Unraveling the Plant-insect Interactions Taking Place in Your Native Garden

by Billy Krimmel[1] and Haven Kiers[2]

One of the key reasons native landscaping is so important ecologically is that native plants provide food and habitat for native insects, which then gets transferred to larger animals up the food chain when the insects get eaten. For gardeners, the interactions between plants and insects are often most observable in their yards, but it can be difficult to make sense of these interactions without some basic tools. This article lays out a basic protocol and tools for unraveling these fascinating interactions. The first step of understanding plant-insect food webs is the foundation of coming up with hypotheses for scientific research.

Why come up with hypotheses? Certainly, this is not the only way to understand what kinds of interactions are taking place in your garden; you could simply look up the known ecology of the plants and animals present and leave it at that. But what if you see something that is not known or fully understood? There are so many species of plants and insects and even more types of interactions between them, and as a result, there is a lot that we do not know. Citizen science is emerging as an important way to generate scientific data and to bring a wider diversity of ideas into the ecological sciences. If you have children, hypothesis generation in this context — where traits and interactions are observable through touch, feel and smell — is a fun and accessible entry into the scientific process. The general methodology of observation, hypothesis generation, and testing can be applied to any scientific field.

Step One: Choose a plant to focus on and observe it

You may have a variety of plants in your garden, some native, some non-native. The first step is to identify a plant-insect system that is both interesting and readily observable. What makes it exciting depends both on your personal interests and on what is happening in your garden. For example, you may love your California poppy plant and want to know how it interacts with insects, but if none or very few insects are on it in your garden, it will be difficult to observe such interactions. Some insects can be more difficult to observe. Native pollinators, for example, tend to have narrow windows each day when they are active; thus trying to observe a pollinator in the middle of the day when it is only active during sunrise will yield little results. So, take a look at plants during a time of day when you will be able to observe them regularly and focus on the insects you see during that time.

Observing plants and insects can be done in many ways, but here are two of my favorite methods:

1. Watch. Watch, watch, and keep watching. Don't be afraid to crawl around or just sit down next to a plant for a while (think of this as a mini-meditation break!). Try to look closely at various parts of the plant, including under the leaves, as this is where insects often hide and lay eggs (Figure 1). Put your face within a foot or two of the plant and look through it stem-to-stem in a methodical way to ensure consistency in observation from plant to plant. If you see an insect on a plant, try to figure out what it's doing. Is it feeding? Is it grooming? Is it mating? Or is it trying to hide from you? What part of the plant is it on (e.g., leaf, stem, flower bud, etc)? Is this consistent for most of the insects you see? Are the insects alone or in aggregations (groups)? If there is an aggregation, are the sizes similar, or is there variation? Are they all adults, or are there immatures also? Keep your eyes open for eggs as well — many can be seen with the naked eye. Insect eggs tend to be white or off-white, and the shape of the egg can be indicative of the type of insect that laid it. Next, look for signs of plant damage (e.g., cut leaves, asymmetrical leaves, splotching, crinkling of leaves, girdling of stems, etc). These can be useful clues for what is stressing the plant and what is causing the different types of damage. Frass — caterpillar and beetle poop — can be very helpful clues, especially when the insects themselves may be cryptic. Plants can also catch diseases from insects feeding on them as well as soil pathogens. Diagnosing what is causing plant damage is a fun exercise and, in many ways, is similar to how human pathologists diagnose disease and sickness in humans. Although this method of simple observation takes time, it consistently yields the most informative insights.

2. Collect. Use a beat net (Box 1) or tray and tap plants with a stick to knock insects off the plant and onto your net or tray. This method is fun and can yield a lot of insects that might have been hard to see by just looking at the plant. Insects like thrips, minute pirate bugs, plant bugs, stilt bugs, assassin bugs, crab and jumping spiders, tiny caterpillars, and other cryptic insects can be found this way. It is also a great way to get rough counts of the number of a given type of insect on a plant, especially when a standard sampling protocol is used. This is a great method for sampling a wide range of plants when time is an issue. It can also be an easy way to engage children, as you'll see a lot more insects in a shorter amount of time compared with watching the plants. As you start to get a sense of what insects are on certain plants, make sure to also pay attention to signs of plant stress and insect damage on the plants. Are there correlations between the insects you find and the types of damage to the plants? Do any insects, in particular, correlate with strong signs of plant stress? Is one insect only around when another type of insect is? Are any insects eating each other when they fall in your net or tray? This can be particularly informative; since this sampling method forces insects into an open, shared space, predation interactions can be encouraged and observed. But importantly, these can also be unrealistic if the insects have means

continued next page

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Unraveling the Plant-insect Interactions Taking Place in Your Native Garden

continued

of avoiding each other on their shared plant. If you see predation in your net or tray, you'll want to check that it actually occurs on the plant, by looking for the same insects on plants and watching them.

