balance against out favor, too few predators for the number of whiteflies present, sprays would have to be used perhaps even sooner than normal.

Thus, there could be specific ratios, predators to prey, that govern specific actions by growers.

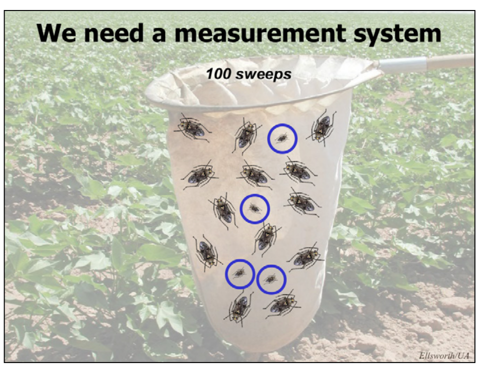
With high predator : prey ratios, when predators' effects outweigh the whiteflies, their potential for damage to the crop is minimal and sprays should be deferred.



Similarly, when predator densities are very low relative to higher whitefly densities (low predator : prey ratios), predators' effects can't suppress whiteflies or their impacts. Sprays are needed under these conditions, even sometimes before the usual action threshold for whitefly control.



The question to be answered here is deceptively simple, but represents a complex ecology of the system. Some things are needed, too, to make such information practically available to pest managers.

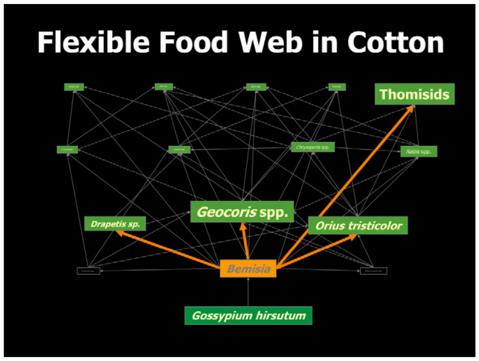


We need a measurement system for the natural enemies in our system. And, conveniently, PCAs in our system routinely sweep cotton in order to monitor for Lygus bugs. These same sweeps can be used to count key natural enemies and estimate the size of their populations.

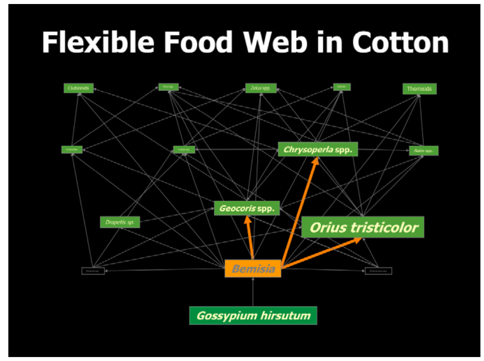
We have a large complement of potential generalist predators. About 20 or so, and just a few pictured here.

[We also have 2 parasitoids; however, Anaphes, an egg parasitoid, will not readily colonize cotton; and I've seen Peristenus (nymphal parasitoid) just once in 27 years.]

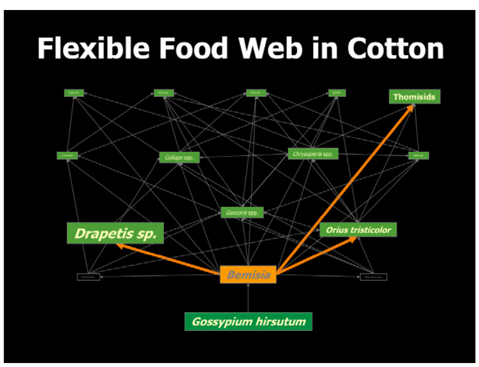
These predators play a role in primary pest control (whiteflies and Lygus), while suppressing/controlling all secondary pests (mites, leps, etc.).



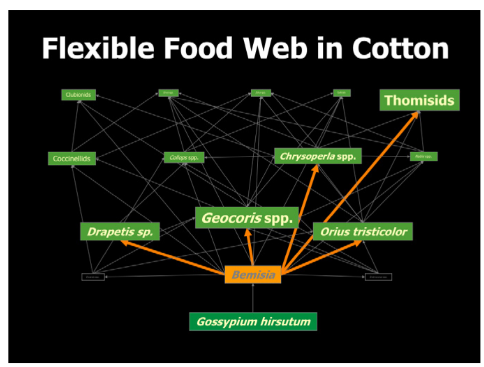
The food web under study is highly flexible and variable. Species importance is represented by a set of species weights in each field under study. Here I have represented these weights by sizes of their labels in the food web. In this particular year for the cotton-whitefly system, we can see that there are 4 species that dominate the system for that year and location (i.e., for the Principal Response Curve calculated for this trial).



However, in this year and location, these three species are driving the system.

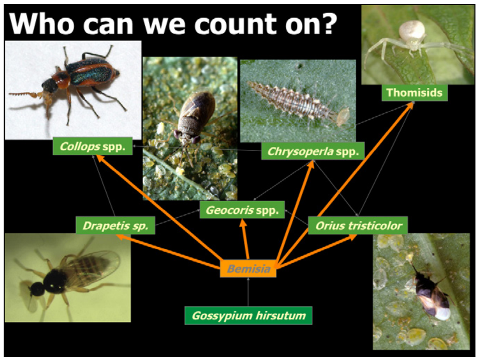


And a different set of 3 species in this year.



And 5 species dominated the system in this year.

So this is a testament to the resiliency and flexibility of a complex food web that has multiple membership by generalist predators. Each year, each location might be more or less affected by any number of predators. This is also why studying single species or very small species assemblages in lab or caged studies are less informative of the dynamics that really play out in the cotton system.



