Draft Report on 2016 Ecological Monitoring at the Farm Hub. C. Vispo, March 2017

Introduction

At least three considerations help explain both the excitement and challenge of studying on-farm ecology.

First, the landscape is awash in life. Some of that life 'puddles' in particular places on the landscape – in wetlands, in forests, on farm fields, for example. Other life flows more uniformly across the land, either because it might be found anywhere at any time or because it may, across the year and during different stages of its life cycle, utilize distinct habitats. The ecology of a farm can thus not be understood in isolation, but must recognize that each organism will have its own 'flow pattern'. Deriving a working understanding of the wild organisms within a farm's fences will often require considering what is happening beyond those fences, from storms that waft in leafhoppers from far away to eroding, sandy stream banks which harbor bees to adjacent forests which may be launching points for ballooning spiders.

Second, we will probably never be able to identify the vast majority of insects and other invertebrates which share the farm with us. (Spiders, millipedes, snails and many other invertebrates we captured are not true insects, but, as a shorthand, I will here use "insect" to include these creatures as well). Unlike the case with vertebrates and, thanks to genetic analyses, with some microbes, many of the insects and other invertebrates we regularly catch during our work are unidentifiable, not only by us, but also by just about any living expert. However, just because they are unknown does not mean they are unimportant from the perspective of nature conservation or farming. Furthermore, almost any capture or observation technique, short of total fumigation, has biases and probably leaves certain groups of organisms underrepresented.

Finally, nature is not a comic book. In an agricultural context, we cannot expect wild organisms to be easily definable super heroes or villains. The terms "beneficial" and "pests" are value judgments we assign to particular organisms. This does not mean that the corn borer who decimates a crop and the parasitic wasp that may stymie those ravages are not, in that particular case, clearly damaging or protecting the crop. Rather, we should always hold in our minds the realization that "beneficial" and "pest" is as much defined by context as by an organism's inherent characteristics and, in any case, those inherent characteristics are rarely perfectly aligned with human desires. For example, the spider web that might catch a leafhopper or tarnished plant bug, may equally capture a native bee or lady beetle. While biodiversity assessment can be approached with a simple species list, assessments of (agro) ecological function, i.e., of the beneficial and pestiferous activities of the fauna, are based not just on presence but also behaviour. For many organisms, identity alone is not sufficient to fully define behaviour; it must be measured.

Given these considerations of scale, role and practicality and the unavoidable limits they imply, what then can we hope to accomplish? At which scale should we define the farm landscape? Which groups of organisms should we try to identify and at what level? Which survey techniques will be both efficient and yet sufficiently varied so as to index the invertebrate community in different, ideally complementary, ways? Lastly, in terms of agricultural significance, how do we interpret species lists and what techniques can we use to better understand the behaviour which links taxonomy and agroecological significance?

This report has two tracks. First, as an effort to learn from what has essentially been a pilot project, it tries to begin answering some of the above questions and to plot a way forward. In doing so, we hope that it also begins to serve a second purpose of providing a little more insight into the largely unseen flow of on-farm wildlife.

The report begins with a description of techniques used. Aside from being a way of archiving the details, it is important to consider what these techniques did and didn't accomplish. What was and was not sampled in terms of places and organisms? We then summarize the different organisms we found and the taxonomic levels at which we tried to identify them. This is the cast of characters, and, as will be discussed in more detail, it's worth considering what levels of taxonomic detail are truly useful. With those preliminaries under our belt, we'll consider our results from the perspective of answering the question, 'do wilder areas provide meaningful habitat for beneficials and biodiversity in general at the Farm Hub?'. We won't answer that question conclusively, but we'll begin to describe some of the evidence. Finally, we'll conclude by discussing some ideas for the 2017 monitoring season.

Sampling Sites

Sampling was conducted in fields 8, 10 and 15 (Fig. 1). In each field, a series of four points was established extending from a woodland point (ca. 10-30' from the field edge) to an edge point on the field side of the border road around each field and then to sites at 300' and 600' from that edge point along a line roughly perpendicular to the forest edge. Generally speaking, field 8 was in grain during 2016 (oats and rye), field 10 was in vegetables, and field 15 was fallow (although field preparation was beginning during the last visit). These sites were visited at the end of May, June, July and August.

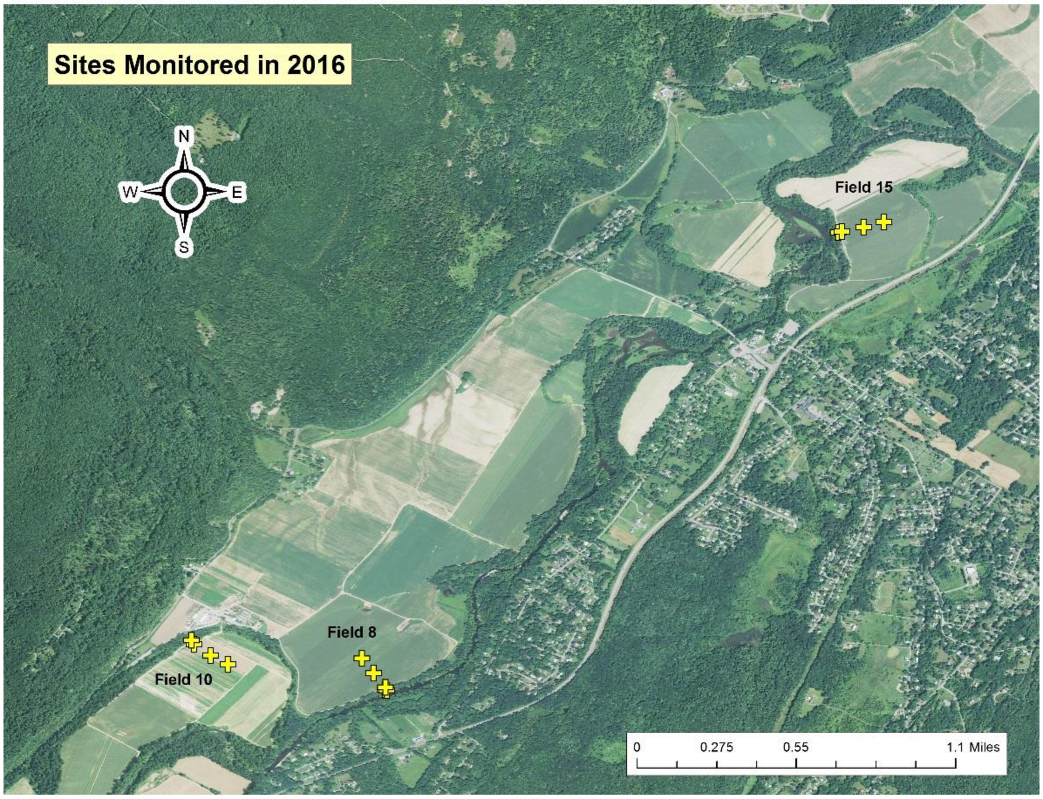

Figure 1. 2016 sampling points. The "woods" and 0' sites were located quite close to one another and cannot be separted on this map.

Sampling Techniques

One of the basic goals of this suite of techniques was to sample different physical layers or realms in each field: the malaise traps intercepted airborne creatures, the sweep netting primarily knocked creatures off of standing vegetation, the pit traps caught those who were surface active, and the Berleses funnels extracted some of the soil life. Additional techniques were added so as to include or improve sampling of certain organisms or to gain some measure not just of abundance but also of activity.

Sweep Netting: Once during each visit each sampling point was sampled with an 18" diameter sweep net. After 25 swings of the net through the surrounding vegetation, the contents of the net was emptied into a bug house and the visually tallied, mainly to gross taxonomic group. Bees and wasps were collected for subsequent identification.

Malaise Trapping: Large, tent-like Bug Dorm "SLAM" traps were used. These are four-sided malaise traps measuring 156cm square and 170cm high. These were set from roughly 10AM to 6PM for one day at each point in each field during each outing. Captures were collected in soapy water and the entire sample was saved for later counting.

Pit traps: Pit traps were only set during the June, July and August outings. A manual ground search was conducted in May. Pits were made from 32oz yoghurt containers with a 3" hole cut in their tops. These were set into the ground so that the tops were flush with the ground surface. No killing fluids were put in them, because relatively few organisms needed to be collected for identification. Pit contents were tallied to general group with unknown ground beetles collected for identification. After installation, traps were left out continuously and checked once each morning. Data was recorded on a per-check basis and analyzed as average catch per trap night. In some cases, the number of trap nights varied across fields because not all pits could be set during the first day. Three pits were set at each sampling distance.

Berlese Funnels: These were only used during the last sampling period, and technique needs to be further standardized. On 31 August 2016, a 6" deep sample of soil was collected at each sampling point, stored cool and then a 32 oz subsample was placed in a Berlese funnel. Light intensity was gradually increased and the samples were extracted for more than a week. The organisms collected in alcohol at the bottom of the funnel were sorted into broad categories.

Time-lapse Cameras: The presence of an insect does not necessarily mean its 'doing its work'. For example, although we can tally the catch in a pit trap, that doesn't mean that all those organisms are contributing 'services' in the same proportion. To get one measure of 'services', we set out 4.75" diameter yoghurt tops sprinkled with freeze-dried meal worms and freeze-killed Fall Army Worm eggs. We then used Wingscape Birdcam Pro close-focusing time lapse cameras to take a photograph of the baited top every minute for approximately 24 hours (minus the time needed to collect and move the cameras). These photographs were then reviewed and the general category of insect observed on the tops was recorded.

Motion-sensitive Cameras: To index small mammal activity, we used Wingscape Birdcam Pro cameras with a motion-sensitive setting focused on a yoghurt top baited with peanut butter and sardines. Again, traps were left out for approximately 24 hrs, and the animals appearing in the images were tallied.

Bat Detectors: We piloted an assessment of bat activity by using an Anabat II, an Echo-Meter equipped Ipad and an Anabat Express to record bat activity at the 0', 300' and 600' points. Periodic equipment failures, the likelihood of inconsistencies among detectors, and avoidance of thunderstorms meant the data were incomplete and not well standardized. Nonetheless, side-by-side trials suggested gross level similarities in detection among the detectors. Calls were analysed using Analook (for 'manual ID') and Echoclass software (for automated ID). Not all bats can be definitively ID'd to species using calls, however species groups can be consistently identified.

Moth Lights: As we all know, moths are attracted to lights in the night. Other insects also are, either because of a similar attraction to light itself or because of the food fest it engenders. We used Bug Dorm night collecting tents erected over the frames of our SLAM traps and lit by 15 watt Bioquip black lights. The locations of the woods and 0' lights were staggered to reduce the competition between them. Lights were run all night and checked at sunrise. Approximate number of macromoths at each light was tallied and photographs were taken of each distinct species. Occasionally the presence of other organisms, such as ground beetles, was also noted and sometimes collected. Moths were identified by photograph using the Peterson Moth Guide and other on-line resources. While photographic ID is not 100% accurate, it provides us with a general description of the moth community.

Bee Bowls and Vane Traps: Malaise traps intercept a variety of flying insects including bees. In an effort to get more information on bee diversity and abundance, during the last outing at the end of Aug/beginning of Sept., we also used bee bowls and vane traps. These traps are especially intended to capture flower visitors. For one day at each sampling point, we put out a yellow and blue vane trap together with 6 bee bowls (2 each of yellow, blue and white color). These were out for approximately the same period as the malaise traps. All insects were collected and counted to general group; bees were identified to species. Bee bowls captured relatively few bees and are not discussed here.

Sound Maps: Finally, as an experimental attempt to 'paint a picture' of one aspect of the insect landscape, we made sound recordings during our August/September outing. Several species of crickets and katydids were calling, and we walked approximate grids in fields 10 and 15 and, because we wanted to include a field with more complex plantings, in field 20 (which was then in various cut flowers and cover crops). In each field, we made recordings at GPS-tagged points located in an approximate grid pattern. We then analyzed the strength of sound at various frequencies known to be used by calling insects. The resulting sound-intensity maps give us one way of picturing the habitat use of such insects across the field. Only the field 15 maps will be presented here.

Creatures Observed

Birds. Aside from the occasional cameo at a camera, birds were not registered during this season. However, Anne Bloomfield has begun standardized bird surveys at the Hub, and we hope those data will become part of future reports.

Bats. Based on recorded calls and no other form of confirmation, Big Brown Bat (*Eptesicus fuscus*), Silver-haired Bat (*Lasionycteris noctivagans*), Red Bat (*Lasiurus borealis*), Hoary Bat (*Lasiurus cinereus*), Eastern Pipistrelle (*Perimyotis subflavus*), Little Brown Bat (*Myotis lucifugus*) and Indiana Bat (*Myotis sodalis*) were present at the Hub. The Indiana Bat is an Endangered Species known to summer throughout much of the region. Although its calls are difficult to distinguish from those of other Myotis species, it was identified as being present on three different dates in 2015 and 2016.

Bats are known to consume agriculture pests. For example, in certain situations the Big Brown Bat, one of our more common species (probably accounting for around 60% of the recorded calls; calls were not distinguished from the rarer Silver-haired) is known to consume ample stink bugs and other agricultural pests. Furthermore, although there is little physiological work, there is reason to believe that pesticide application may affect bat health. Monitoring bat activity on and around farms as they transition thus seems important.

Small Mammals (other than bats). Our motion-sensitive cameras indicated that *Peromyscus* mice (i.e., Deer Mice and/or White-footed Mice) were the most common visitors to our bait, although lighting and focus may have led to occasional confusion with House Mice. Meadow Vole appeared once and, perhaps surprisingly, neither rats nor shrews were ever recorded. Raccoon, Grey Squirrel, Groundhog, and Opossum all made guest appearances.

Ground Beetles. For unknown reasons, the abundance of ground beetles in the Hub's agricultural fields was much higher than what we have commonly observed elsewhere. We have identified 47 species of ground beetles (Carabidae) at the Hub (Appendix 1), seven of which were non-native. As with moths, we sampled ground beetles both as an indicator of biodiversity and because of their agronomic importance. Seven of the species we observed were new to our list of regional ground beetles; two of these may be state records.

Ground beetles are generally considered to be beneficial because some of them feed on insect pests (including wireworms and other beetle larvae) and weed seeds. A few are sometimes pests of soft fruits, but are unlikely to be pests at the Hub. While we can broadly assume that many of these species are beneficial, that conclusion remains more hypothesis than proven fact.

Bees. We have found roughly 41 species of bees that Hub so far (Appendix 2). That number is approximate because one of the most common genera (*Lasioglossum*) is composed of tiny bees which are often difficult to identify. Although bees are primarily discussed because of their importance in agriculture, this focus has also led to relatively abundant information on their diversity and distributions which gives any survey a useful biodiversity context. Perhaps because of its sandy soils (which encourage ground-nesting bees) and the proximity of various forests, the Hub is relatively diverse in bee species. Three of the bees we found, including the European Honeybee, are non-native; eight are considered to be rare or declining.

The importance of these bees for crop pollination at the Hub depends, of course, on what flowering crops are of interest. Many bees are generalist pollinators and visit a variety of flowers although a flower's color, size and morphology do influence which species visit it and how adept they are at its pollination. Consultation of published lists can indicate which bees are likely to be important for a particular crop, although direct observation is also valuable.

Moths. 110 species of moths have so far been identified at the Hub (Appendix 3). We surveyed moths both as indicators of biodiversity and because some of them are agricultural pests.

