Insect Insider

Popular science articles by graduate students at UC Riverside Entomology Department

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Ants in extreme environments: will they persist under changing climates?

Madison Sankovitz

The Namib Desert of Namibia is a vast landscape of dunes under the pressure of intense heat for much of the year. With a starkly smooth landscape of sand against the bold backdrop of the sky, this ecosystem might appear to be void of life at first glance. But many unique animals thrive in this environment, especially ants. Namibia is home to the Namib Desert dune ant, which is exceptionally well-adapted to deal with the intense heat of the dunes (Curtis 1985). This Namib Desert dune ant has longer legs than most other ants on Earth. This feature allows them to keep the rest of their bodies elevated above the hot sand so that they can stay cool. Additionally, they use these long legs to sprint across the sand, reducing their time exposed to the sun while foraging for food.

Ants, in general, have adapted to survive in extreme environments worldwide. They are one of the most widespread insect families, existing on every continent except Antarctica, and take up an estimated 15-20% of terrestrial animal biomass. The vast success of ants is due in part to their ability to cope with challenging environmental conditions, such as extreme heat, especially in the face of climate change. *Cataglyphis rosenhaueri* desert ant workers tolerate thermal stress through low breathing and metabolic rates. Additionally, they have unique behaviors such as raising their abdomen to protect the vital organs within it from high temperatures (Cerdá & Retana 2000). The red honey ant is similarly thermophilic (or 'heat-tolerant'), actively foraging at soil temperatures above 70°C and able to survive for an hour at 54°C.

Natural land isn't the only habitat ants can dominate; they colonize human-built cities as well – and do quite well in these areas. To test the heat tolerance of city ants compared to rural ants, entomologists observed leaf-cutter ants from South America's largest city (São Paulo, Brazil) and those from outside the city under the heat stress of 42°C (Angilletta et al. 2007). Ants from within the city took 20% longer to lose mobility at that high temperature than ants from outside the city. This study shows that ants have not only become good at living in human-made environments, but they are becoming more resilient because of it.

Ants have also adapted to cold climates, generally appearing darker and larger in these environments. The dark coloring of the exoskeleton allows heat from the sun to be absorbed instead of reflected, and large body size allows heat to be retained easily (Downes 1965). This body size pattern is conversely demonstrated in thermophilic desert ants that live in extreme heat: the workers are all of small body size (Cerdá 2001).

Although some ants are well-adapted to today's extreme environments, how might Earth's warming climate affect ants everywhere in the long term? In short, we don't know yet, but this is a topic of current research. Anthropogenic climate change puts pressure on species without the evolutionary time for them to adapt. In a recent study, I explored how temperature shapes nest architecture. I collected *Formica podzolica* ants from high and low elevations in the Colorado Rocky Mountains. Ants nested in experimental chambers with soil surface temperatures matching the approximate local temperatures of high and low sample sites and measured nest architecture characteristics. Overall, I observed both a plastic response of nest architecture to conditions experienced during nest construction and evidence of local adaptation to differing conditions. My results suggest that subterranean ant nest architecture plays a dynamic role in colony life. My data also show that nest architecture may be a plastic trait that has contributed significantly to ants' widespread success. A five-year climate manipulation experiment in North American forests revealed that heat-tolerant ant species persist in nests for more extended periods under warmer temperatures, as one might expect (Diamond et al. 2016). But instead of species-level interactions continuing as usual, ant communities became unstable and fragile, with regular activity and movement amongst colonies diminishing. This result might seem unintuitive given the resiliency of many ant species, but this large-scale manipulation experiment gives a peek into the window of the future: destabilized ant communities could have implications for ecosystem stability worldwide. If climate warming continues as projected, many ant species that are not heat-adapted might go extinct. Additionally, if thermophilic ants dominate forest ecosystems, the soil and arboreal interactions of many birds and reptiles that prey on ants could be altered.

Ants are not only widespread, but they are considered 'ecosystem engineers', organisms that significantly change the habitat in which they live. Ants play a crucial role in regulating soil quality, are a huge food source for many animals, and control prey populations such as aphids and fungi (Folgarait 1998). If ant communities are disrupted, their ecosystem services will consequently change in unforeseeable ways. Will the ecosystem services provided by ants persist under climate change due to their resiliency in extreme climates? Will unstable communities lead to further ecosystem deterioration? Only time will tell, but scientists continue to investigate these questions, learning more every day about these dominating terrestrial insects' unique climate tolerances.