Over many years of intensive field study, Naranjo and I have found that most often one or more of these six predators dominated the relationship between whiteflies and their predation. Tim's work definitively confirmed that these are in fact the key predators of our cotton – whitefly system. They include:

A small empidid fly that feeds exclusively on whitefly adults (not eggs or nymphs) and other insects.

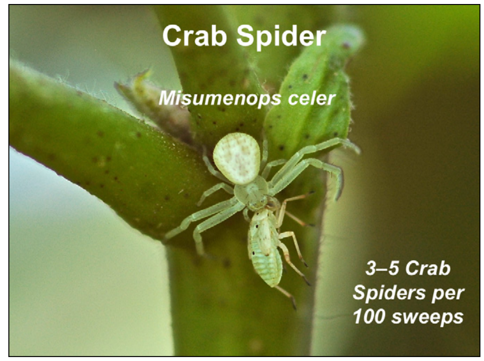
Collops beetle.

Big-eyed bugs.

Lacewings.

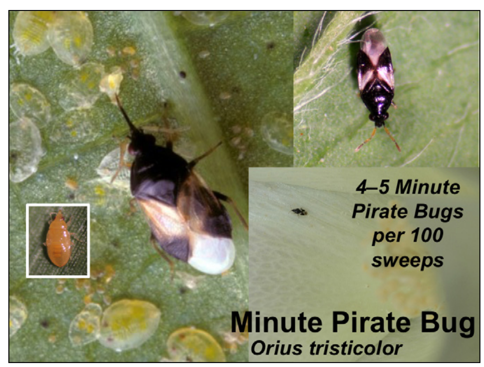
Crab spiders (though other spiders can also be present in large numbers).

Minute Pirate bugs.

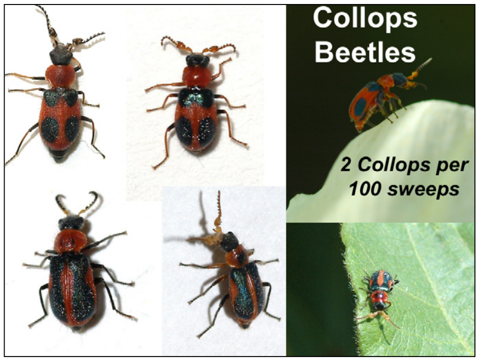


Tim determined that there were critical ratios of each of these predators to whitefly prey that indicate the balance we are seeking for biological control. For crab spiders, when 3–5 spiders per 100 sweeps are present and whiteflies are at or near threshold, it is possible to continue deferring a spray against those whiteflies. If levels fall short of this for crab spiders, a spray might be needed even sooner to protect against whitefly losses.

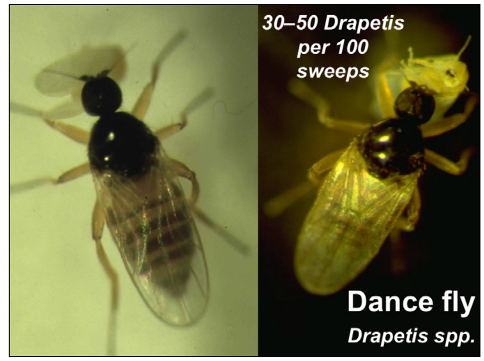
For big-eyed bugs, 1 per 100 sweeps is needed.



For Orius or minute pirate bugs, 4–5 per 100 sweeps are needed to defer spraying.

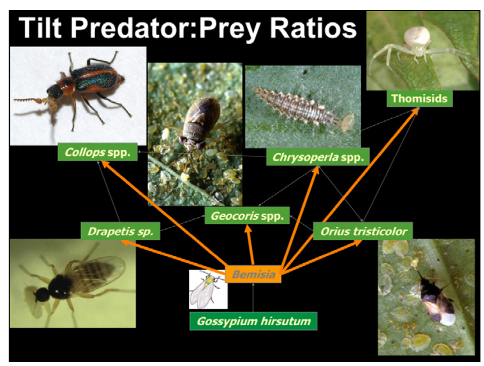


For Collops beetles, of which there are two species in Arizona fields, 2 per 100 sweeps are needed.

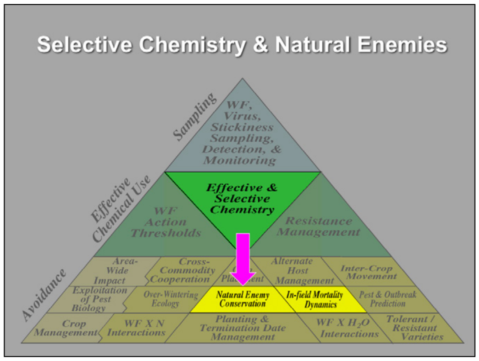


For Drapetis flies, a very small predaceous fly with a nervous movement in the net, you would need 30–50 per 100 sweeps to continue deferring a whitefly spray around threshold.

Lastly, lacewings, in particular, lacewing larvae at levels of 1–2 per 100 sweeps indicates a well-functioning biological control when whiteflies are near threshold.

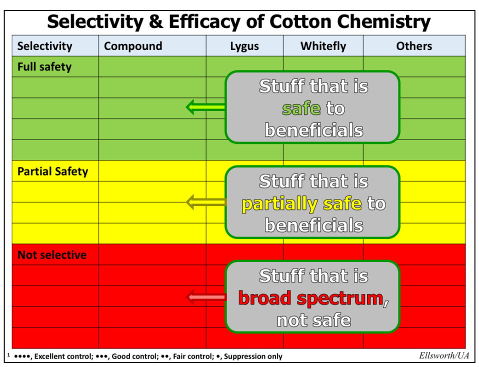


The goal once again is to achieve a "balance and harmony" that tilts the ecology of the system towards our effective predators for biological control.