Once you have observed plants that have reliable populations of insects on them, choose one or two to focus on. Ideally, your chosen system should be one in your garden that has multiple plants of the same species, with at least one abundant insect species on them (ideally multiple) and, for extra points, some form of common plant damage. The reason that plant damage is useful is that it can provide insight into what insects are good or bad for the plant, which informs the interpretation of how plants may be selected evolutionarily to support or defend against the insects.

Now that you have a system (or two!), spend more time observing and sampling it. Start coming up with some basic hypotheses as to what is doing what. If you see large aggregations of a certain insect on plants that look stressed, you may hypothesize that those insects are harming the plant. If you see certain insects (especially predators) on plants that seem particularly healthy, you may hypothesize that those insects are beneficial to the plant. If you see certain predatory insects or spiders on plants only when there are large numbers of herbivores (e.g., aphids, whiteflies, caterpillars), you may hypothesize that these predators are feeding on the herbivores.

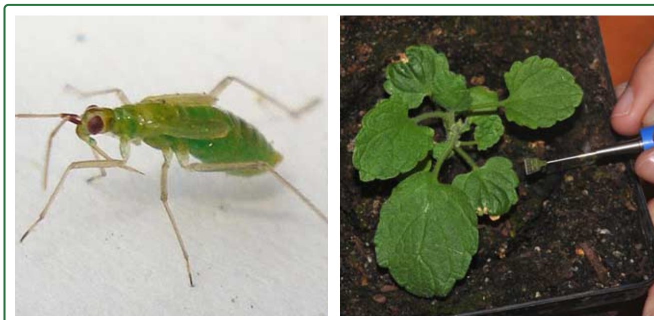
Look for other important clues — do you see eggs on the plant? If you see aggregations of both juveniles and adults, then they are likely feeding and reproducing on the plant — this is the basic definition of a 'host plant'. If you only see adults, they may just be temporarily feeding or looking for mates. Pay attention to the type of damage on the plants. Can you see actual chewing damage (e.g., holes in leaves or flower buds, abrasions to the stems, etc)? What kind of mouthparts do the insects you are observing have (e.g., chewing mandibles like caterpillars and beetles, or piercing-sucking mouthparts like aphids and other true bugs)? Does the damage you observe on the plant correlate with the mouthparts of the insects you observe? In some cases, it can be obvious when an insect feeds on a plant. Caterpillars and beetles are great examples because you can see them feeding on the plant and damaging it directly. Other insects, like thrips and most bugs (Hemiptera), cause damage that tends to manifest as leaf splotching and crinkling. See Box 2 for information on different types of insect mouthparts and the corresponding plant damage they cause.

Dead insects can be great clues too, as can shed exuviae (exoskeletons) on the plants (Figure 2). Are you seeing a lot of dead insects on plants? Is it usually the same kind? Is it one of the species you also observe alive on the plant or on something else? When you see dead insects, what else do you see? These observations can provide clues as to whether there is significant predation by one insect on another in your plant-insect system. Understanding how an insect died simply by observing

continued next page

Figure 1: Stink bug eggs on the underside of a leaf. Stink bugs tend to lay eggs in groups, while some other insects will lay them singly. *Image from WikiMedia Commons*

Box 1: A beat net is a great tool for sampling insects on an individual plant basis. It is essentially a shallow canvas net that is placed below a plant while the plant is tapped with a stick. The tapping causes many insects to drop off the plant, landing in the shallow net for quick observation, identification or collection. Beat nets are also great for collecting seeds from some species of plants. Evening primrose (*Oenothera elata* ssp. *hirsutissima*, left) being sampled using a beatnet. Stilt bugs (*Jalysus wickhami*, right) in beat net after tapping plant with a stick. *Photos courtesy Billy Krimmel*



Box 2: Insect mouthparts can be categorized into two broad groups. The first is the piercing-sucking type of mouthpart common in bugs (Hemiptera) like aphids and (left) this nymphal plant bug (*Dicyphus hesperus*). Insects with this kind of mouthpart often cause leaf crinkling, such as the woodmint (*Stachys bullata*, right) that had previously been fed upon by *D. hesperus*. The other broad category of mouthparts are chewing mouthparts, such as those of beetles and caterpillars, which are more common and whose damage to plants is more obvious.