Six of the moths we found are deemed 'uncommon' by the *Peterson Field Guide to Moths of Northeastern North America*; none are considered species of conservation concern at the State or Federal level. One of the interesting species found was the Birch Dagger (*Acronicta betulae*). The caterpillars of this species may specialize on the leaves of River Birch, a tree that reaches unusual abundance along the Esopus. We have not found it during our work in Columbia

County nor do on-line databases (i.e., bugguide, Moths and Butterflies of North America, Moth Photographers Group) record its presence in New York.

Moths, or more precisely, their caterpillars are sometimes major agricultural pests. Table 1 lists the moths we found which have at least sometimes been considered pest species. We did not attempt to document their damage at the Farm Hub, and some of these are only pests of fruit trees or forests.

Table 1. Moths observed during Hub monitoring and considered pests by at least some sources.

Carrot Seed Moth	*Sitochroa palealis*
Celery Leaftier	*Udea rubigalis*
Common Looper	*Autographa precationis*
Dingy Cutworm	*Feltia jaculifera*
European Corn Borer	*Ostrinia nubilalis*
Faint-spotted Palthis	*Palthis asopialis*
Forage Looper	*Caenurgina erechtea*
Forest Tent Caterpillar	*Malacosoma disstria*
Garden Webworm	*Achyra rantalis*
Greater Black-letter Dart	*Xestia dolosa*
Green Cloverworm	*Hypena scabra*
Green Pug	*Pasiphila rectangulata*
Gypsy Moth	*Lymantria dispar*
Lucerne Moth	*Nomophila nearctica*
Oblique-banded Leafroller	*Choristoneura rosaceana*
Pepper and Salt Geometer	*Biston betularia*
Salt Marsh Moth	*Estigmene acrea*
Smeared Dagger	*Acronicta oblinita*
Sod Webworm	*Pediasia trisecta*
Soybean Looper	*Chrysodeixis includens*
Tufted Apple Bud Moth	*Platynota idaeusalis*
Unicorn Prominent	*Schizura unicornis*
Vagabond Crambus	*Agriphila vulgivagellus*
Virginian Tiger Moth	*Spilosoma virginica*
Western Bean Cutworm	*Striacosta albicosta*

Wasps. Describing the wasp fauna was more of an aspiration than a reality in that their meaningful identification remains challenging. As pest predators and parasitoids, wasps may be one of the most important groups of agronomically beneficial insects. Yet, they are less appreciated and more difficult to study than most other groups. Identification of the parasitoids (i.e., those wasps which are fatal parasites of their hosts), many of which are tiny, is particularly challenging. While certain pest/parasitoid systems have been identified, understanding which wasps are influencing the populations of which pests is often beyond our abilities. Although we began an attempt to identify at least select groups of wasps, that effort is still far from complete.

Flies. Many of the issues which apply to wasps apply to flies, although the ecological diversity and overall abundance of flies is notably higher. Some flies are parasites (e.g., the Tachinids), some are predators as adults or larvae (e.g., Robber Flies, Hover Flies and Long-legged Flies), others are pests, and the role of many is not clear. Flies were the most common single group of insects caught in our malaise traps and sweep nets, accounting for roughly 80% and 44% of the captured individuals respectively. Again, outside of certain groups, such as Hover Flies and Robber Flies, species-level identification is difficult, and we did not attempt it for any fly group during 2016.

Spiders. All spiders are predators, although, unsuprisingly, they do not discriminate between organisms we consider to be pests and beneficials. In general however they are considered to be beneficial organisms that have the potential to help control pest outbreaks. Spiders vary in their hunting tactics including where and how they hunt. Some, such as Wolf Spiders, usually chase down prey on the ground; others, like Jumping Spiders, stalk and pounce; while 'classic' spiders capture prey with a variety of webs. During work in 2016, we only identified a few categories of spiders (i.e., Crab Spider, Wolf Spider, and Jumping Spider), but good identification resources are available and more is possible. This is one of the groups we hope to work with more in the future.

Other Insects. We captured a wide array of other organisms. True bugs, leaf hoppers, aphids, and 'beetles other than ground beetles' were tallied to general group. There are pests within each of these categories, although beneficial predators exist within at least the true bugs and beetles, and agronomically neutral organisms are probably found in all groups. Aside from a better effort to note and tally specific pests, it is unlikely we will soon do more work with these organisms.

<u>Distribution across the Landscape</u>

We looked at the distribution of these creatures across the Hub landscape in a couple of ways: by sampling three different fields at the Hub and by sampling a forest to field middle transect in each field. Our general goal with all of this work, aside from establishing baseline data, is to gather descriptive data that better permit us to identify those characteristics of a farm landscape which enhance general biodiversity and/or beneficial insects.

We worked in fields 8, 10 and 15 during 2016. During the late May to early September study period, field 15 was fallow (although it had been ploughed before the last sampling period), field 8 was in oats and rye, field 10 was in diverse vegetable production. Although imperfect, these fields thus do provide a gradient of use intensity that may hint at certain patterns. As noted in methods, in each field, we sampled woodland, forest edge, and two distances into the field itself. The intention was to explore a gradient of proximity to relatively wild areas.

Below, I will explore the data through by-field and then by-distance analyses.

Occurrence across Fields. At ground level, the pit trap data (Fig. 2) suggested that field 15 was the liveliest: ground beetles, spiders and ants were all most common there. These particulars are only partially confirmed by the camera data (Fig. 3), in which ground beetles and ants were at least somewhat more common in field 15, but spiders were generally rare overall and not noticeably more common in that 15. In the camera data, slugs and other life were also most common in field 15. The abundance of ground beetles and spiders in field 15 supports the value of untilled areas as reservoirs for beneficials – this field was fallow until autumn of 2016 and, prior to that, had not been plowed since XXXX; in comparison, the two other fields had been plowed in the Spring of 2016 (???).

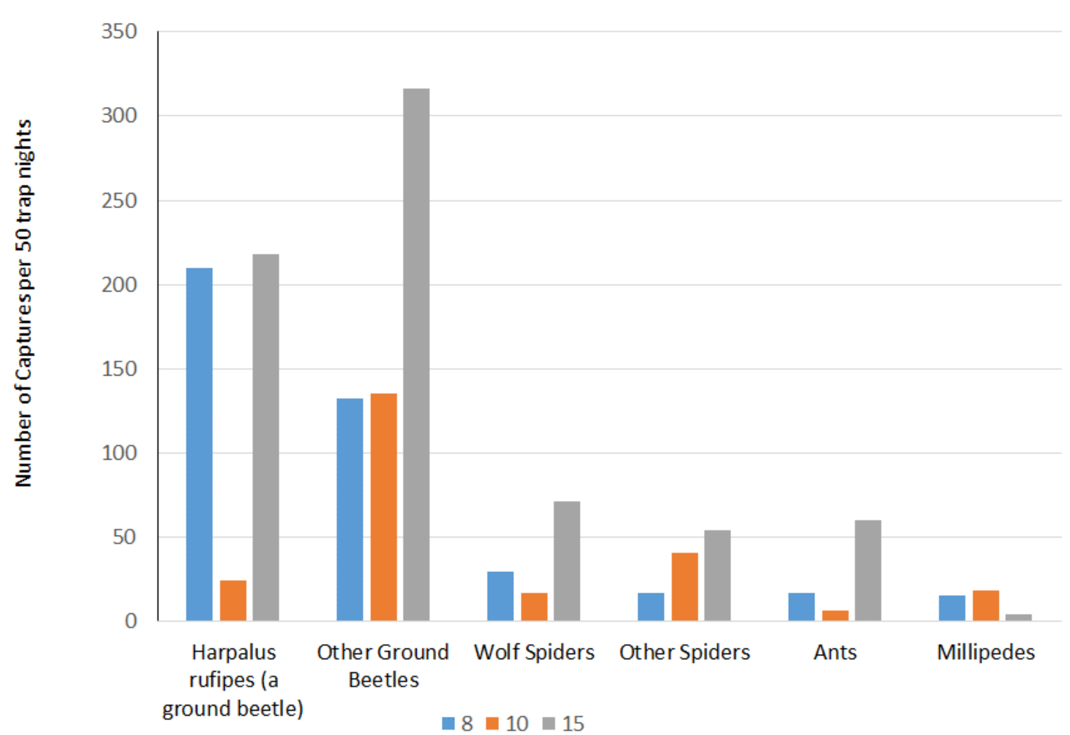

Figure 2. Pit trap captures by field.

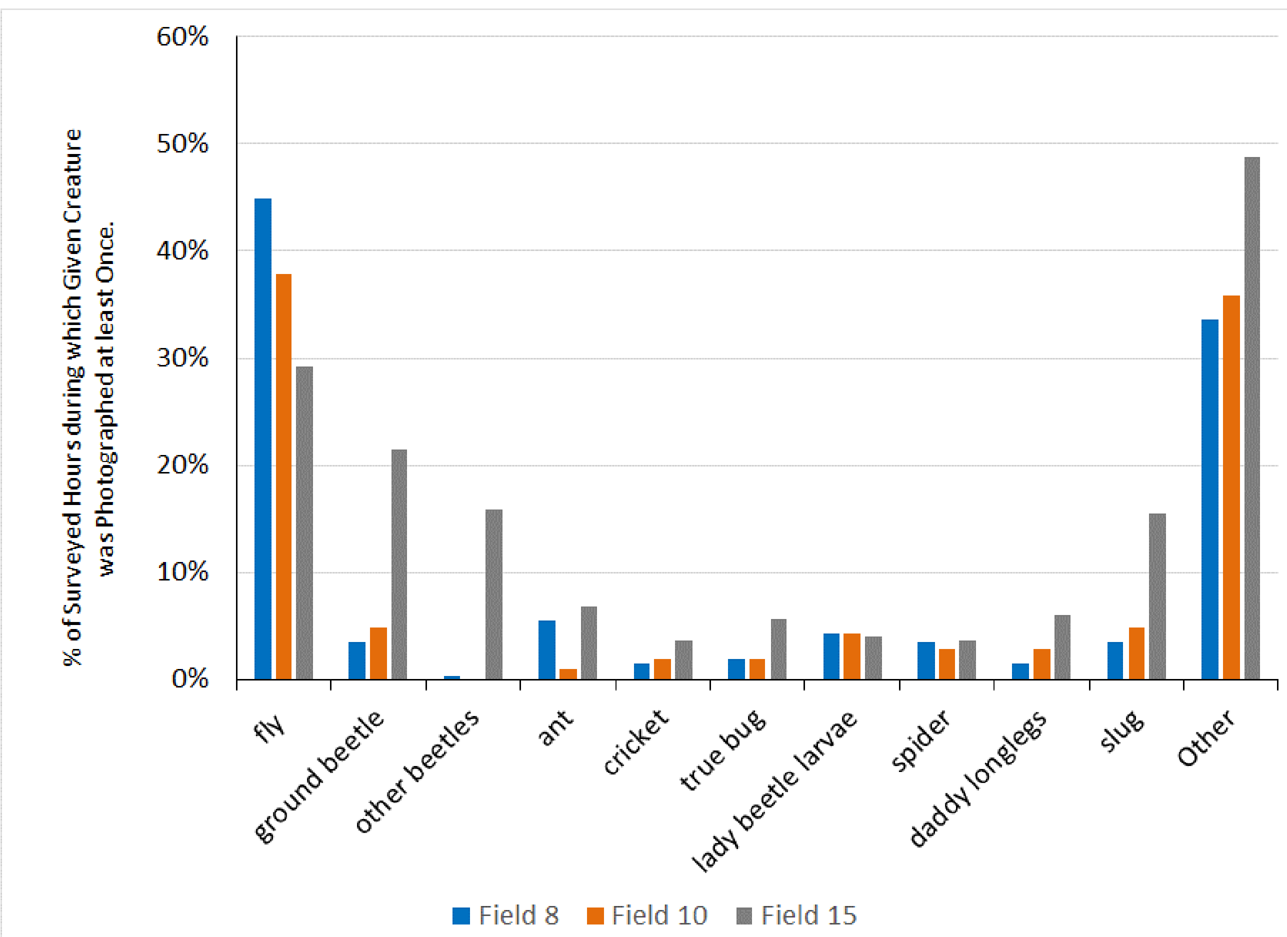

Figure 3. Creatures photographed at meal worm and fall army worm bait.

The ground beetle species composition (Fig. 4) differed across the fields. For example, Bequ (*Bembidion quadrimaculatum*), a tiny apparently relatively plow-tolerant species, was more common in field 10 while Hape (*Harpalus pennsylvanicus*), a larger species which might favor reduced tillage, was more common in field 15.

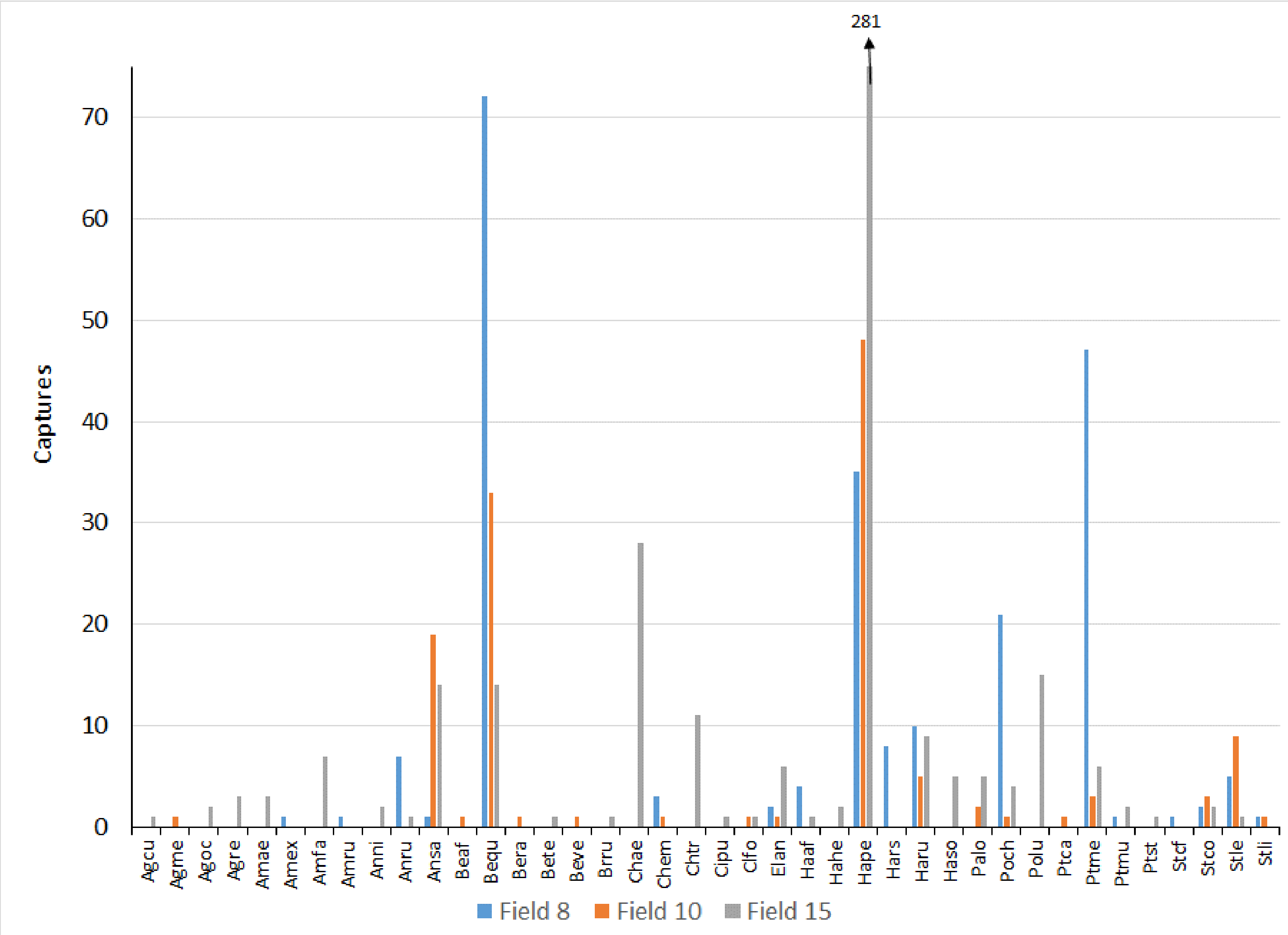

Figure 4. Ground beetle species composition across fields. Abbreviations are the first two letters of the genus combined with the first two of the specific epithet; scientific names are in appendix.