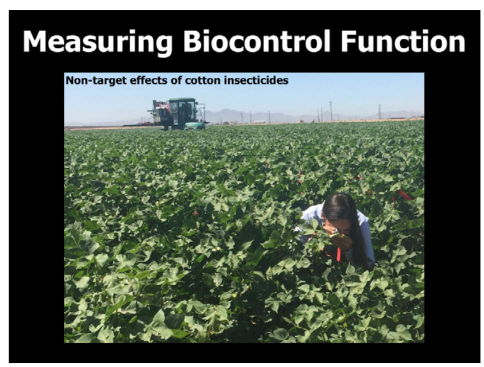


All of this, of course, is predicated on our access to selective chemical controls and our ability to conserve the natural enemies that are present in our fields. This requires understanding of the ecology of chemical control. Which products are safe to beneficials and which are not?

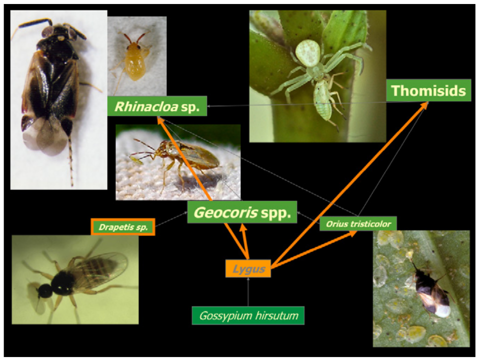
The study of these non-target effects of cotton insecticides is the topic of my student, Isadora Bordini.



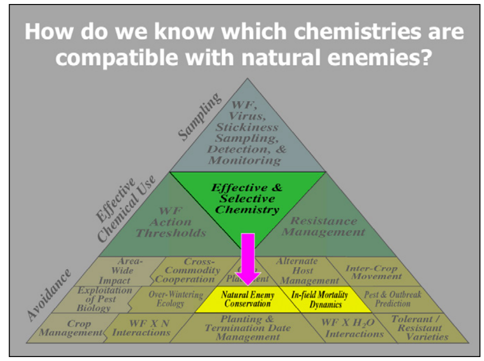
Our goal is to inform growers about those compounds that are safe to beneficials, those that are partially safe, and those that are broad spectrum and not suited to natural enemy conservation. This stop light metaphor is a convenient way to organize our chemistry, but should not be taken to mean that broad spectrum chemistries are never needed. There can always be those scenarios where and when they are needed precisely because of their broad-spectrum control of arthropod pests for which we have no selective alternatives.



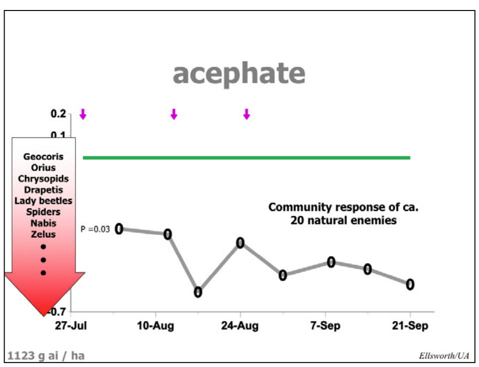
Isadora will take our assessments one important step farther by directly measuring biocontrol function in her studies. This is a painstaking method to track and measure the removal of prey, in this case whiteflies, from the system.



The cotton food web is complex, dynamic and resilient. But how does one measure the community effects of insecticides on this food web?

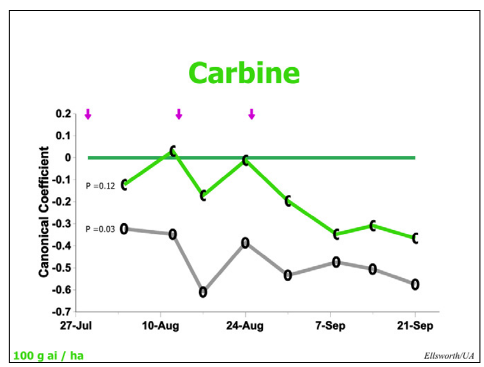


In short, how do we actually know which chemistries or products are compatible with natural enemy conservation?



We do this through standard field procedures, repeated sprays of candidate insecticides in contrast to unsprayed checks, counting what remains after each of these sprays, and analyzing them with these Principal Response Curves shown here. These charts show the response of an entire community of predators and other beneficials after spraying with insecticides and in comparison to an unsprayed check (green line). The unsprayed line is kept constant and what we see is the relative change in the aggregate density of predators compared to that check (represented as canonical coefficients).

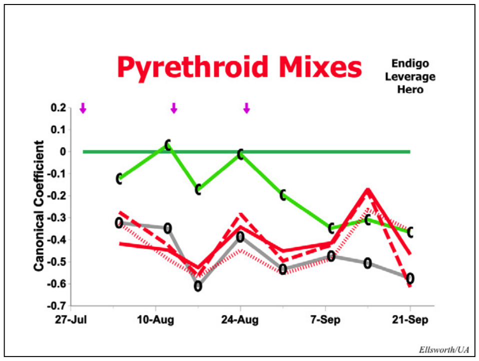
This chart shows us what many already know. Acephate or Orthene sprayed on cotton will significantly reduce the number of natural enemies present relative to the unsprayed check.



Carbine at the maximum labeled rate turned up not significantly different from the UTC, i.e., fully selective or fully safe to beneficials in our system.