Unraveling the Plant-insect Interactions Taking Place in Your Native Garden *continued*

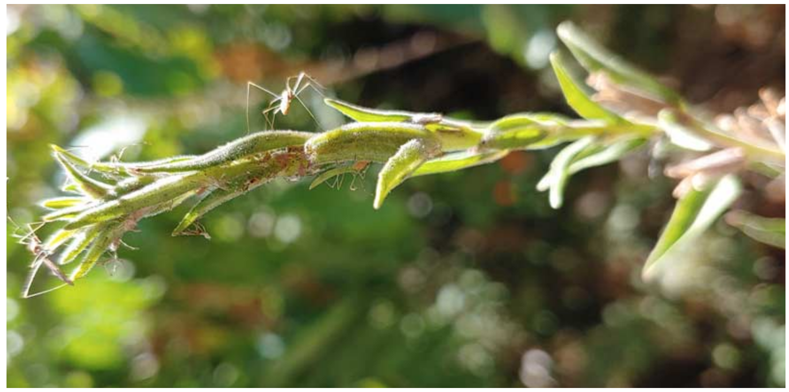


Figure 2: Live stilt bugs (*Jalysus wickhami*) next to two shed exuviae, hanging off the left side of the plant (evening primrose, *Oenothera elata* ssp. *hirsutissima*). *Photo courtesy Billy Krimmel*

the corpse is difficult, and often some further experimentation or observation is needed to get a better sense of the cause of death. Exuviae are used to determine whether multiple generations of insects are growing on the plant. For insects like bugs that do not have a larval stage, juveniles are similar in form to adults but smaller, and they shed their exoskeletons when they grow, leaving exuviae on the plant.

Finally, use your observation skills to pay attention to observable plant traits. Is your focal plant fragrant? If so, does it smell stronger when touched? Does it have hairs on the leaves, buds and/or stems? If so, are they clingy, and do they have debris or dead insects stuck in them? When you break a leaf, does it squirt out white latex? Do you see more or less of these traits on plants with higher or lower abundances of the insects you are observing? These are all important clues into how the plant may defend itself from insect herbivores.

Step Two: Do some preliminary research on your plant and insect species

Now that you've spent some one-on-one time out in the garden with your plant and its insects, it's time to identify the species in your system and learn about their basic natural histories. For the sake of this essay, I'm going to assume you already know the species of plant. Start by using Calscape (**www.calscape.org**) or Calflora (**www.calflora.com**) to determine your plant's natural growing range. This can give you a better idea of whether your plant naturally grows near your garden and will give you a sense of how likely it is that the insects that usually live on it will actually be in your garden.

Identifying insects can be intimidating at first, but there are some great resources available, especially if you live near a land grant university that has extension staff. In order to get an insect identified by a

continued next page

professional, it's important to collect it and prepare it properly so that once the professional has it, she can identify it efficiently. The best first step here is to call your local extension. Explain your goals and intentions, and ask whether they could help and, if so, how they would like the specimens prepared. Sometimes this involves sticking a few in some alcohol (especially for small insects), and in other cases, it's more helpful to mount the insect on an insect pin and keep it dry. In either case, the insect will need to be killed, unless the extension staff person says that live specimens are acceptable. For common insects, a photo is often sufficient.

If you are interested in learning how to identify insects yourself, a great place to start is BugGuide (**bugguide.net**), a free website with lots of pictures of insects and basic natural history and taxonomic information. "Seek" by iNaturalist is another good way to automatically identify insects (**www.inaturalist.org/pages/seek_app**) It's important to note that it is not always necessary to identify an insect to the level of species to know what it is doing; in fact, in some cases, this is not even possible, as many insect species have not yet been described. You may even discover a new species! In general, getting the identity to a level beyond family is important in order to understand its life history. Sub-family or genus are very informative, as feeding behavior tends to be the same for insects within these groups.

Once you know your plant species and some taxonomic information on your insects, do some quick internet research. Google the species of plant and one insect at a time. Make sure to check Google Scholar to see if these species pop up in any published research. Search for the insects and plants on BugGuide to see if other people have observed them and if so, what they noticed. See if there is information on Wikipedia or other free, reliable resources on the plant and insects, and read through what is known about their ecology and natural history. You may find some fascinating information and generate some ideas as to what is going on in your plant-insect system.

Unfortunately, peer-reviewed primary research papers are usually difficult or expensive to access unless you have an affiliation with an institution that subscribes to these. There are several open-source publications available, which are free to the public, but not all are as rigorously vetted as conventional publications. Luckily, the authors of peer-reviewed publications are also owners of the content and can send you PDFs of their papers for free. You just need to email them directly, or if you're lucky, they may have links to papers on their webpages. Even if you can't find all the original articles that are relevant to your plant/insect system, reading through the abstracts (which are free) can be very helpful.