The sweep netting data (Fig. 5) highlights field 10's role as a veggie field. Most pest organisms – flea beetles, aphids, and leafhoppers – reached their highest abundance in this field. Flies as a general group were also noticeably more abundant in field 10. At the same time, and perhaps in response to the abundance of pests, certain pest predators/parasitoids, such as lady beetles, wasps and assassin/ambush bugs were also at relatively high levels. Bees (also relatively common in the field 10 sweeps and vane trap captures) may have been responding in part to flowers in and around the garden, but they also may have benefited from field 10's sandier soils. Numerous ground-nesting bees were seen in the drive strips of this field. Interestingly, spiders were, if anything, less common in field 10 than in the other fields.

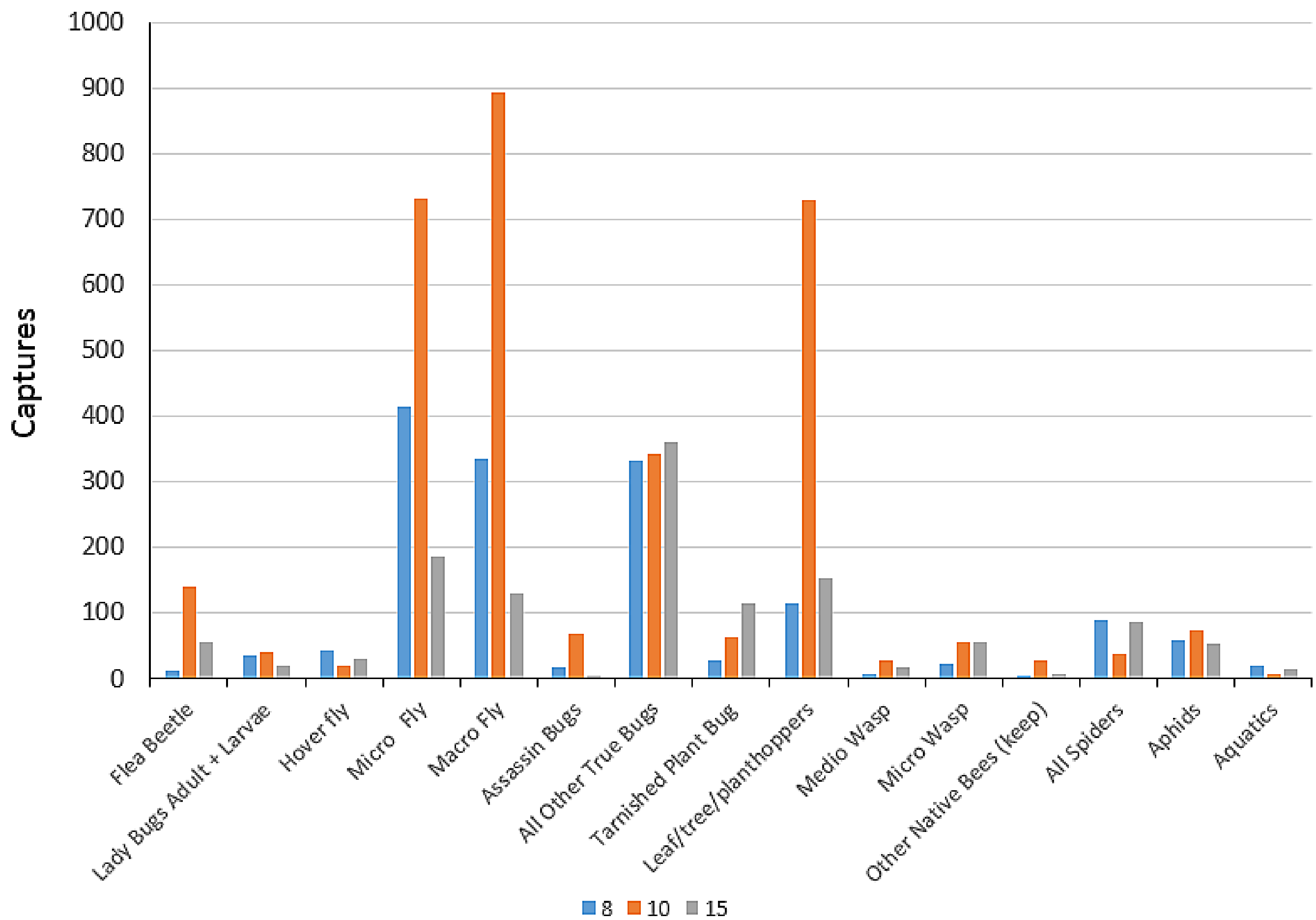

Figure 5. Sweep net results compared across fields.

Surprisingly, the malaise traps (Fig. 6), which were intercepting flying insects near the areas surveyed with by sweep net, showed a distinct pattern. In general (Fig. 7), malaise traps caught relatively fewer of the more sedentary or weak-flying insects, such as true bugs and leafhoppers and, correspondingly, higher proportions of the strong fliers such as flies, bees and wasps. That said, even within some groups, the relative abundances across fields in the sweep vs. malaise data were not comparable. For example, the sweep net data suggested that field 10 had relatively high numbers of flies, whereas the malaise data suggested they predominated in field 15, a result seconded by the vane traps. Although we did not ID flies to species, I would suspect that the two techniques were capturing somewhat different fly species with different ecologies and behaviors.

Moths, as counted at the moth lights, were more than 50% more abundant in field 15 vs in field 8 (we had insufficient data for field 10).

Looking at diversity rather than abundance, ground beetles and moths appeared to be most diverse in field 15, while bee diversity was approximately constant across fields.

To certain degree paralleling the above insect results, bats were most abundant in field 15, which averaged 100 calls/night as compared to 73 and 62 for fields 8 and 10 respectively.

The above results suggest the potential benefits of fallows as habitat for beneficials. For ground beetles and spiders, this is probably at least in part due to their reduced tillage. Fallow habitat would likely be even better for bees and wasps if it were enriched with wild flowers.

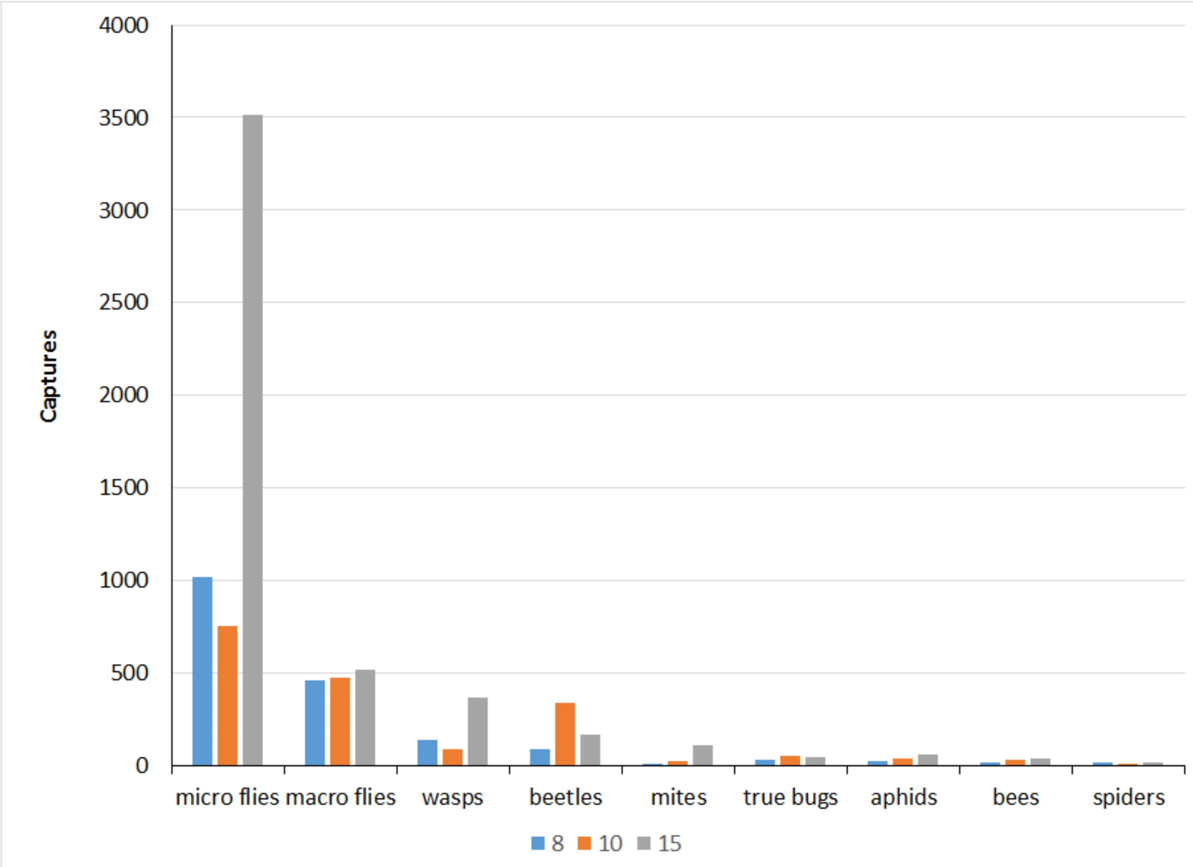

Figure 6. Malaise trap captures compared across fields.

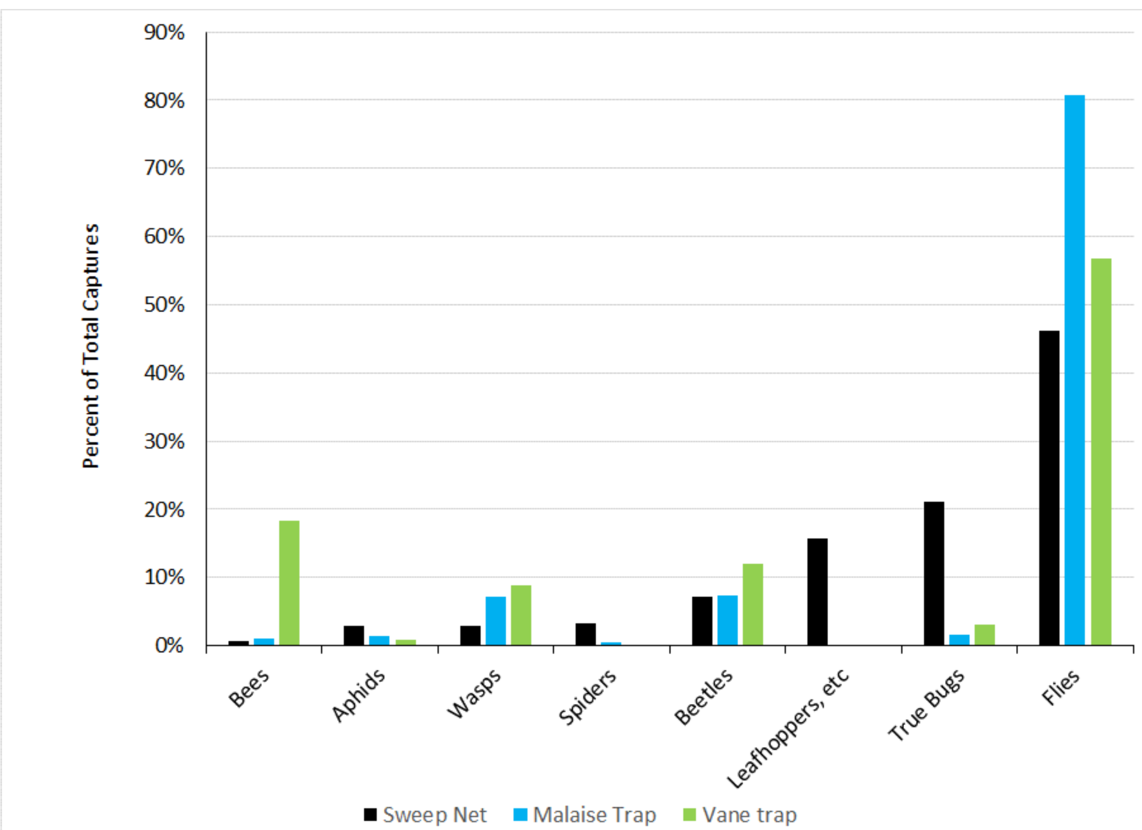

Figure 7. A comparison of captures using three different types of trap.

Distribution across Distances within Fields. To a certain degree, our 'forest to field center' results help us look at the same question of management effects as discussed above. By highlighting those species or groups of species which are more common in the wilder areas, these results could, theoretically at least, suggest the possible consequences of expanding such habitats farther into field areas. Furthermore, by looking at the ecological 'seepage' from such areas into adjacent fields, these results could hint at the range over which wild-area effects might operate. There are a couple of considerations which cloud the simplicity of these statements, but let's first look at the data.

On the ground, the gross-level pit trap results (Fig. 8) suggest that forests harbor distinctly more ants and millipedes than the adjacent fields, but that for wolf spiders, the pattern appears to be the opposite. For ground beetles, the pattern in the general data is largely unclear, but becomes more apparent as one delves into the species level data (Fig. 9). At this level, it is evident that there is a large faunal turnover as one crosses the forest/field boundary. In fact, most ground beetles species were found either in the forest only or in the field only, with slightly less than ¼ found in both habitats. Clearly, forest and field are seen as markedly distinct habitats by ground beetles, and so there may be only limited potential for forested areas to serve as reservoirs for many species. That said, it's also clear that some of the most abundant (and so presumably most important in terms of ecological services) in-field ground beetle species did occur in both habitats. Except perhaps for the abundant and agronomically important *Harpalus pensylvanicus*, there is not a clear drop off from field edge to field center for those species found in both field and forest.