Insect Photos

A collection of insect photographs

Madison Sankovitz

The scented landscape: it's all right under our noses

Dani Ruais

She navigates on transparent wings through an ocean of colorful odors, dipping, banking, zoning in on the specific scent she needs—the specific scent that identifies the location of her next victim. Each odorous blend denotes the location of a potential host. But she's only interested in one distinct odor combination which emerges from the background haze. This precise cocktail denotes her special host.

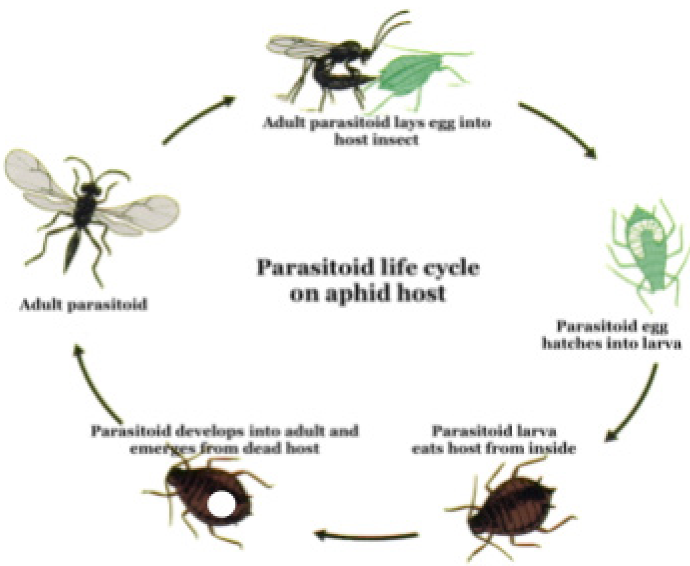


Figure 1: Figure adapted from Biocontrol Network

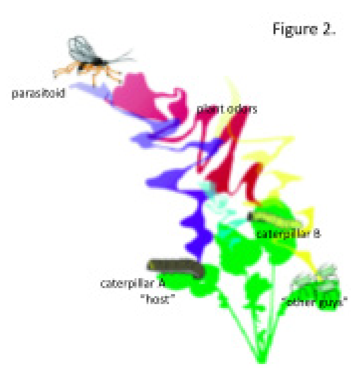
Parasitoids are rather fascinating creatures. They are typically very small insects that lay their eggs on or inside the bodies of other insects called hosts. Their eggs hatch and the developing parasitoids consume their hosts. They then emerge from their host's bodies as new adult parasitoids. But when you think of their tiny size and their need for a particular type of insect (many parasitoids specialize on only one type of host), you may ask, "how do these tiny insects find their hosts in the first place?"

The world is a big place, especially for a tiny parasitoid. These minute insects can't afford to spend all their energy flying around looking for their exact host in the vast landscape of acres of crops. They need signals like the Bat-Signal, or even GPS, to help them locate their hosts. And they are in luck, because plants have developed just the mode of communication that steers the parasitoids directly toward their prey.

This method of communication doesn't just benefit the plant, which is essentially calling "All hands on deck! There's an insect eating me!" This is a two-way relationship: the parasitoid gets a host to reproduce on and the plant is rescued from further injury by the pest. So, just what are these signals made of? Well, they are mostly air-borne chemicals that are collectively called "herbivore-induced plant volatiles" or HIPVs for short. These chemical odors are released when plant-feeding insects injure the plant with their mouthparts. In fact, researchers have looked at the release of these odors after a plant has been damaged due to natural caterpillar feeding, damaged by a razorblade, or damaged by a razorblade and then had caterpillar saliva applied to the plant's wound. It was found that the two wounded plants that came into contact with caterpillar saliva released equal amounts of odorous blends. Furthermore, the release of these odors were not limited to the exact site of the wound, but leaves that were left uninjured on the same plant also emitted these odors—a holistic response to insect-feeding damage! This means that the whole plant lights up like a beacon in the landscape, clearly standing out against the neighboring plants that are not under attack by hungry caterpillars.