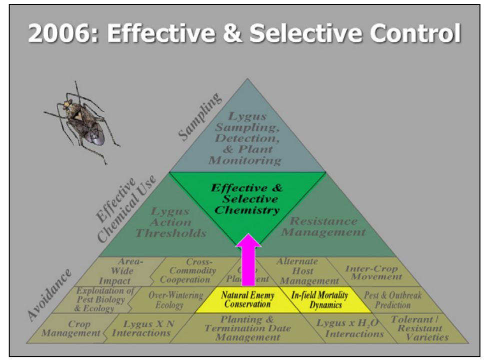
[The late season decline in numbers could reflect the declining amount of prey items, in this case Lygus, for predators to feed on in the Carbine plots. In other words, Carbine has effectively controlled Lygus there.]

09F3L 2.8 oz of Carbine

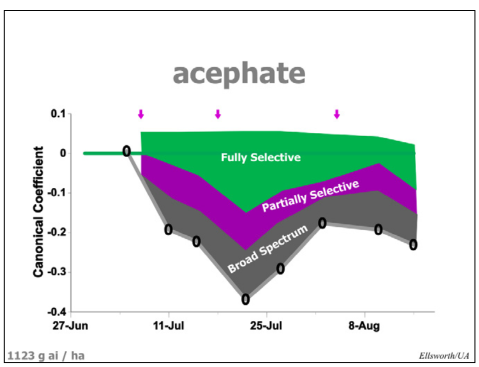


If there is any doubt, pyrethroid mixtures are very potent and damaging to natural enemy populations, just as damaging as Orthene.

09F3L Hero, Endigo, Leverage360Hi



2006 was an important year in the development of selective systems for Lygus control, with registrations of flonicamid or Carbine.



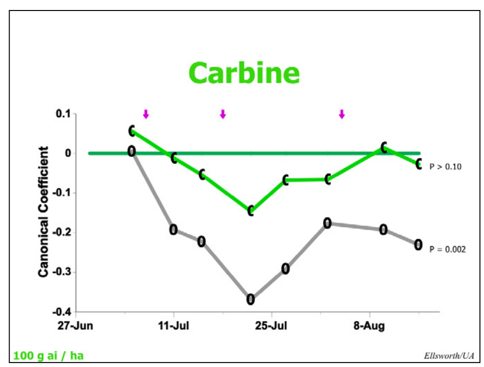
Our system of evaluation allows us to categorize insecticides as either fully or partially selective, or broad spectrum.

Responses at or near the response of Orthene would signal a compound with broad spectrum impacts on this natural enemy community (ca. 20 species).

Responses at or near the y=0 or untreated check line would signal a compound with great safety for the natural enemy community, which we term fully selective.

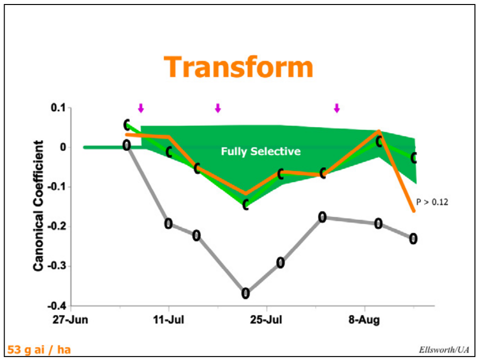
Responses falling between these two zones would be classified as "partially selective".

11F32NTO



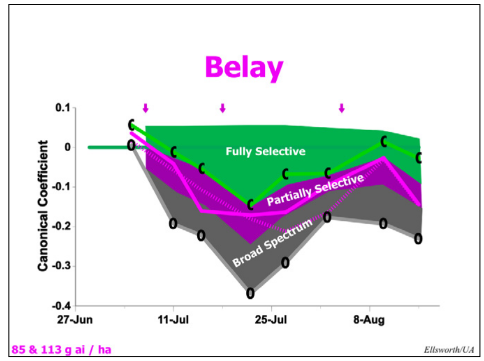
Again, Carbine at the maximum labeled rate was once again not significantly different from the UTC, i.e., fully selective.

11F32NTO 2.8 oz of Carbine sprayed 3 times



Transform at the Lygus rate (at 1.5 oz/A) was not significantly different from the UTC and fell at or above the Carbine line in most cases, i.e., fully selective.

11F32NTO 1.5 oz of Transform sprayed 3 times



Belay was tested at two rates, 4.5 and 6 oz / A (solid & dashed line, respectively). In general, the response falls between the broad spectrum and fully selective zones; i.e., partially selective, regardless of rate used.

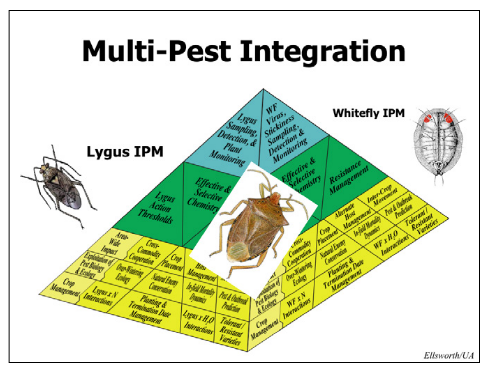
11F32NTO 4.5 & 6 oz rates of Belay, each sprayed 3 times

So what happened here? Inappropriate selection and use of a broad-spectrum Lygus insecticide (acephate, Orthene) destroyed the NE complex. Only this time, whiteflies did not resurge nearly as much as did two-spotted spider mites. The resulting stress on the plants defoliated the entire plot right down to the row. In contrast 3 sprays of any of the other products including Transform at 1.5 oz / A (or no sprays at all, UTC) resulted in conserved NEs that were critical in maintaining <u>natural</u> control of spider mites.

These sorts of results on a large plot basis give us the confidence to categorize products as to selectivity in our system.