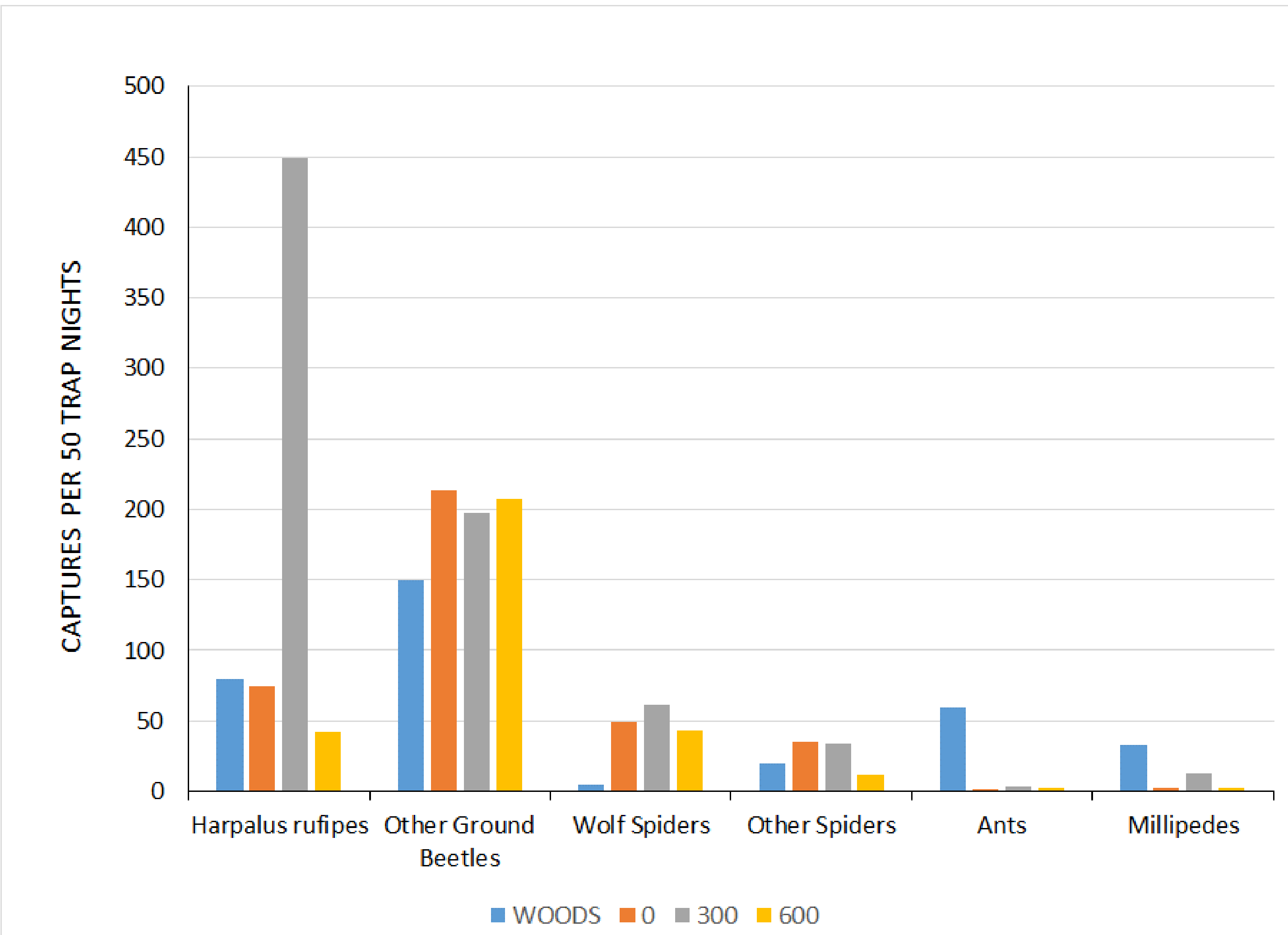

Figure 8. Pit trap captures across locations at each field..

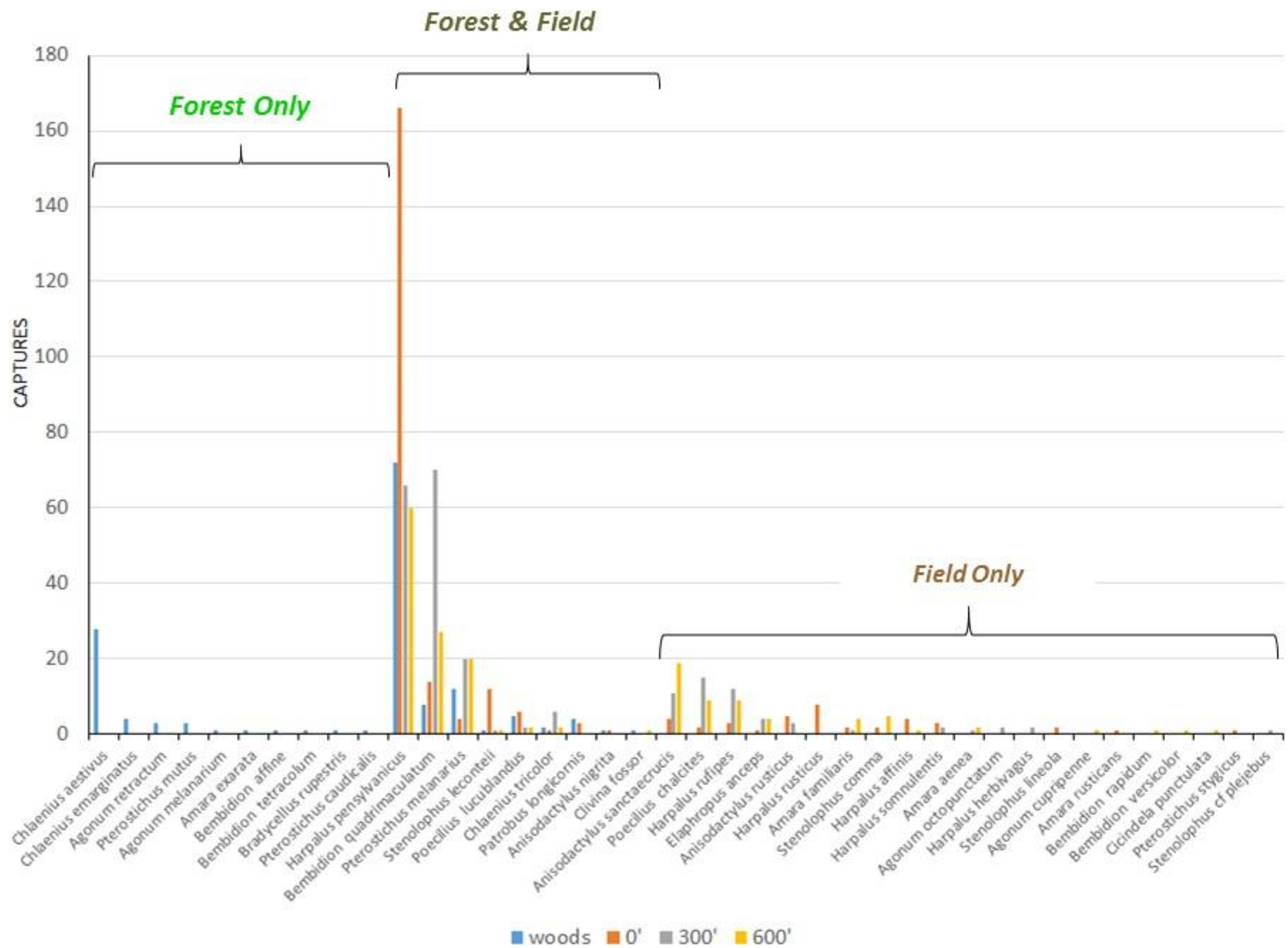

Figure 9. The captures of various ground beetle species across locations at each field.

Ground beetles pick their habitats for a variety of only partially understood reasons, which include soil conditions, diet and microclimate. We have not yet delved into the ground beetle data enough to provide much explanation for the pattern, although a suite of traits that makes specific species more or less sensitive to ploughing may be important.

As a prolonged aside exploring faunal turnover that forest/field transition, we can look at some of the other groups for which we have species-level data. Perhaps do to the greater mobility of moths (many ground beetles are flightless) and the alluring nature of our light traps, a greater proportion of moth species occured in both forest and field habitats (Fig. 10). Nonetheless, if we compare the average caterpillar diets (based on the literature) of the species found in the forest and in the field (recognizing that some species occur in both), we see a noticeable decline in those species whose caterpillars feed on woody plants as one shifts for field to forest. There is nothing particularly surprising about this, but it illustrates one of the ecological factors influencing species turnover across habitats.

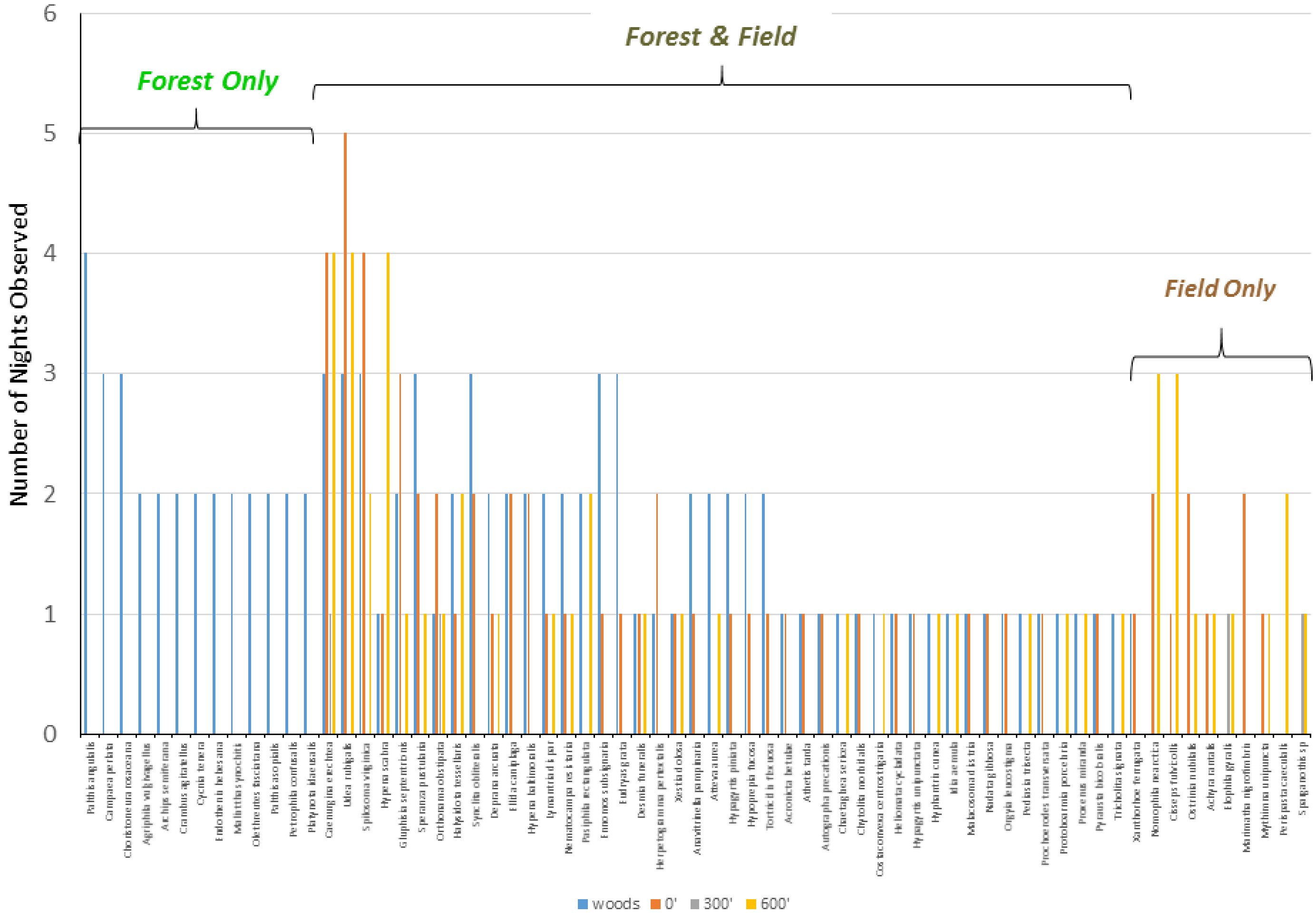

Figure 10. Moths photographed at various locations at each field. Sorry for the infinitesimally small print; will improve it, meant to illustrate general patterns. Only shows those moths found on more than one night.

Another insight into the ecology of this transition comes from the bee data (Fig. 12). In this case, most species (almost 70%) were found only in the fields. Preferred nesting locations differ amongst bee species with some preferring holes in the ground, others cavities in stalks or wood, and yet others simply seeking suitable holes or openings wherever they may be found. All three bees species which were found only in the woods nest primarily in stalks or woody debris, whereas almost half of the field-living bees are ground nesters, four more are parasites primarily of ground nesters, and most of the remaining species are general cavity nesters. Only two of the 20 species which we found solely in fields are considered wood nesters, and one of those was the large and mobile Carpenter Bee.

A pictorial view of different species habitat affinities comes from our sound maps of Field 15 (Fig. 11). In these images, the intensity of sound at various areas of the recording grid is shown. One of the signing insects (at 3962 Hz, perhaps a tree cricket) was rare throughout much of the site, but seemed to be calling from near one point in the NW corner. Another (at 7100 Hz, perhaps a trig) appeared to be an edge species, calling primarily from the vegetation along the road and apparently rare in the fields themselves. A last species (at 9474 Hz, perhaps a conehead) seemed to occur in the fields themselves and perhaps also deeper into the forest, but was rare along the road at those sites favored by the previous species. Much work needs to be done to properly interpret these maps, not the least of which is finding and confirming the identity of the signers.

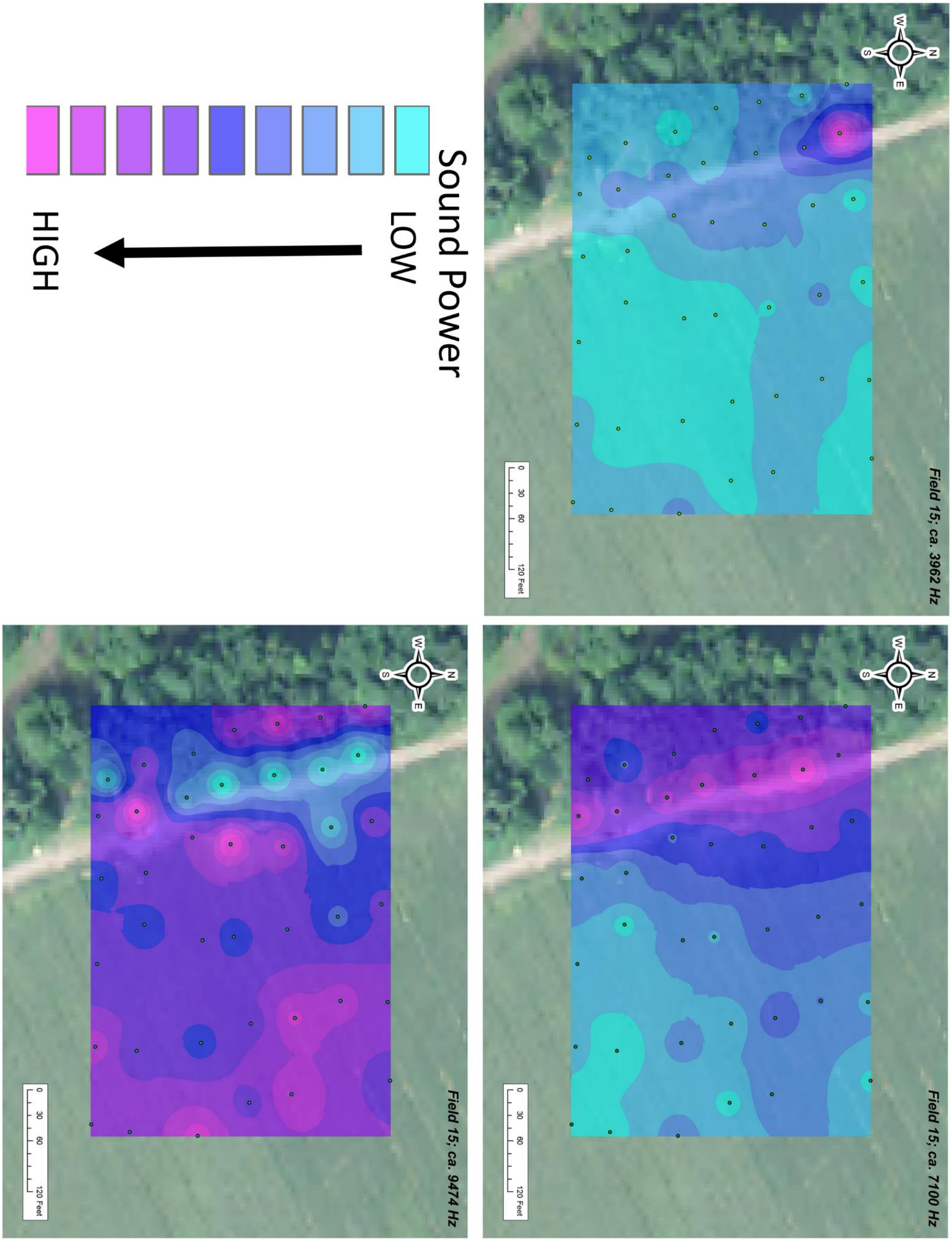

Figure 11. Sound maps at three different frequencies (probably representing three different crickets or katydids). Dots indicate the points at which recordings were made.

