Farmer Rancher Grant Program

Final Report Form

PROJECT IDENTIFICATION

- Name: Steve Tennes
- Address: 4648 Otto Road
- City, State, Zip Code: Charlotte, MI 48813
- Phone: 571-543-1019

- Project Title: Integrating Bats into Organic Pest Management
- Project Number: FNC09-755
- Project Duration: two years
- Date of Report: 2013

PROJECT BACKGROUND

Country Mill Farms is a 120-acre, fruit and vegetable farm with a farm market that offers "family fun on the farm." Apple and pumpkins are the major cash crops. We also grow peaches, farm products directly to the consumer. Over the last three years we have made a major effort to make our farm sustainable and energy independent. We now use our apple prunings along with pressed canola seeds (canola cake) to heat our farm market. For the past two years, half of our orchard has been certified organic. We have several experiments going on in the orchard in order to reduce off farm inputs. One example is the use of legumes like white and red clover planted in the tree rows to fix nitrogen that is then incorporated beneath the apple trees. This practice now provides 100 percent of the fertility needs of our trees.

We do have an organic orchard that has no synthetic pesticides being used since 2005. This orchard uses insect traps as a primary form of control for Plum Curculio. Furthermore pheromone mating disruption is the primary form of control for codling and oriental fruit moths since 2006. Finally, we have established native flowering plants to increase native pollinators and beneficial insects since 2008.

PROJECT DESCRIPTION

GOALS:

a) Determine whether the addition of bat houses (artificial habitat) to apple orchards increases bat activity.
b) Determine to what degree that bats in apple orchards feed on key insect pests.
c) Determine the impact of bat activity in apple orchards on codling moth presence and associated damage.
d) Deliver science-based information to apple growers on the importance of bats to codling moth management and how to maximize their impact.

PROCESS

Bat houses were established as close to open bodies of water as possible. The reason for this is that bats drink their water on the fly and do not land to drink. Refer to bat house installation in detail from the Organization of Bag Conservation for your local area. The color of bat house and positioning vary by your region in the United States. Ensure that the bat houses are not in direct contact with an air blast sprayer regardless if using organic chemicals or not.

PEOPLE

- Dr. Matt Grieshop, Michigan State University, CIPS 205, East Lansing, MI 48824 (517-432-8034). Supervised the placement and set-up of insect monitoring. Offered expertise on all insect related portions of the project.
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  Dr. Allen Kurta, Eastern Michigan University, Department of Biology, 316 Mark Jefferson, Ypsilanti, MI 48197 (734-487-1174). He oversaw the placement and set-up of bat houses and monitoring. Offered expertise on all bat related portions of the project.

- Brenna Smith, form Biology Graduate Student from Eastern Michigan University, Department of Biology, 316 Mark Jefferson, Ypsilanti, MI 48197. She monitored and identified bat species throughout the summer, consolidate and summarize data in year two.

- Jeanette Yaklin, IPM Scout, 5865 Burdick Rd, Lapeer, MI. Conducted insect scouting and identification for 17 weeks in year one of project.
- Rob Meis of Organization for Bat Conservation, constructed and installed bat houses in year one of project. In year two completed additional mist netting and collected guano samples.

- Dr. Tom Unruh, USDA Research lab in Washington state, conducted a second round of DNA analysis of bat guano that confirmed the results of the first round done at EMU.

- Steve Tennes, farmer and project coordinator, coordinated all meetings, plan formulation and implementation, outreach to school children, project report.

RESULTS

Activity, diet of bats and damage by coding moths in apple orchards in southern Michigan were studied. There was no difference between organic and conventional orchards in number and composition of insects captured with light traps, number of bats captured with mist nets, or number of acoustic files of bat activity that were recorded. The majority of insects captured wer Coleptera, Diptera, Hemiptera, Lepidoptera, and Trichoptera. Only two species of bats were caught: big brown bats (Eptesicus fuscus) and eastern red bats (Lasiurus borealis). Most calls swere produced by big brown bats, followed by hoary bats (L. cinereus), red bats, and Myotis. Coleoptera dominated the diet of big brown bats cought in orchards, followed by Diptera, Lepidoptera (family for codling and oriental fruit moth), Hemiptera, and Hymenoptera. Analysis of the DNA of insects in feces indicated that big brown bats consumed several species that are economically important, including mosquitoes (Aedes), spotted cucumber beetles (Diabrotica undecimpunctata), and pavement ants (Tetramorium caespitum).