11F32NTO, 2011 large plot study, 3 sprays at roughly 2 week intervals; effects visible prior to 3rd spray.

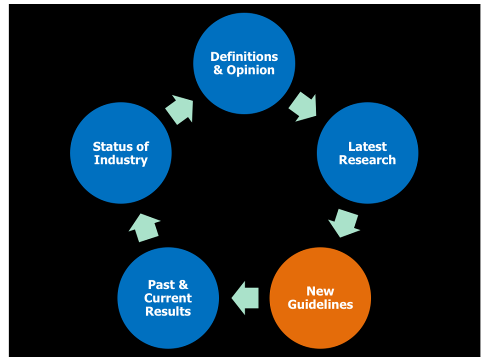
This is a non-target study.



Our IPM system is not for a single pest; it is integrated over the full range of key and other pests present in the system. Sometimes things change and another potential pest emerges like the brown stink bug which first broke out in 2012 after nearly 50 years since the last outbreak in Arizona cotton.

This is where Lydia Brown's work came in. After a wide range of studies and very detailed economic assessments, Lydia concluded that chemical control for Brown Stink Bug was a losing proposition with net losses possible, in part because of the very poor efficacy of any chemical control and in part because of the cascade of negative effects of using these broad spectrum insecticides, which destroyed natural enemies and increased costs of control for mites and whiteflies.

New Research & Trends in Cotton Insect Control May 9, 2018



With each student's work and other research, we revisit our guidelines and make the necessary changes and additions.

New Research & Trends in Cotton Insect Control May 9, 2018

Selectivity & Efficacy of Cotton Chemistry

Selectivity	Compound	Lygus	Whitefly	Brown stink bug
Full safety	Courier		•••• (N)	
	Carbine	••••		
	Knack		•••• (E,N)	
	Oberon[1]		•••• (N)	
	Transform	••••	•	
Partial Safety	Assail / Intruder		••••	
	Belay	••	••	
	Venom		•••	
	Centric		••	
Not selective	Pyrethroid			•?
	Acephate	•••		•?
	Bidrin	•		•?
	Diamond / Rimon	•	•	•?
	Vydate C-LV	•••		

Exirel Sivanto PQZ

Cormoran ○○

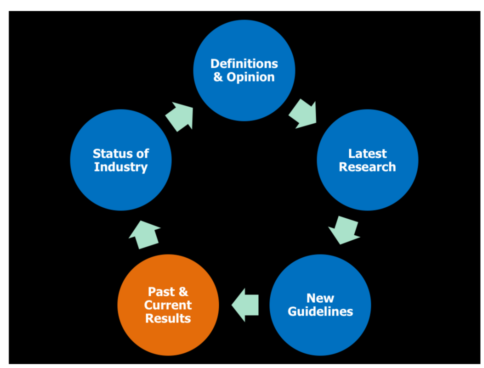
[1] At 0.125–0.156 lbs ai / A only (4–5 oz); ••••, Excellent control; •••, Good control; ••, Fair control; •, Suppression only *Ellsworth/UA*

This table summarizes what we know about cotton chemistry and its efficacy and selectivity against our two key pests and the brown stink bug.

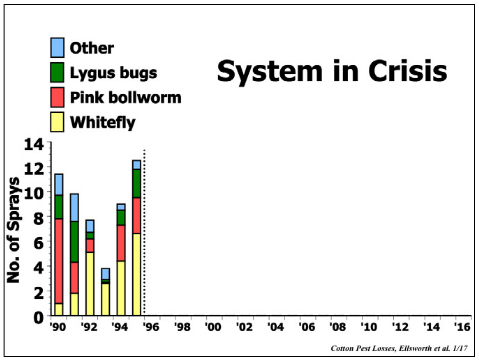
We have excellent options in whitefly control, even in the face of developing resistances. And, we have fewer, but excellent options in Lygus control. Transform is particularly well suited to our system as the only compound with at least some efficacy against both Lygus and whiteflies while being fully selective and safe to beneficials.

At present, we do not have effective <u>or</u> selective options in the control of the brown stink bug. And, Lydia's work makes it clear that chemical controls should not be deployed for brown stink bug. Isadora's work will help us determine just where Exirel, Sivanto, and PQZ go in our table.

New Research & Trends in Cotton Insect Control May 9, 2018



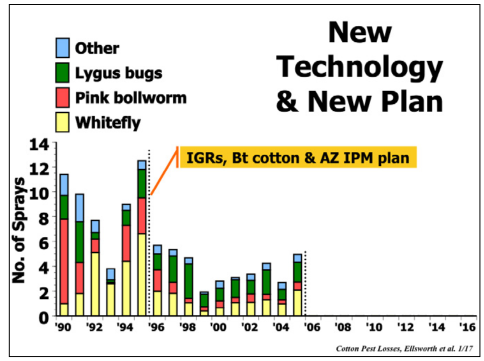
Because of the dedicated cooperation and collaboration with PCAs and growers, we have a rich source of data with which we can assess the past and current outcomes of our IPM systems.



Our Cotton Pest Losses data on number of sprays used to control our key and other pests tells a powerful story that I share regularly with audiences.

In the early 1990s, the cotton industry was reeling after a historic PBW outbreak and the introduction of a new invasive whitefly species. This was a system in crisis and entirely dependent on broad-spectrum insecticides, because that was all that was available.