Step Three: Come up with some research questions

This is a fun step in the process. What do you think is going on in your system? What insects are using the plant as a host? Which are herbivores? Which are predators? Which are likely causing damage to the plant? Which are likely helpful to the plant? How does the plant defend itself from the herbivores? You don't need to ask or answer all these questions, but perhaps some seem likely or obvious in your system. Or you may come up with more specific questions, like how do males of a species find mates, or how does a species of insect hide from predators? These questions can be re-written into hypotheses very simply.

The point here is to come up with simple *questions that can be answered through observation and/or experimentation.* For example, if your question is *Which insects are causing damage to the plant?*, your hypothesis may be *We hypothesize that the caterpillar is causing damage to the plant by feeding on its flower buds.*

Don't worry about revolutionizing the field of science for your first hypothesis. Keep it simple. Your priority should be coming up with a hypothesis that you can resolve through simple observation and/or experimentation. As you become comfortable with this process, you can begin asking questions aimed at advancing the field, but first, you need to get a sense of what questions can be answered and what gaps in understanding exist.

Step Four: Collect data to test your hypothesis

Now that you have some hypotheses, it's time to collect data that will support or reject them.

Here are some examples of simple, testable hypotheses, and what information is needed to test them:

> **Example 1 Hypothesis:** *We hypothesize that INSECT SPECIES 1 uses PLANT SPECIES as a host.*
>
> Information needed: Are juveniles and adults both commonly found on the plant species?
>
> **Example 2 Hypothesis:** *We hypothesize that INSECT SPECIES 1 causes damage to PLANT SPECIES.*
>
> Information needed: Does the insect feed on the plant? How so? Is this type of damage observed on plants? Is it more common when more of the insects are seen on the plant? Can you replicate this damage by putting insects on the plant in controlled conditions? For extra points, if you can demonstrate that the insect causes a reduction in seed set for the plant, you can then conclude that it is reducing the plant's evolutionary fitness (i.e., reproductive output), which is the currency of evolution.
>
> **Example 3 Hypothesis:** *We hypothesize that INSECT SPECIES 2 is beneficial to PLANT SPECIES by preying upon INSECT SPECIES 1.*
>
> Information needed: Is *INSECT SPECIES 1* harmful to the plant (see example 2)? Is *INSECT SPECIES 2* found where *INSECT SPECIES 1* is found? Is *INSECT SPECIES 2* known to feed upon, or scare away, *INSECT SPECIES 1*? Have you observed *INSECT SPECIES 2* feeding on or scaring away *INSECT SPECIES 1*? Some experiments could be helpful to

continued next page

further understand what is going on, such as caging *INSECT SPECIES 2* on plants with *INSECT SPECIES 1* and observing whether there is a resultant decline in *INSECT SPECIES 1* — note that a control would also be needed in which *INSECT SPECIES 1* is caged without *INSECT SPECIES 2*. This 'control' would be used to compare with the 'treatment' in order to understand how the cage might also affect the interactions between *PLANT SPECIES* and *INSECT SPECIES 1*.

The ease of testing your hypothesis comes down to the way in which you ask your research question and word your hypothesis. The key here is that you want to collect data that supports or rejects the hypothesis, and you want to make sure you are using some kind of standard data collection protocol when collecting the data. Hypotheses can be tested with observational data and also with experimental data. Experimental data tends to be more powerful because you can manipulate specific variables, so you know that the factors you manipulate cause the changes you see, but in some cases, observational data can be more realistic because you are observing interactions in their natural settings. The best research often includes both: observational data gives a holistic sense of field conditions, and experimental data can isolate individual factors.

Statistics are often needed to turn the data you've collected into a result. This is because the world is a messy, complicated place and no matter how good your observations are or how well you control conditions in an experiment, you will not see the same result every single time. But perhaps you usually do see the same outcome; statistics are a scientist's way of defining "usually". We won't go very far down this rabbit hole, but in general, simpler questions can be answered through simple statistics.

Conclusion

Native landscapes are beautiful and full of fascinating stories — some known and others untold. The more you learn about what is happening in these miniature ecosystems, the more special they become. This basic methodology of observation, question generation, and data collection is the foundation of science in any field, not just ecology. But ecology offers a uniquely accessible door into science, especially when it occurs in your backyard. Interactions can often be seen with the naked eye. Relevant plant traits can be touched, smelled, counted. Think about helping your kid do an ecological study in your backyard for next year's science fair or use these tips to unravel some of the mysteries unfolding in your garden! For further reading on making ecological observations and testing hypotheses, check out the book *How to do Ecology* by Karban & Huntinger.