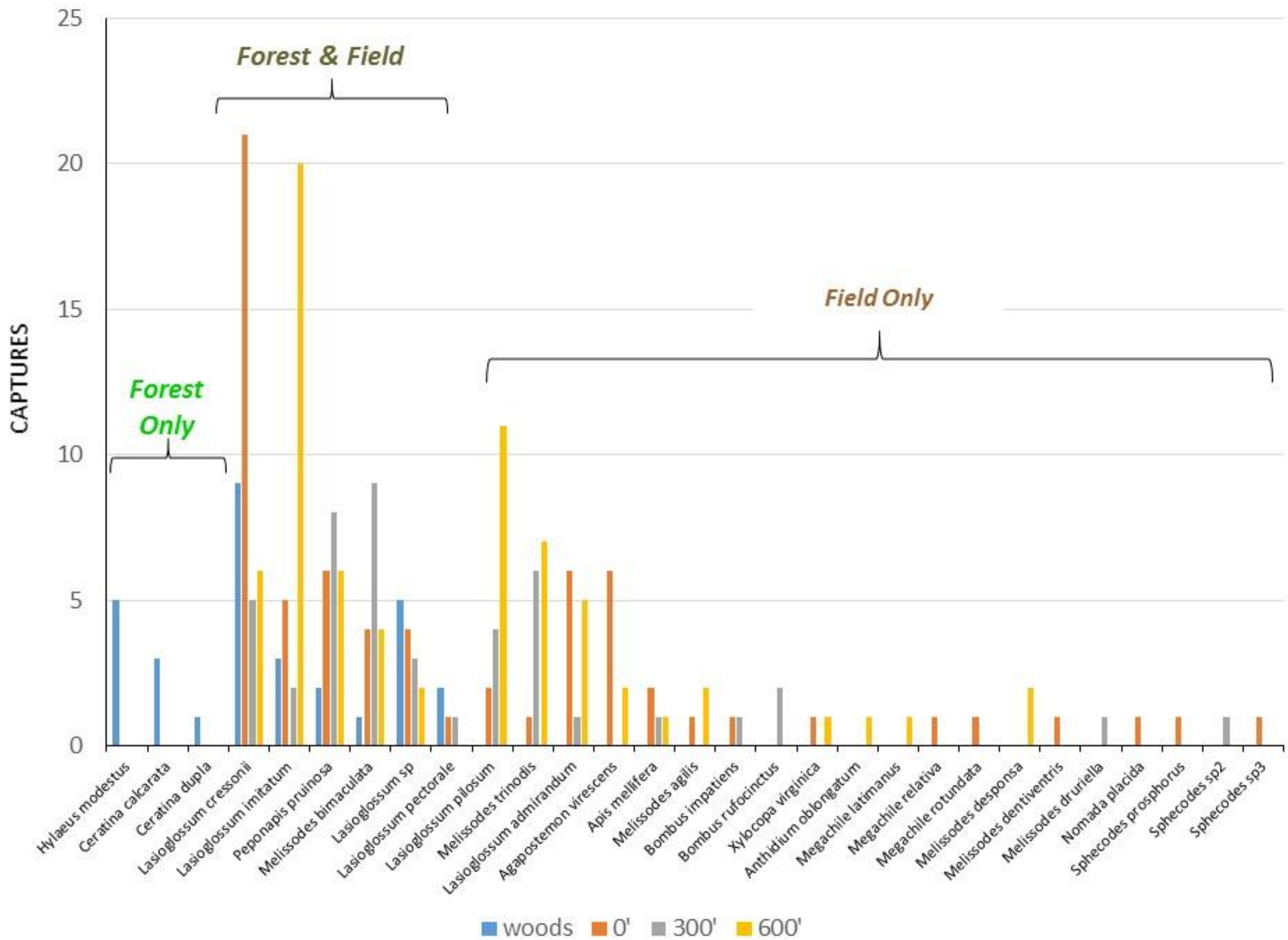

Figure 12. Bee species captures at various locations at each field.

Returning to our consideration of on-the-ground activity, in contrast to the pit trap results (Fig. 8), the camera results (Fig. 13) showed that adult beetles, slugs, spiders, ants, crickets and daddy longlegs were all more active in the woods, while lady beetle larvae and true bugs were only active in the fields.

The sweep net results (Fig. 14) suggest the importance of the forested edges for the smaller wasps, for spiders and perhaps for small flies (many of whom were aquatic midges), whereas many of the pest groups, such as flea beetles, leaf hoppers, true bugs and aphids, tended to be more common in the field areas. Certain of their predators, e.g., lady beetles and hover flies, were also most common in those areas.

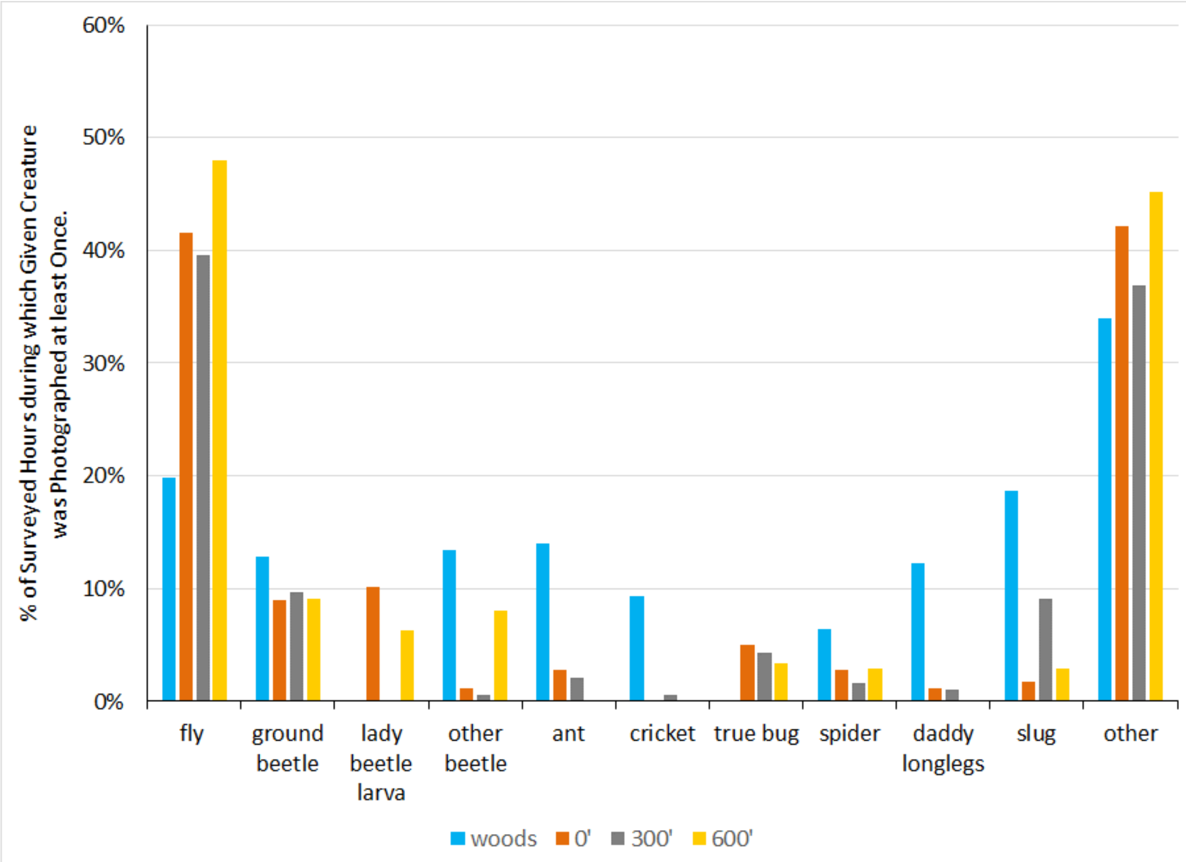

Figure 13. Creatures photographed at various locations at each field.

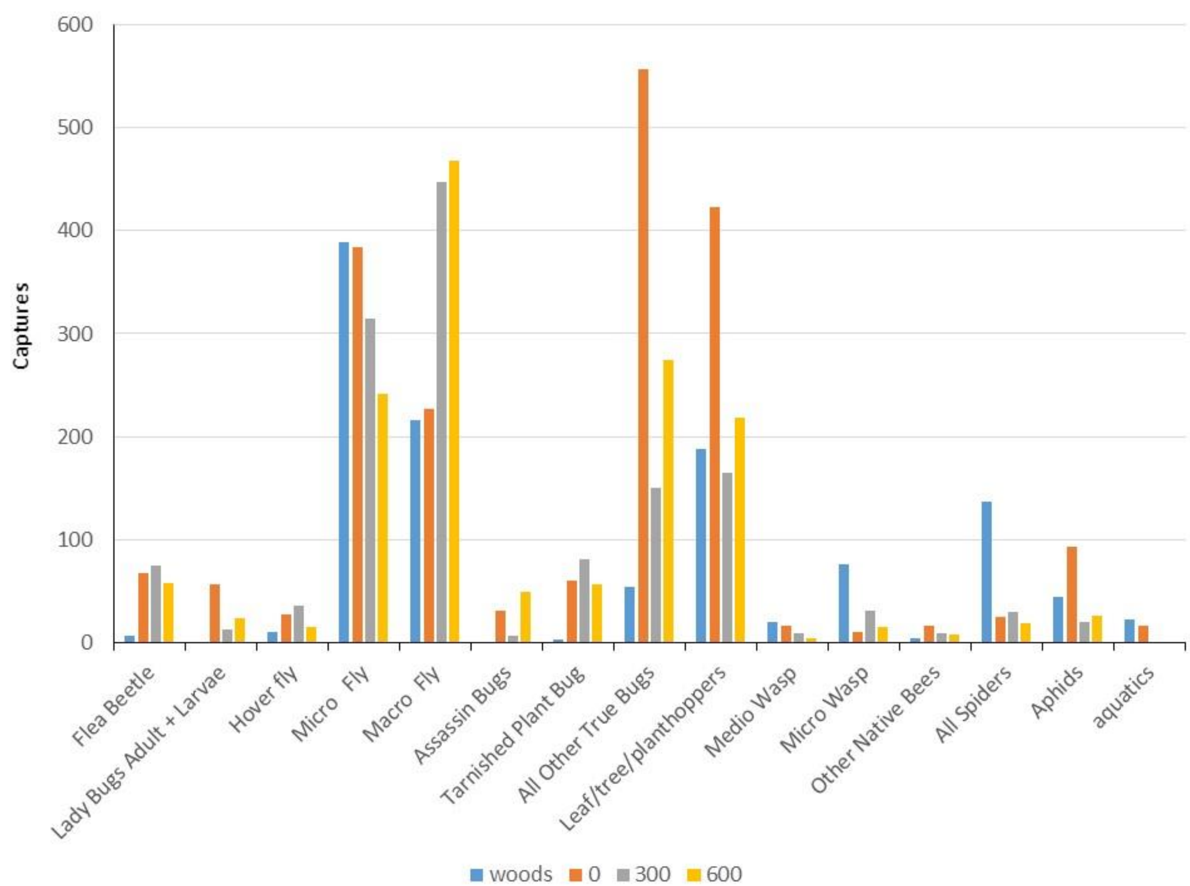

Figure 14. Sweep net captures across various locations at each field.

Again, the malaise trap data (Fig. 15) are less clear cut – as with the sweep data, smaller flies do appear most common in the forest, wasps were most common in the forest and at the field edge, and true bugs were most common in the field areas, however patterns for the remaining groups are generally unclear.

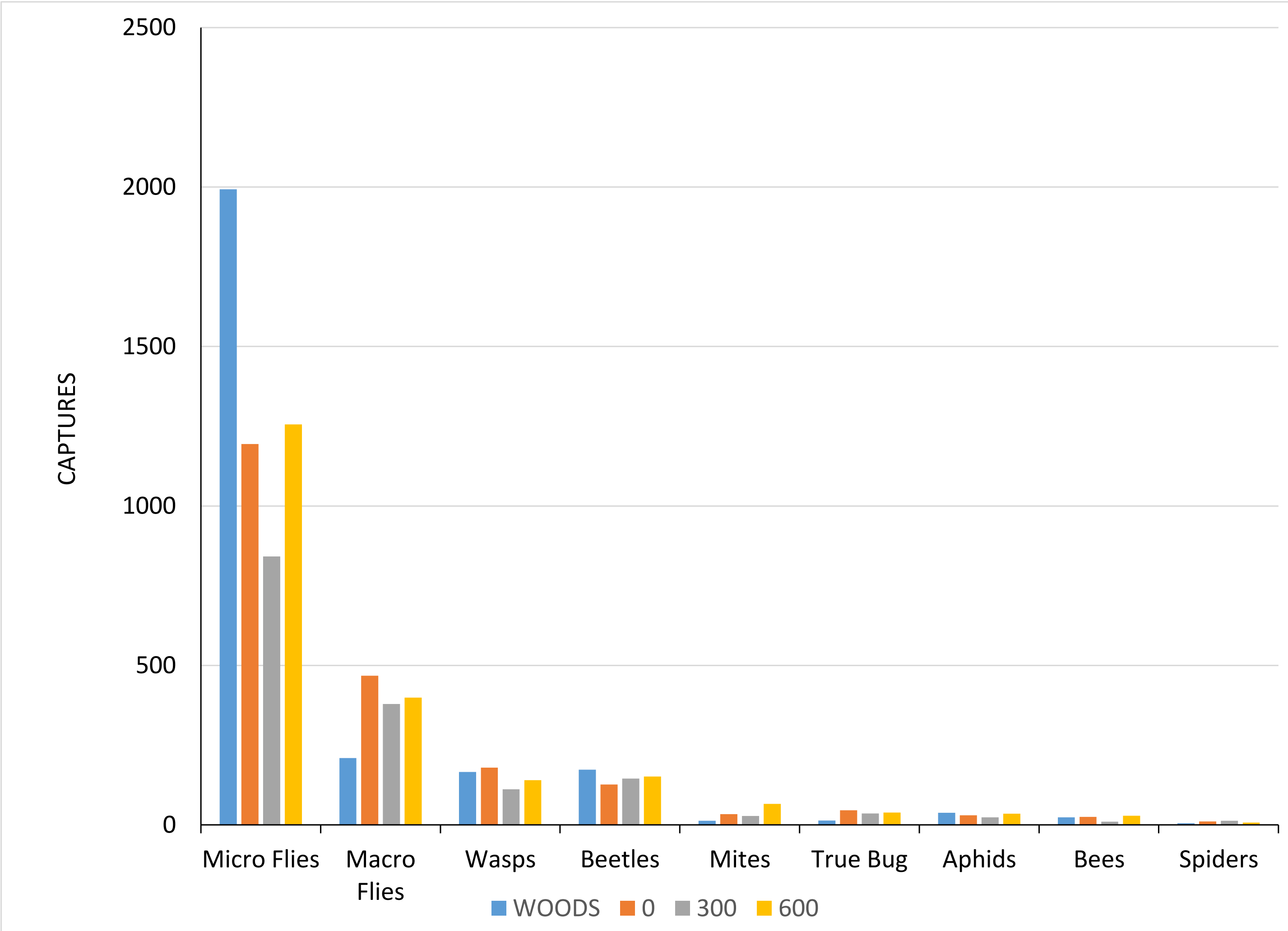

Figure 15. Malaise trap results across locations at each field.