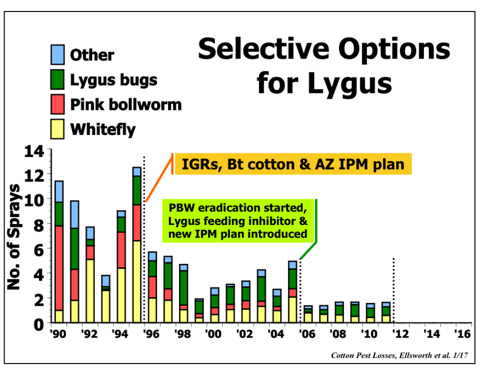
Adapted from Naranjo & Ellsworth 2009, & Ellsworth, unpubl.



New technologies and a new IPM plan began in 1996.

We gained insect growth regulators (IGRs) for whitefly management, Bt cotton for lepidopteran control, and developed a new Arizona IPM Plan. These advances in "selective" technologies and approaches to insect pest management were based on our need to better manage and conserve the natural controls in our system, such as predators of whiteflies and secondary pests.

Adapted from Naranjo & Ellsworth 2009, & Ellsworth, unpubl.

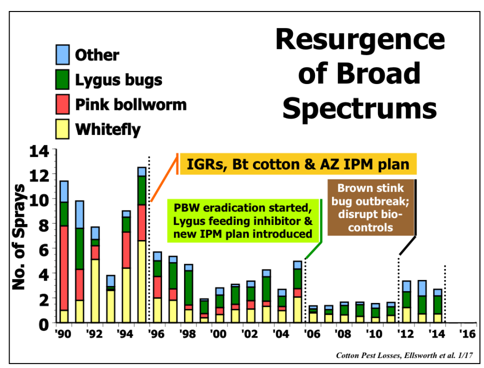


Progressive improvements to the system continued…

In 2006, we saw deployment of a selective Lygus feeding inhibitor [flonicamid (Carbine)] and the cotton industry banded together to develop a major pink bollworm eradication campaign.

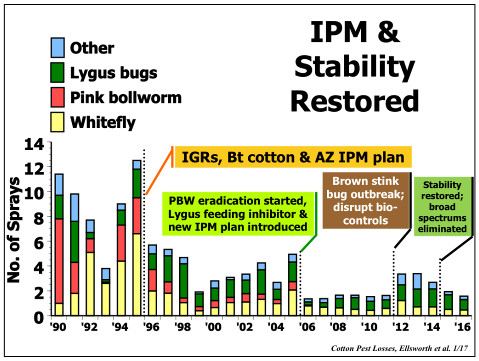
Under this new IPM plan, growers and pest managers throughout the state saw a continued lowering in the need for foliar insecticides for all insect pests, halving it once again relative to the previous period.

Adapted from Naranjo & Ellsworth 2009, & Ellsworth, unpubl.



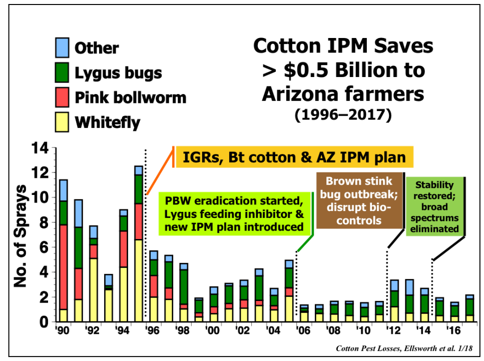
Set-backs occur, too! An outbreak of a native pest that hadn't been seen in damaging numbers since 1963. The brown stink bug brought with it efforts to control it with broad spectrum chemistry.

In 2012, we see an increase in the use of broad spectrum insecticides in response to elevated populations of BSB. In many areas, the use of broad spectrum insecticides disrupted biological control and led to resurgences of whiteflies and outbreaks of mites.

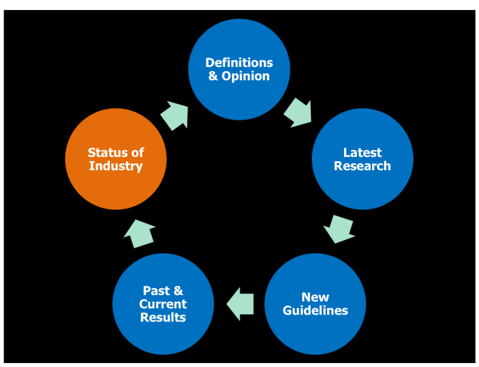


By 2014–2015, most growers were abandoning efforts to chemically control brown stink bugs. Our research was showing that most chemistries did nothing at all and even the best ones were not efficiently killing brown stink bugs in a large degree. It also showed that these broad spectrum chemistries were creating conditions for primary pest resurgences (Lygus and whiteflies) and secondary pest outbreaks (mites and others).

With the return to little to no use of broad spectrum insecticides, stability returned to our system.



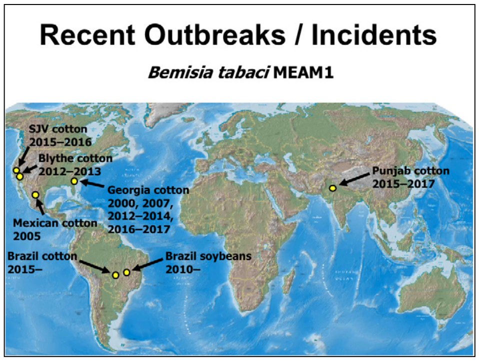
And that stability continues through till today. 2017 saw slight increases in pest pressures but still relatively low numbers of sprays required, just 2.2 on average. The average since 2006 stands at 2 sprays ± 0.2 sprays, and 1.88 sprays over the last 3 years.



What is the status of the cotton industry more broadly?

Look at this video and guess when and where it was shot?

In southwestern Georgia in 2017! This part of Georgia has struggled for some time with whiteflies and has cropping system characteristics similar to Yuma, i.e., vegetables and field crops growing nearly year round. However, they have not coped well and there were widespread scenes just like this. In my opinion, they are not following the Arizona program and example, and they have not established the "balance and harmony" needed in their system.