For these blends of odors to be useful to parasitoids (and other predatory insects), they need to be specific enough for parasitoids to distinguish between suitable hosts and those "other guys". The plant's odor cocktail can only say so much: the parasitoid needs to be able to identify the HIPVs associated with that particular host insect and concurrently use its other senses, like sight, to home in on its victim. It has been shown that some parasitoids show the capacity for learning when it comes to discerning odors released from injury to the same plant caused by two different species of caterpillars. This kind of learning is associated with host-searching behavior and is reinforced when parasitoids find their hosts. JACKPOT!

Figure 2: Figure adapted from Aartsma et al., 2017



Further lab studies have been done with parasitoids to determine how they learn and what researchers have found is quite amazing. Not only do parasitoids learn through experience—a bit of trial and error until they correctly discern the scents of their hosts—but they can also be trained to associate certain smells with their hosts. One such study trained parasitoids to associate the smell of vanilla extract with the presence of their caterpillar host. The female parasitoids flew to the source of the vanilla extract even though the host was not present. This finding is particularly important to understand why parasitoids that are grown in labs may not be as efficient at finding their hosts when they are released into a crop field. If these parasitoids were brought up in a lab setting where their hosts were reared on synthetic food instead of plants (which is done to increase efficiency and mass production of insects), those smells will be different than what the parasitoid encounters in the real world.

Some researchers have suggested preparing the parasitoids for the real world by training them on the smells they would likely encounter when released. In fact, researchers found that when they released these trained parasitoids, not only did the parasitoids find their hosts right out the gate, but they decided to stick around in the crop that they were trained to associate with their host. The parasitoids surrounded themselves with the familiar smells they were brought up to know and love. Some researchers think that these odors that plants release were originally used as a tool to defend themselves against plant-feeding insects because some of these odors act as feeding deterrents. Now that we know that parasitoids and predators have the capacity to also pick up on these odors and can learn to discern which ones will lead to their prey, we think parasitoids have learned to exploit this defensive system. Perhaps we can exploit this communication method too. Can we take advantage of these scented cues to help protect our valued crop plants by attracting more parasitoids and predators to our fields?

Figure 3. Various parasitoids and their hosts

YES, WE CAN! There are several ways we can attract parasitoids to a crop so that they can be there "ready and waiting" for their prey to show up. We can spray certain elicitors, or chemical compounds, on the crop plants that cause the plants to release those scented cues that the parasitoids and predators use to find their hosts. We can also recreate specific HIPV blends in the lab that are known to attract parasitoids and predators by producing synthetic versions of those blends and strategically placing them in the crop. Like flies to manure, those parasitoids and predators will surely come. You might pose the question, "but if I put out those scents and attract the parasitoids and predators, and I don't actually have any prey for them, won't the parasitoids learn to associate those smells with the lack of prey?" And I would say to you "excellent point." That's where the next two strategies come into play… The crops we grow today are basically highly inbred versions of their wild relatives, selected and selected again until they produce bountiful yields worth growing ($). These wild relatives often produce and release these odors that parasitoids pick up on better than their more fertile counterparts that have been so focused on producing bigger and better yields. If we consider using relatives of our current crops that will possibly produce "less bang for our buck", but will certainly be better at attracting parasitoids and predators, we may just reach a happy medium. If that doesn't work, we can certainly toss the problem over to our geneticists. They can manipulate the genes of plants—even insert genes from one plant (say, strawberries) into another (insert favorite crop here)—that will release odors to attract parasitoids and predators. They can even generate plants that release higher amounts of those attractive odors after insect feeding. Therefore, those pesky plant-feeding insects have to first be present and then inflict damage on the plant crop before the specific odors will be released and the parasitoids swoop in to save the day.

The potential for weaponizing these parasitoids against pest insects remains largely untapped because we still don't know exactly how parasitoids find their prey. We know that they definitely use smell, as well as sight and pattern recognition to navigate their environment. But we are still not able to have reliable control of crop pests by simply releasing parasitoids into a field (the term for such a practice is "biological control"). The issue is twofold: parasitoids and predators have to be recruited to and stay in a target area (our crop), and they must maintain a high kill rate once they take up residence in the crop.

For now, management of most of our major crop pests is dependent on synthetic pesticides despite the serious downsides: environmental pollution, health risks to laborers, possible food contamination, and development of resistance to the pesticides by crop pests. But the next steps to curb our dependence on pesticides are within our sights. More field studies are needed to determine the reliability of using the above tactics to exploit this communication system between plants and parasitoids and other predatory insects. Man is now entering the battle against plant-feeding insects on the side of the plants, and we've got a few tricks up our sleeves.