We have only begun to look at soil creatures. Somewhat surprisingly the Berlese funnel results suggested increasing soil fauna with increasing distance into the field. Mites (Fig. 17) showed this pattern at all three fields. Results for Springtails (Fig. 16) were less distinct but, if anything, hinted at a similar pattern. These results are counterintuitive, at least for mites, because these organisms are thought to generally favor less-disturbed, moister soils such as would be typical of forest rather than open field. More sampling and mite identification should help explain this apparent pattern.

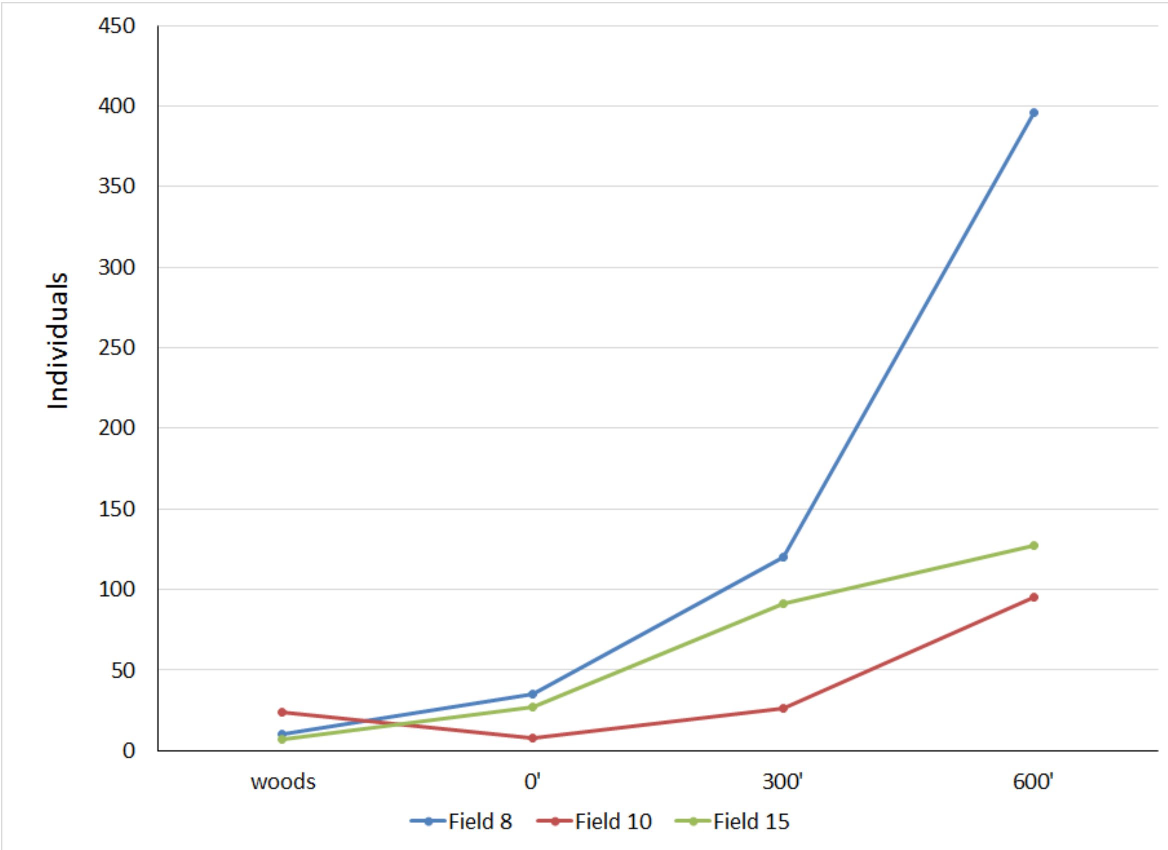

Figure 16. Mites counted in soil samples extracted with Berlese funnels.

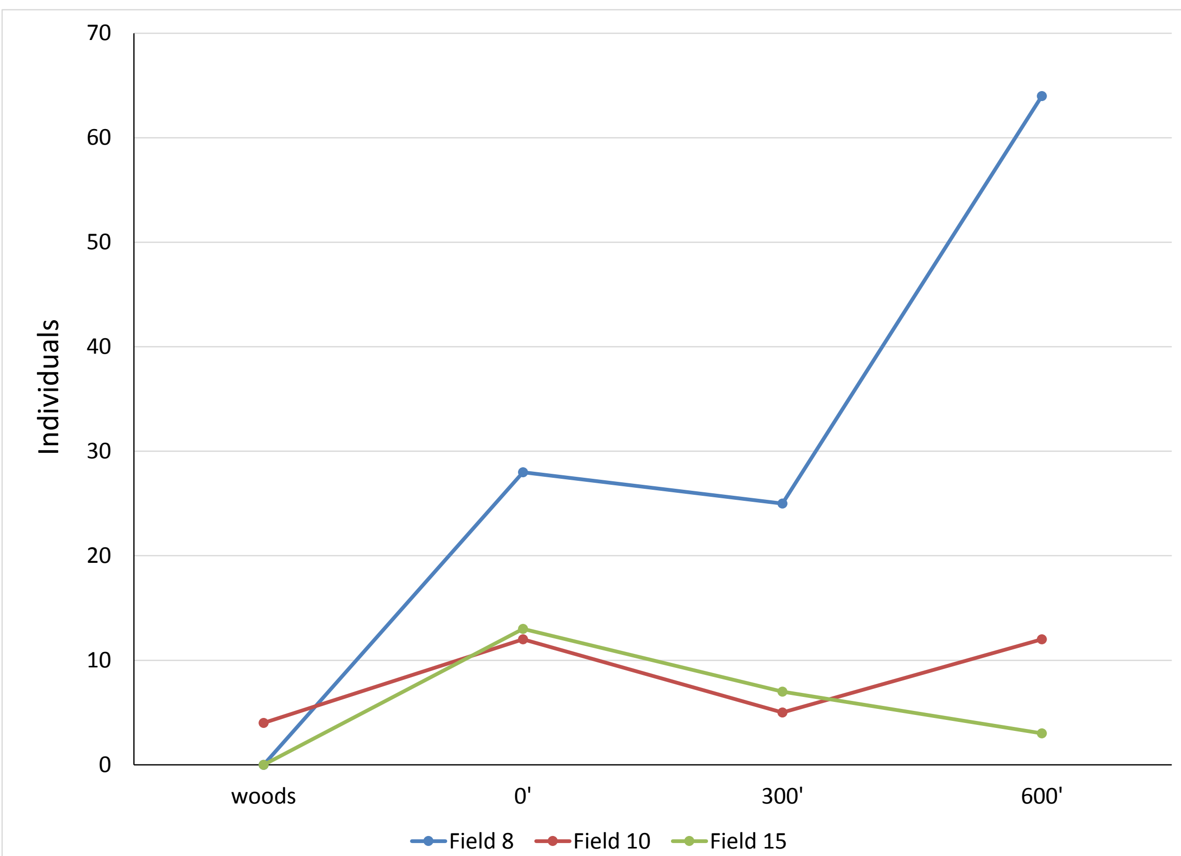

Figure 17. Springtails counted in soil samples extracted with Berlese funnels.

The bat activity patterns differed amongst fields (Fig. 18) and bat species. In field 15, activity decreased uniformly from field edge to center whereas in field 8, the reverse pattern seemed to hold. Field 10 showed yet another pattern, with bat activity peaking part way into the fields. It is probable that the highly mobile bats were responding to the activity patterns of night-flying insects, something we did not, for the most part, directly index. In both the malaise and moth data, forest and field edge did show higher insect activity than the rest of field 15; however, the patterns for the other fields were not clear cut or obviously correlated to bat activity. The sweep data seemed unrelated to bat activity with total catch in field 15 *increasing* from edge to center. The activity of Hoary Bat and Myotis species may have decreased with distance into field, Pipestrelle activity may have increased, and the pattern for Big Brown Bat/Silver-haired Bat (whose calls cannot be reliably distinguished and is our most common species group) was unclear.

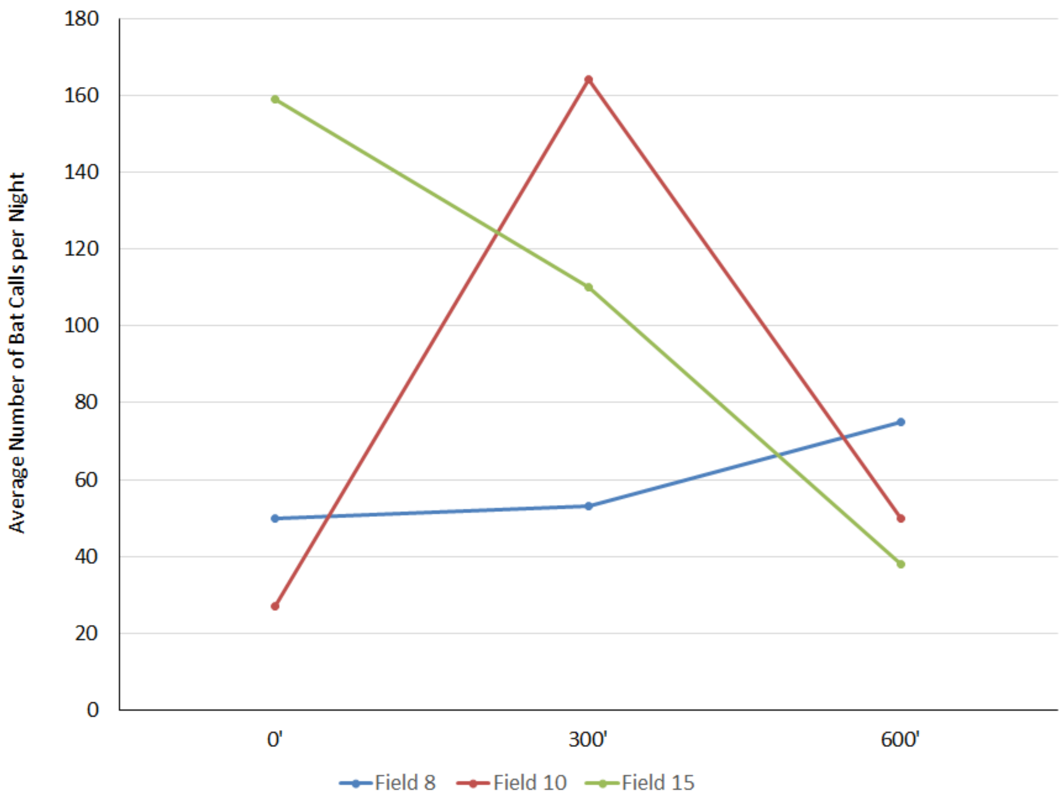

Figure 18. Bat calls at each field and at three distances into those fields. (Bat detectors were not set up in the forest.)

Terrestrial mammal activity (Fig. 19) was generally highest in and near the forest. The apparently high *Peromyscus* activity at 600' was almost entirely due to high May activity in Field 8 rye. Larger mammals (in the "other" category) seemed to remain in or near the forest.

Presence vs. Action

Surveys of insect numbers can give one insight into which organisms may be around, but they do not directly measure activity. For example, just because bees are caught in vane traps, are they pollinating crops? Or, just because ground beetles show up in pit traps, are they consuming pests? Measuring 'services', as well as diversity and abundance, can be important. In 2016, we only made such measurements in one way: by photographing visitors to baited yoghurt tops. Although we have alluded to these results above, Fig. 20 presents a direct comparison of the results from pit trapping and camera traps. There are distinct differences with ground beetles and spiders being less active at bait than suggested by the catch in pit traps. Slugs and "other beetles" appear to be more active. Interestingly, the apparent activity of slugs at insect bait was also noted in a published camera study by Matt Grieshop and colleagues. He suggested that at least some slug species are more active predators than generally realized.

Any such technique measures only one aspect of what is happening. Our camera technique had its own biases. For example, it should be no surprise that spiders, predators of live prey, were relatively rare at our bait of dead insects. The goal is not to discover THE technique but rather to use a variety of methods that help one get a more complete picture. The role of ground beetles in consuming the eggs and larvae of other insects is, for instance, supported by these data, although their role does not appear to be as overwhelming as the pit trap results would suggest.

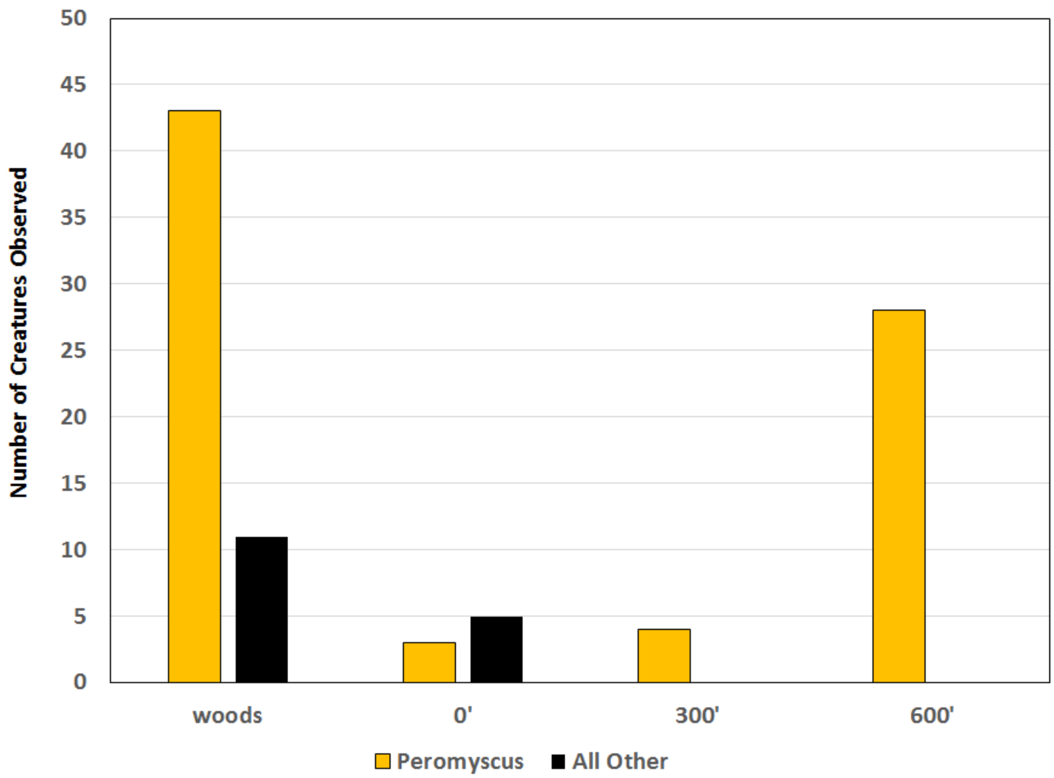

Figure 19. Mammals photographed at various locations at each field.