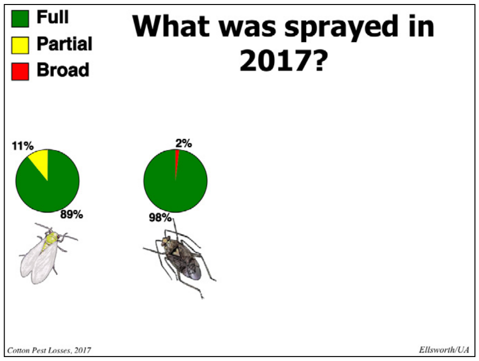


If one traces through the recent outbreaks of whiteflies worldwide, a pattern starts to emerge. From outbreaks over the last decade or so in Georgia, to problems in California, to elimination of the cotton industry of Yaqui Valley of Mexico, and the rapidly increasing cotton and soybean industries of Brazil, to the old world and cotton in the Punjab region of India and Pakistan, one common theme emerges: overuse and/or over-dependence on broad spectrum insecticides for control of whiteflies or other pests in their systems, a total loss of "balance and harmony."

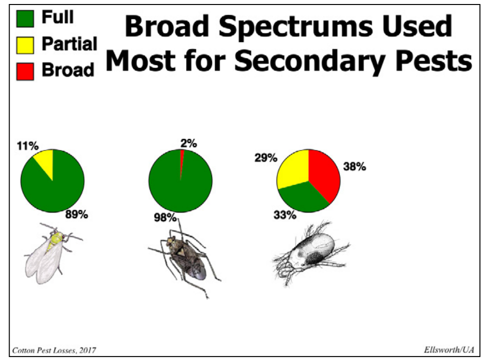
For the younger members of our industry, they may not have ever experienced or even heard of "sticky" cotton, the phenomenon where honeydew excreta from whiteflies falls onto and contaminates exposed lint, which then disrupts the processing chain and causes major losses to mills. The last "stickiness" episode we experienced in AZ was more than 23 years ago! Kudos to everyone in our industry who makes sure our cotton is clean. But the problem is not far from home. Recent reports in the ag press document a 2-yr period in California where stickiness has become a real issue for them.

As devastating as whiteflies were to U.S. farmers, real tragedy was felt in Pakistan where losses extended to 2/3rds of the crop and farmers were actually killing themselves.

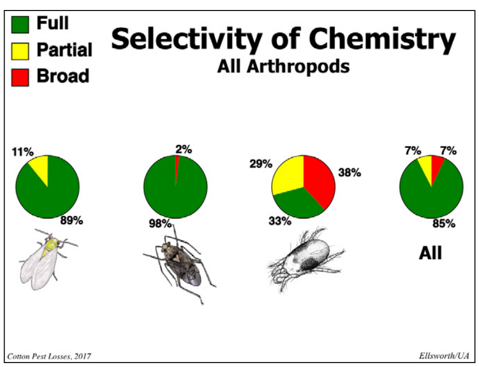
In 2005 here, we saw scenes like this from the Yaqui Valley of Sonora, Mexico. This was the appearance of 7-leaf cotton in some areas, completely encrusted in whitefly nymphs. The growers invited me there again this past April over concerns that they <u>not</u> repeat the episodes of 2005. In 2005, fields like this had already been sprayed 4 times with methamidophos, endosulfan, and dimethoate for thrips and aphids. To recover from the induced whitefly problem, this grower had to apply acetamiprid (Rescate = Intruder) multiple times. The overall approach was very costly.



This makes the achievements here in Arizona all the more impressive. The character of the chemistry used today in Arizona cotton is unlike in any other system with major insect challenges. The vast majority of sprays deployed for whitefly or Lygus control are fully selective or safe to the natural enemies of this system. A small portion are "partially selective" and only the smallest fraction are broad spectrum insecticides.

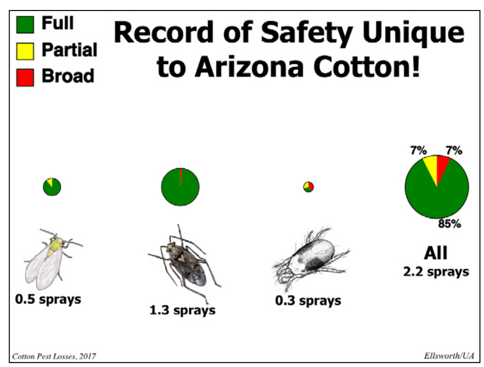


Secondary pests by their very nature should only occasionally require controls, when primary pests are properly managed. However, spider mites, aphids, thrips, stink bugs and others are occasionally sprayed in our system. Unfortunately, selective approaches do not exist for all of these targets. As a result, over 1/3rd of our sprays against secondary targets are with broad spectrum chemistries.



Overall, less than 10% of what is sprayed is broad spectrum.

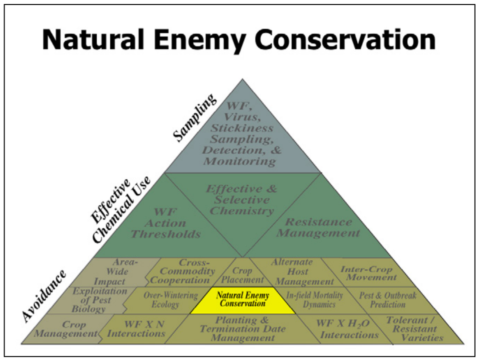
But this is just the proportions of use. When we scale this same information according to the actual number of sprays made, we see and even more dramatic trend…



This depicts the same data but with the distributions scaled according to actual usage (with average no. of sprays noted).