Summary points:

- Plants that are injured by plant-feeding insects emit odorous cues that are exploited by parasitoids and predators to locate their prey.
- These signals denote which plant is under attack by plant-feeding insects and which plant-feeding insects are doing the damage.
- Parasitoids are capable of learning which scent profiles will lead them to their specific host.
- There are several options for taking advantage of plants' ability to produce odors prompted by insect feeding damage in our agricultural crops! **SCIENCE TO THE RESCUE!**
- Attracting parasitoids and other insect predators to a crop can help keep our food safe and save growers from having to rely solely on pesticides for crop protection. Which makes our crops and laborers safer. **EVERYBODY WINS!**

The global resurgence of bed bugs

Mark Dery

Bed bugs (*Cimex lectularius* L.) are blood feeding, external parasites that are infamous for infesting the mattresses of their primary host, humans. Bed bugs have been parasitizing humans for at least the entirety of our recorded history, from ancient Egypt to the present day. However, bed bug infestations were greatly reduced in industrialized countries following the development and subsequent widespread use of synthetic pesticides in the middle of the twentieth century. While bed bugs fell from prominence as a major pest, they lingered in the public's imagination under the mistaken belief that only those who lived in unhygienic conditions could be affected.

The turn of the twenty-first century was accompanied by a worldwide resurgence in bed bugs as a major urban pest. The scale of the resurgence is astounding. In the U.S. in 2016, over 900,000 professionally conducted pest control jobs targeting bed bug infestations were estimated to have been conducted. The corresponding information regarding bed bugs from the early twenty-first century is difficult to determine, but the resurgence likely represents an increase in the many thousands of percent. The worldwide economic impact of bed bugs is similarly large, almost certainly in excess of a billion dollars annually. Not only is there the cost of this professional control, estimated at over $600 million in the U.S. alone in 2016, but also more indirect costs that result from bed bug infestations. Costs are accrued by those attempting to treat bed bug infestations themselves, which can often result in mattresses and clothing being needlessly discarded. Infestations of bed bugs also represent a major cost to many businesses such as hotels, where a single bed bug infestation can result in an economic impact in the many thousands of dollars as a result of pest control costs, bad publicity, and increasingly, legal settlements.

Why the resurgence in bed bugs? No single reason can be clearly identified as the source of the dramatic increase. Instead, the reasons for the revival are likely the result of a perfect storm of factors that have each contributed to the reemergence of bed bugs as a major pest. One of the primary causes is the widespread resistance to insecticides. The use of an insecticide on bed bugs represents a strong selective pressure for resistance, and bed bugs have been able to develop resistance against many classes of insecticides. One such class of insecticides, pyrethroids, targets the nervous system of bed bugs and exposure results in paralysis followed by death. However, resistance to pyrethroids is now extremely widespread in bed bugs around the world, as these insecticides are the most commonly used to combat infestations. As a result of the over reliance on pyrethroids for bed bug management, these are now often ineffective at achieving high mortality. New products are now being used that contain a mixture of insecticides that are more effective at controlling bed bugs, but it may be just a matter of time until these are also rendered less effective. To combat the increase of insecticide resistance, an integrated pest management strategy that utilizes monitoring, and both chemical and non chemical control methods should be conducted by a pest management professional.

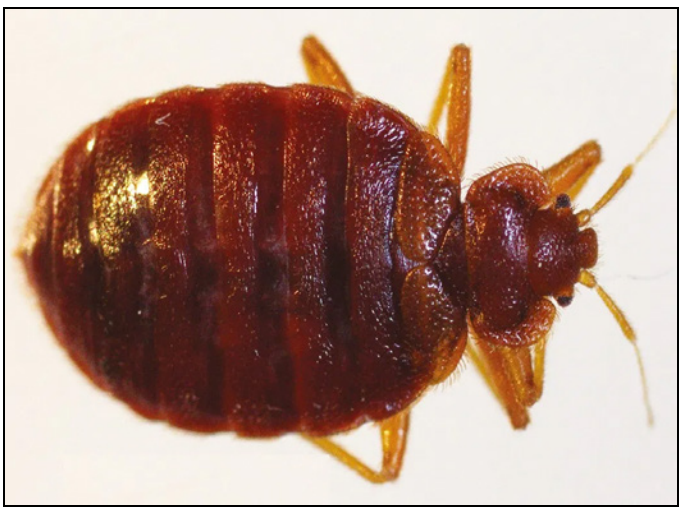


Image from Entomology Today Blog by Andrew Porterfield.