Conclusions

Aside from creating some baseline data which will only become interesting in future years, these results have at least four immediate implications for monitoring and perhaps management going forward.

1) Seek to create and monitor half-way wild areas.
2) Monitor, envision, and manage for the role of different habitats in a year-around context.
3) Work with those organisms which can be identified to species (or close to it).
4) Add study techniques which allow measurement of 'services' (and even agronomic benefits).

In closing, I will briefly summarize each of these points.

Create and Monitor Half-way Wild Areas. Forests are not teaming reservoirs of beneficial insects waiting to do their work in welcoming fields. As suggested earlier, for a variety of reasons, many forest organisms will not venture into open fields. As some of our previous work has documented (Fig. 21), it is 'half-way wild' areas such as unmowed grassy areas, which appear to share the most biodiversity with agricultural fields. Our work in 2016 did not really include any such areas, although field 15, as a fallow, probably came nearest. This is not a new result, and it is with reason that much of the 'beneficial habitats' that Xerces and others suggest creating are herbaceous. However, such habitats are relatively rare at the Hub, and it will be interesting to see the ecological results as they are expanded. We will be including some such areas in our future monitoring. However, as the considerations below suggest, this does not mean that forested areas are unimportant from the perspective of in-field beneficials.

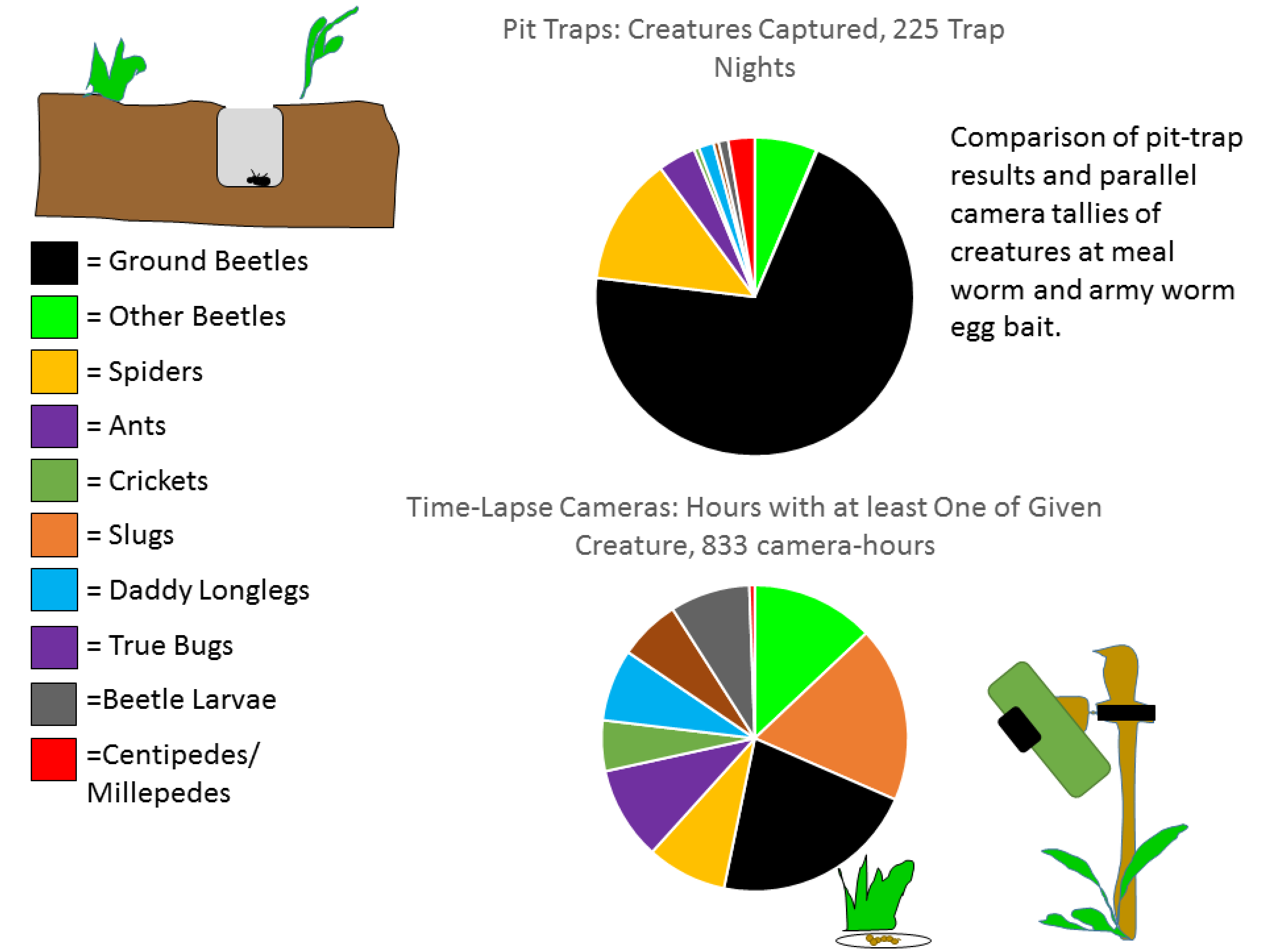

Figure 20. A comparison of proportional occurrence of several different insect groups in pit traps and at adjacent baits.

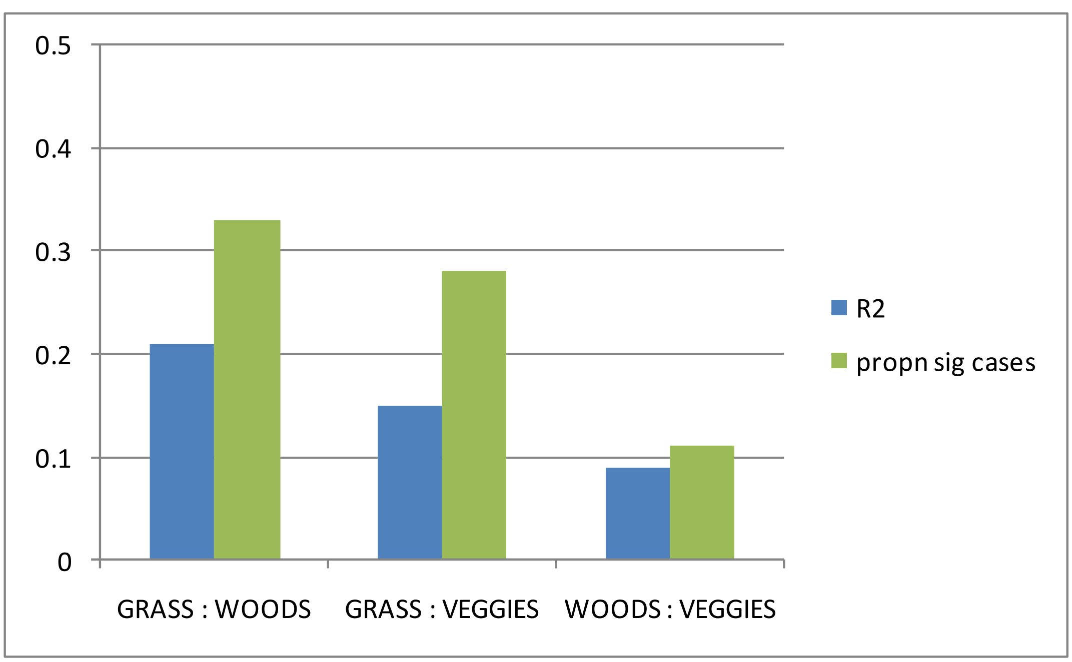

Figure 21. Data from a 2010 study of 19 Columbia County vegetable farms showing the degree of faunal similarity between three different kinds of habitats. Higher R2 and proportion of significant cases indicates greater similarity between indicated habitat pairs.

Monitor, Envision and Manage for the Role of Different Habitats in a Year-around Context. The 2016 work we did at the Hub occurred between late May and early September. Our work and that of others suggests that understanding organism location during these periods of the year is only part of the picture. For example, work we did at Hawthorne Valley following spider abundances in various habitats across a slightly longer season (Fig. 22) suggested that wilder areas may have been refuges from which spiders expanded as the growing season progressed. Similarly, our work on bees together with Martin Holdrege (Fig. 23) demonstrated that at least a quarter of the bee species around crops in mid-summer began their flight season nectaring at the early flowers in forested floodplains. Work by others (Fig. 24) has more specifically looked at the role of wilder habitats as winter refuges for beneficials, again emphasizing the need to consider the larger landscape.

In 2017, we hope to extend our monitoring season and perhaps even begin to look at insect emergence from wilder areas.

Work with those Organisms which can be Identified to Species (or close to it). Those of you who have plowed through the preceding pages may appreciate the greater insight which comes from looking at species-level data. Looking at the patterns of ground beetle, bee, and moth biodiversity, for example, gave us much more insight into what was happening than did considering general patterns such as the abundance of "spiders" or "wasps". Truly understanding the ecology of wild or created beneficial habitat will rely primarily upon species-level biological data.

As alluded to at the very beginning of this report, the challenge is that identifying organisms to species is not only much more difficult, it is often impossible given our current level of knowledge. In 2017, we plan to focus more of our efforts on working with those groups which we can currently identify to species (ground beetles, bees, moths and possibly ants) and expanding our expertise to include some families of spiders, wasps and possibly flies. We will never be able to identify all creatures, and sometimes identification to general group might serve our needs and increase our efficiency. However, species-level identification will need to remain a core aspect of the monitoring.

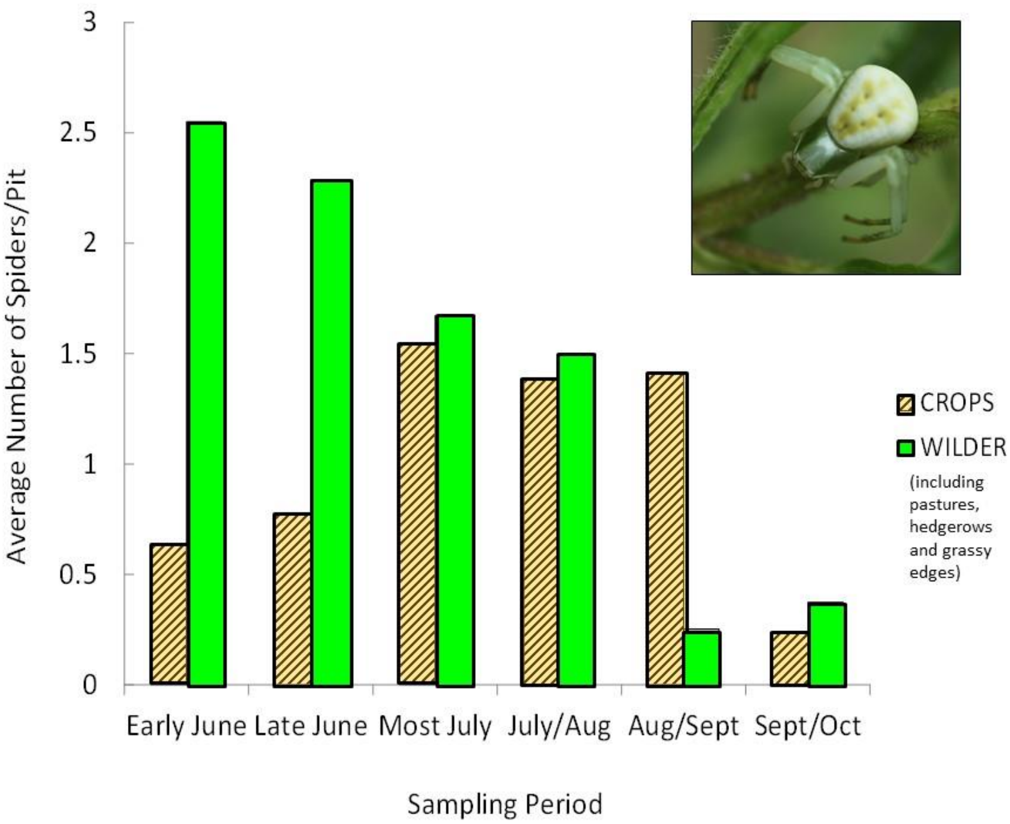

Figure 22. Pit trap results showing change in spider abundance across the season from a 2009 study at Hawthorne Valley Farm.

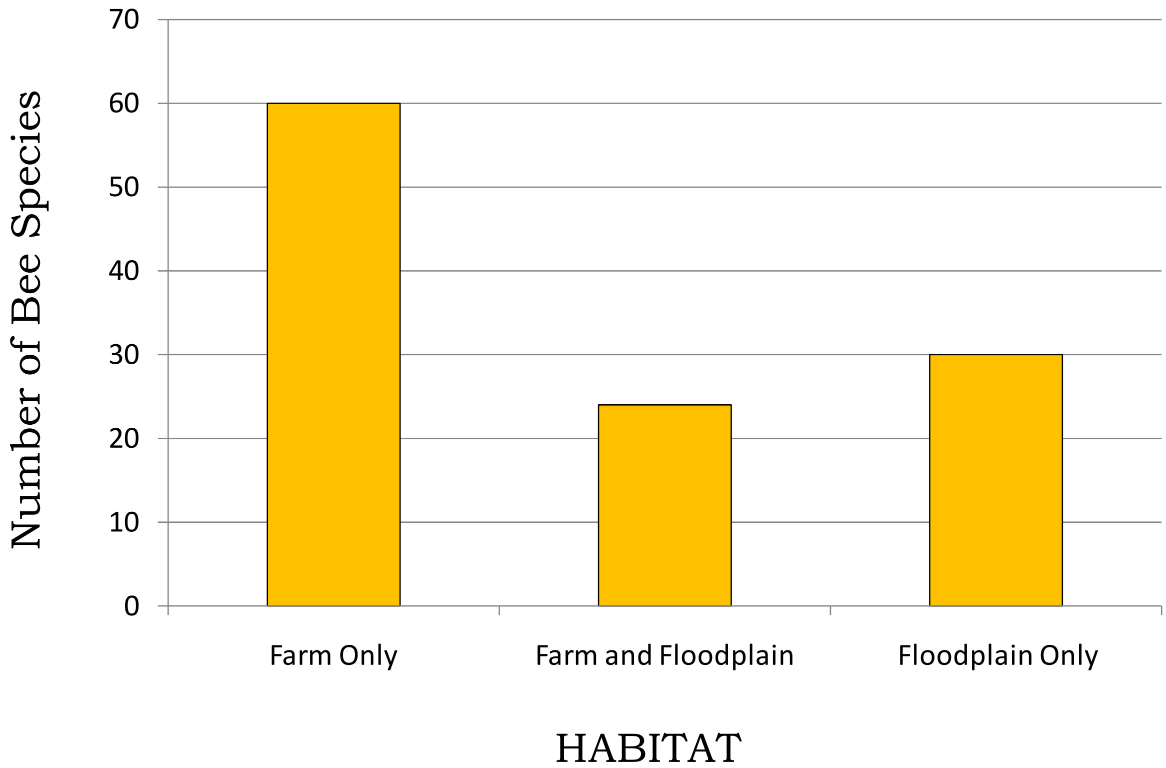

Figure 23. The occurrence of bees on various farms in Columbia County. Work done with the collaboration of Martin Holdrege.