It is quite clear that growers have embraced selective technologies to control their major arthropod pests, and done so despite their higher per application costs.

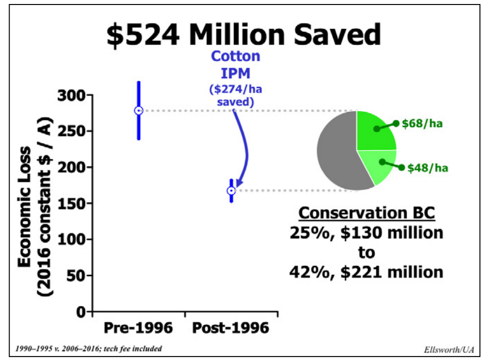
It is likely that no other system can show a similar pattern of limited insecticide use largely made up of fully selective materials. It is an exemplar of how to strategically build an IPM program that does integrate biological and chemical controls, and of stewardship of technologies.



Zalucki was critical of IPM, as preached by academics and as practiced by the masses, in large part because natural enemies have been largely ignored.

Not true in Arizona cotton! Nor, do we have a fuzzy understanding of our system. We have detailed information on natural enemy effects, numbers and identities, as well as on precisely how they fair with the chemical controls we currently have access to. Together with information on sampling and thresholds, PCAs can in fact be beneficials advisors.

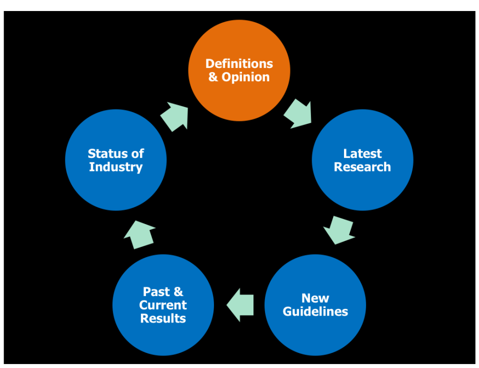
[In a survey conducted 2015, we asked Arizona pest managers (PCAs) how much do they value biological controls in cotton. While the range was large, the average response was $108/ha or about $44/A. This recognition by practitioners is the economic incentive to implement the plan developed and represents an awareness not seen in many systems.]



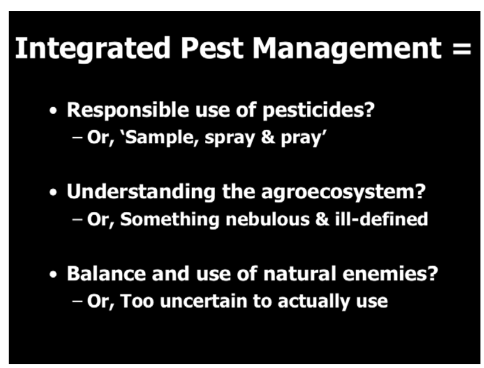
The gains through history since major adoption of both 'soft' and 'hard' technologies are very large for this industry sector. We estimate that since 1996, Arizona cotton growers have saved at least $523,533,918 through the 2016 cotton season, or ca. $274 / ha / year*. What portion is due to biological control? Based on this analyses, we believe up to $221M (or 42%) of these savings were due to the conservation biological control that is enabled by the improved IPM programs.

[This estimate does not attempt to incorporate the additional benefits of preserving an economy and culture that may not have been possible if not for the advances made at the time. It also provides a low end estimate just because Pima cotton was included at Upland cotton prices which are considerably lower.]

***inclusive of costs to the grower of Bt trait technologies.**



We return here now to re-consider the definitions I offered at the start of my talk.



Is integrated pest management merely "responsible use of pesticides", "sample, spray and pray"?

With our IPM, do we understand the agroecosystem? Or, is this just a fuzzy, nebulous thing?

Do we have balance and harmony? Are we using natural enemies? Or, are things all too uncertain to deploy?

I would suggest that at least when it comes to Arizona cotton, growers here are practicing a level of IPM only rarely seen and reaping benefits only rarely measured. I think the state of the industry is strong, far more resilient than the disrupted system of the early 1990s!

IPM
~~Applied ecology~~ is a framework for the application of knowledge about ecosystems **so that actions can be taken to create a better balance and harmony between people and nature** in order to reduce human impact on other beings and their habitats.

Furthermore, I would suggest that not only do we satisfy the criterion for "balance and harmony" in applied ecology, we can confidently say that IPM is in fact the application of ecology in managed ecosystems that benefits people yet reduces our impact on other beings and habitats.

Applied Ecology/Introduction. (2017, July 31). *Wikibooks, The Free Textbook Project*. Retrieved 23:38, May 8, 2018 from https://en.wikibooks.org/w/index.php?title=Applied_Ecology/Introduction&oldid=3252771.

Funding & Support

Grants from:
Arizona Cotton Growers Association
Cotton Incorporated
USDA-NIFA, Extension Implementation Program
Western IPM Center, Project Initiation Grants
Western IPM Center, Crop Pest Losses & Impact Assessment Signature Program

And support from agrochemical industry

The University of Arizona
College of Agriculture and Life Sciences
Cooperative Extension
Arizona Pest Management Center

Arizona Pest Management Center

USDA United States Department of Agriculture National Institute of Food and Agriculture

Western IPM Center

Collaborators:
Dr. Al Fournier
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Lydia Brown
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Tim Vandervoet
Naomi Pier

PCAs & growers statewide

Ellsworth/UA

I'd like to close with the long list of funding organizations and other supporters and collaborators that have been instrumental to the research and Extension programs that support the success of the cotton industry.