Many other factors have contributed to the increase of bed bugs, such as the increased global movement of people. Bed bugs spread from building to building by hitching a ride on people and their possessions. As infestations can be started by the introduction of a single female to a new location, increased travel has helped bed bugs spread more rapidly. Another contributing factor has been the lack of education regarding bed bugs among the general public. The misconception that bed bugs only infest those living in unhygienic conditions makes some reluctant to ask for help, instead attempting often ineffective self-treatments. As a result, these infestations can become a reservoir that acts as a source for new infestations. The decline of bed bugs not only resulted in a decline of knowledge among the public, but also among pest control technicians. The decrease of bed bugs as a major pest for nearly fifty years resulted in a generation of pest control technicians who were not familiar with bed bug management strategies. Finally, a fundamental shift in urban pest control tactics occurred in the second half of the twentieth century. Widespread pesticide application both in homes and within bedrooms have declined due to environmental and health concerns, which has resulted in the overall reduction of pesticide use. Further, as bed bugs are always located in close proximity to their human hosts, fewer insecticides have been approved for use against bed bugs. The lack of variation of insecticides utilized for control further promotes resistance, making insecticides even less effective.

The ultimate consequence of this resurgence is that bed bugs are increasingly being encountered. If you suspect that you may have an infestation of bed bugs, there are several actions to take. First, closely inspect the area where they are suspected. If in a bedroom, inspect the mattress, bed frame and areas surrounding the bed for the bed bugs themselves, as well as for fecal staining, cast skins or blood stains. If an active bed bug infestation is discovered, control by a trained professional is recommended. Bed bugs are among the most difficult pests to effectively control, even for professionals. As a result, do-it-yourself treatments often are not sufficient to eliminate the infestation completely. Further information on the control of bed bugs can be found at the University of California integrated pest management page on bed bug control (http://ipm.ucanr.edu/PMG/PESTNOTES/pn7454.html).

Life in the Web: Thread legged assassin bugs

Samantha Standring

Web-building spiders are incredible predators, using their webs as both a trap and an extra sensory device. Minute vibrations from insects caught in their web act like a mechanosensory organ, alerting the spider to what kind of organism has entered their web. Spiders use these vibrations to locate and identify their prey, and then respond accordingly. Despite the obvious danger and difficulty involved, some insects have adapted to a life in spider webs.

Emesinae (Hemiptera: Reduviidae), commonly called thread legged assassin bugs, possess many unique adaptations that separate them from the rest of Reduviidae and allow them to survive a life in the web. One adaptation is in their legs. In most insect legs, the first segment, the coxa, is short and acts more like a joint. In Emesinae however, their coxa is elongated to be four times as long as wide. Coupled with their long stance and claw projections, these highly adaptive legs allow Emesinae to spread their weight on spider webs and avoid detection. In addition, many have a comb-like structure on the claws of their forelegs, similar to what is seen in spiders, which allows them to break strands of the spider web when necessary. Some Emesinae are so closely associated with spider webs, the females lay their eggs on the web. The entire life cycle of these species is spent on and around spider webs.

One Emesinae species, *Stenolemus giraffa*, possess an extremely long thorax, projecting their head out farther like a giraffe. This allows them to avoid stepping on the spider web entirely, and instead they ‘tip-toe’ around the web until the spider emerges and they can scoop it out of the web and strike. Apparently attuned to the perceptual world of their prey, *S. giraffa* avoids walking on the spider web at all costs to evade detection by the resident spider. When they have to break threads to reach the spider, the tension is released before the strands to limit vibrations. This allows them to sneak closer to the resident spider.