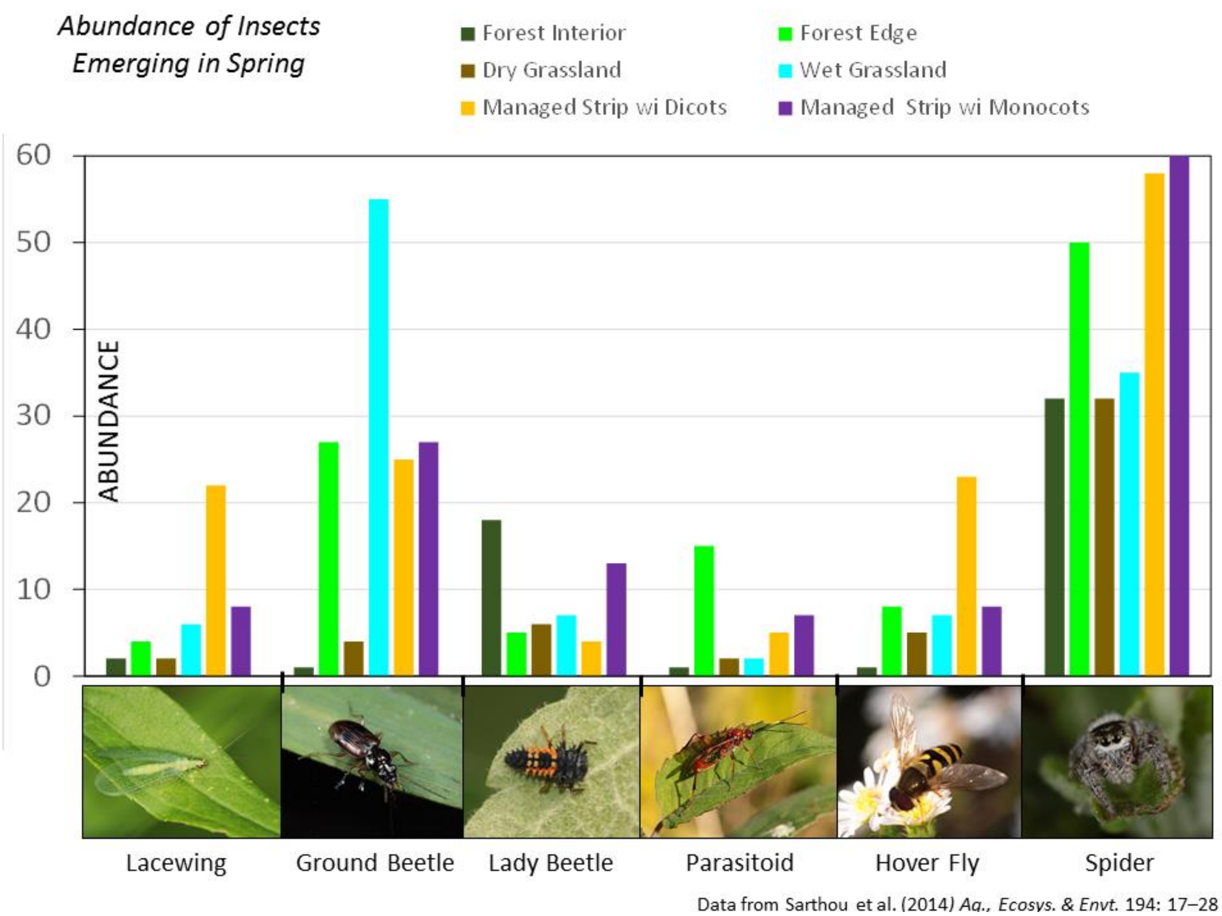

Figure 24. Work by Sarthou and colleagues showing the overwintering habitats (measured as sites of spring emergence) of various beneficials.

Measure 'Services' (and even Agronomic Benefits). Aside from the taxonomic difficulties just described, our greatest challenge in the monitoring is to incorporate more measures of the 'services' of these organisms. Our only attempt this year – the camera monitoring of meal worm and webworm egg bait – provided useful additional insights into the activities of the creatures which appeared in the pit traps. We would like to do more of this, but devising the techniques is not easy. Possibilities include the following:

- Counting (& collecting?) aphid 'mummies' and hatching out the parasitic wasps. Parasitoid wasps can be an important control of aphids. Parasitized aphids tend to become browner and bigger than healthy aphids. Calculating the percentage of total aphids which are parasitized gives an index of wasp parasitism although, hatching out the parasites would be necessary for identifying the specific wasps involved.
- Estimating parasitism of caterpillars. Most caterpillar pests are also affected by parasitoids, however, that parasitism is not always as conspicuous as that of the aphids (Tomato Hornworms are a noticeable exception) and collecting, raising and counting eventual parasitism might be necessary.
- Flower observations. Counting bee visits to crops flowers is one way of directly indexing bee activity. Only a few bee species are easily identified on the wing, but observations can be grouped by size, color and furriness so as to get some indication of diversity and supplemental netting can provide greater precision. Of course, this only makes sense when bee pollination of a particular crop is of interest or if general indices of bee activity are desired but species-level details are unnecessary. We will probably try some of these counts in 2017.
- Other bait observation. Various sentinel cards and plants have been used to index beneficial activity. For example, people have put out aphid- or caterpillar-infested branches and then tallied parasitism. To look at the activity of terrestrial invertebrate predators, researchers have also experimented with various ways of tethering caterpillars to cards with cages to exclude vertebrates. We may attempt this with live house fly maggots or some other live prey that can be easily confined in a container which does not exclude more mobile invertebrates.

<u>Plans for 2017</u>

We are still finalizing details and gathering collaborators, so these plans may well change.

I plan to expand base-line monitoring to six field but reduce the number of points monitored in each field to two (the 600' and forest edge points). Aside from the fields monitored last year, I propose adding field p2, 19 and 24, but am open for suggestions. Monitoring at these points will largely resemble what happened last year including vane traps, except we will not set up cameras and during sweep netting, spiders, wasps and bees will be collected but all other groups will only be tallied as none, few (1-3), some (10 or fewer), and many (>10). When reviewing moth lights, we will photograph panels on each side of the trap to allow generalized indexing of non-moths. These points are meant to provide long-term, location-standardized baseline data together with specimen collections for biodiversity details.

Another set of points will be intended as 'ecological probes' that will provide a basic index of invertebrate activity rather than detailed biodiversity data. Such points may vary from year to year, and their protocol is intended to be somewhat simpler. Techniques to be applied at these points will include time-lapse photography with baits (frozen web-worm eggs, live maggots), visual bee surveys at sentinel flowers and/or crop flowers, and, when appropriate, surveys for crop damage and parasitism of aphids and caterpillars. These may be supplemented by periodic collections of particular groups (e.g., timed ground searches for spiders and ground beetles, pan traps for wasps, sweep netting for bees and wasps). Points to be sampled with these techniques include wild flower trial plots, kernza, and select crops (to be chosen in consultation with the Hub) which we'll plan to monitor over time regardless of their location during a particular year.

Finally, we hope to add techniques that will let us begin to explore the importance of wild areas during various times of year. These would include bee bowls near floodplain forest ephemerals or in late-season flowering wetlands and emergence traps in various semi-wild areas (eventually probably including wild flower test plots and other installed permanent cover). We are experimenting with a new technique of sound mapping, but nothing formal is planned for 2017.

Acknowledgments

Liam Henrie diligently buried yoghurt containers in strange places, bravely attempted to identify ridiculously small wasps, and provided on-the-spot audio reporting at more than 100 sound map points. Dylan Cipkowski somehow managed to review a few thousand thrilling images of plastic tops, listened to and coded Liam's audio reports, suspended clods of soil in Chinese lanterns in our basement, and, together with Liam, sorted through and tallied many of the field samples. The surprising thing is that they both generally did it with gusto. At the Hub, staff, crew, and profarmers were merrily tolerant of our odd hours and devices and facilitated our work whenever possible. Claudia Knab-Vispo provided botanical support and companionship on some outings. Katja Andrea-Poveda lent equipment and advice to our efforts. Thanks to all.

Appendix 1. Ground beetles (Carabidae) tentatively identified at the Farm Hub.

Agonum cupripenne
Agonum melanarium
Agonum octopunctatum
Agonum placidum
Agonum retractum
Amara aenea
Amara exarata
Amara familiaris
Amara rusticans
Amphasia sericeus
Anisodactylus nigrita
Anisodactylus rusticus
Anisodactylus sanctaecrucis
Bembidion affine
Bembidion quadrimaculatum
Bembidion rapidum
Bembidion tetracolum
Bembidion versicolor
Bradycellus rupestris
Calosoma scrutator
Chlaenius aestivus
Chlaenius emarginatus
Chlaenius tricolor
Cicindela punctulata
Clivina fossor
Elaphropus anceps
Harpalus affinis
Harpalus herbivagus
Harpalus pensylvanicus
Harpalus rufipes
Harpalus rusticus
Harpalus somnulentis
Lebia atriventris
Leptotrachelus dorsalis
Paraclivina bipustulatum
Patrobus longicornis
Poecilius chalcites
Poecilius lucublandus
Pterostichus caudicalis
Pterostichus melanarius
Pterostichus mutus
Pterostichus stygicus
Stenolophus cf plejebus
Stenolophus comma
Stenolophus leconteii
Stenolophus lineola
Stenolophus ochreopezus

Appendix 2. Bee species tentatively identified at the Hub during 2015 and 2016.

Agapostemon virescens
Anthidium oblongatum
Anthophora terminalis
Apis mellifera
Augochlora pura
Augochlorella aurata
Bombus impatiens
Bombus rufocinctus
Ceratina calcarata
Ceratina dupla
Halictus confusus
Halictus ligatus
Halictus parallelus
Halictus rubicundus
Halictus tectus
Hylaeus modestus
Lasioglossum cf admirandum
Lasioglossum cf ephialtum
Lasioglossum cf cressonii
Lasioglossum imitatum
Lasioglossum cf oceanicum
Lasioglossum cf pectorale
Lasioglossum pilosum
Lasioglossum sp
Megachile addenda
Megachile latimanus
Megachile relativa
Megachile rotundata
Melissodes agilis
Melissodes bimaculata
Melissodes dentiventris
Melissodes desponsa
Melissodes druriella
Melissodes trinodis
Nomada placida
Peponapis pruinosa
Sphecodes prosphorus
Sphecodes sp2
Sphecodes sp3
Svastra obliqua
Xylocopa virginica

Appendix 3. Moth species tentatively identified at the Farm Hub.

Achyra rantalis
Acrobasis juglandis
Acronicta betulae
Acronicta lobeliae
Acronicta oblinita
Actias luna
Agriphila vulgivagellus
Agrotis ipsilon
Anageshna primordialis
Anathix ralla
Anavitrinella pampinaria
Antaeotricha schlaegeri
Apantesis nais
Archips semiferana
Athetis tarda
Atteva aurea
Autographa precationis
Baileya ophthalmica
Bellura obliqua
Biston betularia
Blepharomastix ranalis
Caenurgina erechtea
Campaea perlata
Cenopis pettitana
Chaetaglaea sericea
Choristoneura rosaceana
Chrysodeixis includens
Chrysoteuchia topiarius
Chytolita morbidalis
Cisseps fulvicollis
Clostera sp.
Condylolomia participalis
Coryphista meadii
Costaconvexa centrostrigaria
Crambus agitatellus
Crambus saltuellus
Ctenucha virginica
Cycnia tenera
Dasychira basiflava
Deprana arcuata
Desmia funeralis
Diachrysia aereoides
Dolichomia olinalis
Donacaula sp.
Dyspteris abortivaria
Ellida caniplaga
Elophila gyralis
Enargia infumata
Endothenia hebesana
Ennomos subsignaria
Eoparargyractis plevie
Estigmene acrea
Euchaetes egle
Eucosma similiana
Eudryas grata
Eudryas unio
Eumorpha pandorus
Euphyia intermediata
Eutrapela clemataria
Feltia jaculifera
Gluphisia septentrionis
Grammia arge
Haematopis grataria
Halysidota tessellaris
Haploa confusa
Heliomata cycladata
Herpetogramma pertextalis
Herpetogramma thestealis
Hydriomena transfigurata
Hymenia perspectalis
Hypagyrtis piniata
Hypagyrtis unipunctata
Hypena baltimoralis
Hypena madefactalis
Hypena manalis
Hypena palparia
Hypena scabra
Hyphantria cunea
Hypoprepia fucosa
Hypsopygia costalis
Idia aemula
Idia americalis
Iridopsis ephyraria
Iridopsis vellivolata
Isogona tenuis
Lacinipolia renigera
Lambdina fiscellaria
Lascoria ambigualis
Leucania scirpicola
Lipocosmodes fuliginosalis
Lophocampa caryae
Lymantria dispar
Macaria aemulataria
Machimia tentoriferella
Macrochilo orciferalis
Malacosoma disstria
Maliattha synochitis
Manduca sexta
Marimatha nigrofimbria
Metarranthis obfirmaria
Misogada unicolor
Morrisonia evicta
Mythimna unipuncta
Nadata gibbosa
Nematocampa resistaria
Nerice bidentata
Nomophila nearctica
Olethreutes fasciatana
Olethreutes nitidana
Orgyia leucostigma
Orthonama obstipata
Orthosia garmani
Ostrinia nubilalis
Paectes oculatrix
Palthis angulalis
Palthis asopialis
Paonias myops
Parapoynx badiusalis
Parasa chloris
Pasiphila rectangulata
Pediasia trisecta
Peridea ferruginea
Perispasta caeculalis
Pero honestaria
Petrophila bifascialis
Petrophila confusalis
Platynota idaeusalis
Prochoerodes transversata
Protoboarmia porcelaria
Proxenus miranda
Pseudeustrotia carneola
Pyrausta acrionalis
Pyrausta bicoloralis
Pyrrharctia isabella
Renia sobrialis
Rivula propinqualis
Schizura unicornis
Scopula limboundata
Sitochroa palealis
Sparganothis sp
Speranza pustularia
Spilosoma virginica
Striacosta albicosta
Synclita obliteralis
Tortricidia flexuosa
Tricholita signata
Udea rubigalis
Urola nivalis
Xanthorhoe ferrugata
Xestia dolosa
Zale lunata
Zanclognatha jacchusalis