Another species of Emesinae, *Stenolemus biterbus*, uses two different predation strategies to attack the resident spider: luring and stalking. Luring involves making vibrations by plucking, stretching and cutting the threads of the spider web slowly until the spider comes out. These vibrations mimic the vibration of prey caught in the web. Spiders respond in a characteristic way to intercepting prey. Upon hearing the vibrations, the spider orients to the source of the vibration and approaches. Higher frequency vibrations lead to an aggressive, rapid response, where the lower frequency *S. biterbus* elicits a slower response from the spider, giving them time to strike first. When luring the spider is not effective *S. biterbus* are forced to stalk the spider by entering the spider web or climbing to a vantage point above the resident spider. This is more dangerous, as the spider’s response is more variable and *S. biterbus* may be seen before attacking the spider.

Though species within *Stenolemus* have been well studied, most behavioral data for other genera is only from natural history observations during collecting trips. Some genera such as *Emesaya* have been recorded eating prey caught in spider webs. In addition, species of *Bagauda* have been found in large numbers deep within caves, eating both spiders and prey caught in webs. It appears that species of *Ghilianella* have no association with spider webs despite maintaining the typical thread-like morphology of Emesinae. Ultimately, to discover how these behaviors evolved further research is needed.

By studying the evolution of Emesinae spider-associated behaviors, we can discover whether these behaviors have led to an increase in diversity within the subfamily. Emesinae belong to one of the most ecologically diverse orders of insects, Hemiptera. Even in such a diverse group of insects however, spider associated behavior is rare, especially to the extent in Emesinae. As additional behavioral data are collected and relationships between genera are discovered, the potential correlation between morphology and behavior can be confirmed, as well as understanding how such unique behavior arose, and whether it evolved several times separately within Emesinae, or just once. Spiders are incredible predators, striking fear into the hearts of most grown men and women. What does that say about the insects that eat them?

Fieldwork & Friends

Photos from fieldwork in Cameroon & Panama's Barro Colorado Island through a National Geographic Fellowship

Samantha Standring

Fantastic Bees and Where to Find Them

Chris Allen

European settlers, bees, disease, islands, and scientists. What sounds like the theme to a cheesy SYFY original is actually the components to a story that forms the foundation of my PhD thesis.

Let's go back, way back, to the 1600's. Imagine, if you will, honey bee hives on the Mayflower. European settlers actually brought honey bee hives with them on their voyages to the New World. Honey bees were, and still are, immensely important since they produce honey, wax, and propolis in addition to pollinating crops. One issue is that these honey bee hives eventually escaped and established feral colonies in the wild. Over the course of 200 years, these non-native honey bees expanded their range from the East Coast to the West Coast of the United States.

The honey bee (*Apis mellifera*) is the poster child for bees, but it may come as a surprise that the honey bee represents just one of the 20,000 bee species worldwide. There are 4,000 bee species that are native to North America, which means that they are naturally occurring and were not introduced here by people. The state I live in, California, is home to 1,600 of those 4,000 species.

Some native bees, such as *Perdita*, are the size of a grain of rice, while others, such as *Xylocopa*, are as round as a ping-pong ball (Figure 1A). And bees come in every size in between. Have you ever heard of *Centris*, with bulging green eyes (Figure 1B)? Or what about *Agapostemon*, which have metallic green bodies (Figure 1C)? Yes, you heard me right, bees come in more colors than just black and yellow. But, if you do see a black and yellow insect flying around, don't assume it's a wasp. *Anthidium* are black and yellow bees that lay their eggs on a pillow of fluffy plant hairs (Figure 1D).

All of these bees share one thing in common. From flower to flower, bees gather nectar and pollen to feed to their young. In doing so, they help the plants to reproduce by pollinating flowers. A relationship between two organisms, like a bee and a flower, where both species benefit is called a mutualism.

The mutualism between flowers and bees seems harmonious, right? Wrong.There's a hidden menace lurking in the flowers. You see, honey bees carry all sorts of different pathogens, nasty microbes such as *Nosema* and *Crithidia*, that live in the bee's stomach and cause dysentery-like diseases. The problem is that if a honey bee is sick with any of these diseases they can leave behind pathogens in the nectar when they visit a flower. Then, when a native bee like *Perdita* or *Agapostemon* visits that flower, they can unsuspectingly pick up these pathogens themselves (Figure 2).

Figure 1: A) A tiny *Perdita* rests atop the head of a massive *Xylocopa* (Photo credit: US Forest Service). B) A *Centris* with her bulging green eyes. These bees are typically found foraging at either dawn or dusk (Photo credit: Noah Project). C) An *Agapostemon* with her metallic green body. *Agapostemon* and close relatives are known as sweat bees because you can find them lapping up the sweat beads on your body on a hot summer day (Photo credit: BugGuide). D) An *Anthidium*, commonly called a wool-carder bee. Here, you can see that she has gathered the hairs from this leaf which she will lay an egg on back at her nest (Photo credit: BugGuide).

Scientists have found these honey bee pathogens in other bee species, but they are still unsure how this impacts the health and functioning of these species.

So this is where I fit into the story. For my PhD, I am studying how honey bee pathogens impact native bee species. To do this I am utilizing one of the last honey bee-free refuges in North America, the California Channel Islands.

Dubbed the Galapagos of North America, the California Channel Islands are an archipelago of eight islands off the coast of Southern California. This island chain is well known as being home to the endemic island fox (*Urocyon littoralis* subsp.), which is smaller than a house cat. Yet, visitors are likely overlooking a diversity of bee species when they come in search of the island fox. Unlike other organisms, which have their highest diversity in the tropics, bee species are extremely diverse in arid, Mediterranean-like climates. Scientists presume that there is an immense diversity of bee species on the islands since they fit this climatic description well. Part of my research also seeks to catalog this diversity before it is lost forever.

You see, island life is not all smooth sailing. Islands are extremely sensitive ecosystems especially when considering that 61% of all extinct species and 37% of all critically endangered species are found on little specks of land that only comprise 5.3% of Earth's total land--with invasive species being one of the major threats to island diversity (Tershy et al. 2015).

Curiously, the California Channel Islands have a unique history with honey bee introductions. Honey bees have been introduced on Santa Catalina Island, they were introduced and then eradicated on Santa Cruz Island, and they have never been introduced to the six other islands. I suspect that honey bees were also carrying disease-causing pathogens with them during these introductions. So for my PhD research, I want to find out the effects of honey bee introductions and the pathogens they brought along with them on native bee species health and diversity.

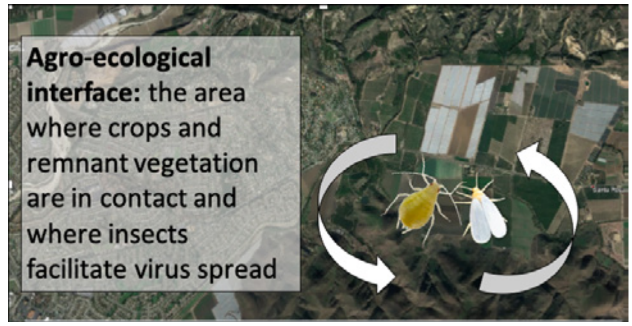
The need to study, protect, and conserve the biodiversity of bee species on the islands is where my motivation lies. As monitoring of these native bees takes place over the next few years I'm excited to share how this research develops. In the meantime, I would highly encourage you to visit the California Channel Islands to explore these fantastic bees for yourself.

Interaction Zones: Viruses, plants, & insects

Tessa Shates

The interaction zone between lands used for crop production and remnant wild plants may be a hotbed for plant disease emergence.

As human populations increase, the need to develop land for homes and food production also increases. This development leads to consequences for the plants and animals already living in the small pieces of remaining wild land, including losses of animal and plant species numbers. One unexpected consequence of decreased wild lands and increased developed lands relates to the interactions between plants and the disease-causing organisms. New diseases that show up in plants are often caused by viruses. Wild plants are often blamed as the virus source. This is directly connected to wild habitats being broken up into smaller fragments because the areas where diseases move between wild and crop plants - the zones of interaction - are growing as wild habitats are increasingly surrounded by developed habitat. However, research on the region of interaction has been neglected. Therefore, a growing number of researchers are set to discover what is going on in this hotbed for plant disease emergence.



So, what do we know about these plant viruses so far?

After the first plant virus - Tobacco mosaic virus - was described in 1886, scientists have learned a lot about how the plants we grow and eat respond to virus infection. These plants experience symptoms including color changes, stunted growth, and production of small, malformed and unpalatable fruit. Crop plants are more susceptible to these disease symptoms as a side effect of plant breeding and domestication across the years. Wild plants, on the other hand, are more capable of fighting off disease. The difference between wild and cultivated plants, and the lack of research on wild ones highlights that we must focus our attention on wild plants.

We've also learned that wild plants can be a source of new virus infections in our food plants. Many viruses exist in wild plants without showing symptoms, and it is only when they interact with a new, susceptible plant species that a disease appears. One example is the Cacao swollen shoot virus, which only jumped from native forest trees after cocoa was brought to Western Africa from South America. One of the most important parts of virus "movements" is that the movement from wild to crop plants are facilitated by insects like aphids and whiteflies. These insects are small, but can fly long distances and pick up, carry and transmit viruses by feeding on the sap of plants. These flights occur in the interaction zone of wild and cultivated plants called the "agro-ecological interface": a continuum of human-managed landscapes (like agricultural "monocrops") to completely unmanaged, wild landscapes. Because the agro-ecological interface is where viruses, plants (local and new), and insect vectors all exist, it is incredibly important for studying disease dynamics.

But, most research done on plant viruses has been done on crop plants that live for only one year, and very little has been done on wild plants that live for many years. PhD scientist Helen Alexander and her team state that "Research with crop species and model organisms over the last century has uncovered much about the mechanisms of virus-host interactions. In contrast, research on virus interactions in natural ecosystems has lagged far behind." And, part of this wild-plant work that has been understudied includes that zone of interaction called the agro-ecological interface where wild plants, native insects and potentially invasive insects intersect. It is necessary to address this missing gap of research because the agro-ecological interface is the hot zone of disease emergence, and researching viruses in this zone will add to essential knowledge of virus evolution and how they change over time in different plants.

Therefore, scientists from different fields that focus on studying insects, viruses and the interactions between living and non-living environmental factors are teaming up to find out more about the agro-ecological interface and viruses in wild plants. Within the past century, the paradigm has been that wild plants are sources and reservoirs for pathogens. But, recent discoveries are more nuanced in regards to the role wild plants play as sources. While wild plants are often sources of viruses, this is especially the case when new crops are introduced and a new interaction takes place. This shows that trading and importing infected plants is another important source of viruses. Unfortunately, viruses are not easy to see - if a plant doesn't look infected, how do scientists know that they have viruses? Scientists can look for signals of viruses by processing plant tissue to isolate viral genetic information. These processes can generally be called "molecular tools." One Australian team of scientists used molecular tools to find out that agriculture and human development brought new plant viruses to native bean plants in one Australian floristic province that was otherwise pristine. Another international team used molecular tools to find that in South Africa and France, proximity to agriculture results in more crop-associated viruses in wild plants. These findings are only the tip of the iceberg on virus ecology research in wild plants.

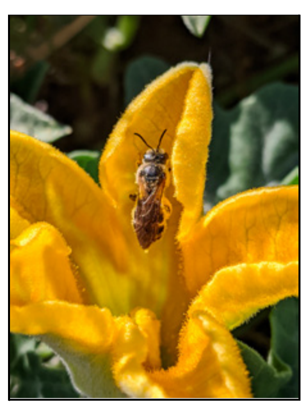
Other research teams are finding that wild plants experience consequences to their health from crop viruses including reduced growth, survival and reproduction of the wild plants. One team found less flowering and decreased survival in wild grasses infected with viruses from our cereal/grain crops in California grasslands. Alternatively, viruses may bring some benefits to wild plants. A different team found virus infection reduced flower attraction of beetles to wild squash plants, resulting in protection from a bacterial pathogen spread by the beetle. The findings are important because as we strive to protect our natural spaces, we must recognize all threats - including those not typically considered for wild plants.

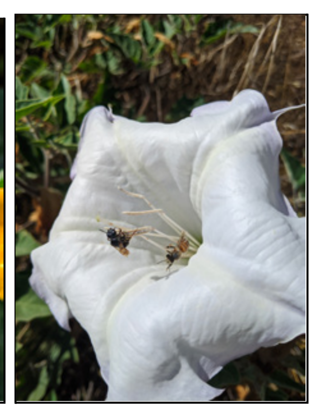
Historically, wild plants are considered the source of viruses that cause devastating outbreaks and food insecurity. But, in reality it is new interactions between the local and the new organisms (microbe, insect or plant) that result in new outbreaks. As more scientists tackle the mysteries of the agro-ecological interface, we can better prepare for new virus emergence and epidemics, and learn to identify new pathogens before they hurt food production or wild plants.

Fieldwork Finds

Tessa Shates

Photographs of fieldwork in Riverside County





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