Insects were trapped on 36 nights in organic sites and 38 nights in conventional orchards, for a total of 74 trap-nights from both field seasons. There was one fewer trap-night in the organic sites for sampling insects compared with netting bats, due to malfunction of the battery. A total of 4,179 insects were captured within the organic orchards, and 5,233 insects were trapped at conventional sites. Overall, 138 ± 22 insects/night were captured within conventional orchards. Overall, five orders of insects—beetles (Coleoptera), flies (Diptera, true bugs (Hemiptera), moths (Lepidoptera), and caddisflies (Trichoptera)—accounted for 96% of the insects captured in the eight orchards. As with the overall number of insects, there was no statistical difference between the two types of orchards in the number of beetles ($F_{1, 6}=0.72$, $P>0.05$), flies ($F_{1, 6}=0.12$, $P>0.05$), true bugs ($F_{1, 6}=0.49$, $P>0.05$), moths ($F_{1, 6}=0.54$, $P>0.05$), or caddisflies ($F_{1, 6}=0.06$, $P>0.05$), that were captured. Beetles (Coleoptera) were the most abundant order of insect in both types of orchard, representing 31.3 and 40.3% of captures in organic and conventional orchards, respectively. The next most common order of insects for organic sites was moths whereas only 116 ± 20 insects/nights were caught in organic orchards. However, there was no significant difference in total number of insects trapped/night between conventional and organic orchards ($F_{1, 6}=0.03$, $P>0.05$) (Lepidoptera, 21.2%), but the second most abundant order in conventional orchards was flies (Diptera, 23.1%).

The two types of orchards also were similar in diversity and evenness of the insects resent. Mean diversity at the ordinal level was not significantly different ($t_{3.2}=1.95$; $P=0.13$) between organic locations (0.71 ± 0.03) and conventional orchards (0.76 ± 0.00). Average evenness at the ordinal level was also not significantly ($t_{3.2} = 1.84$; $P = 0.14$) different between organic (0.82 ± 0.01) sites.

Only two species of bats were caught during the study, although seven species exist in this part of Michigan. During the study, 131 captures (96.3%) were big brown bats, and the remaining five animals (3.7%) were eastern red bats. Of the eastern red bats, one was an adult female, two were adult males, and two were juvenile males. The big brown bats consisted of 44 adult females, 27 juvenile females, 32 adult males, and 28 juvenile males.

For the combined field seasons bat acoustic monitoring comprised, 25, 945 files containing sounds made by bats were recorded during 569 detector-nights, with a detector-night being defined as a complete night of recording, by one detector, from sunset to sunrise. A total of 10, 217 files were recorded on 279 detector-nights within four organic orchards, whereas 15, 728 files were recorded over 329 detector-nights within the four conventional farms. Although more files were obtained numerically each night in conventional orchards (51 ± 14 files/night) than at organic sites (37 ± 8 files/night; the difference was not significant ($F_{1, 6} = 0.20$, $P > 0.05$).

Of those files, 11, 045 (43%) of the 25, 945 acoustic files were identified to genus or species. Most calls from all orchards were produced by big brown bats (58.8%), followed by hoary bats (27%), red bats (13.2%), and Myotis (<1%). All four groups of bats were detected in all eight orchards, except Myotis, which was identified at only six farms. Mean diversity of bats in organic sites (053 ± 0.02) was not statistically different ($t_6 = 0.78$; $P = 0.23$) from that of conventional orchards (0.57 ± 0.05). Similarly, average evenness in organic orchards (0.71 ± 0.02) was not statistically different ($t_{3.6} = 0.71$; $P = 0.32$) from that in conventional locations (0.75 ± 0.07).

Bat diets were analyzed with 131 pellets that were collected from 131 big brown bats and five pellets from five eastern red bats. Lepidoptera (moths, 54% volume) contributed most to the diet of red bats, followed by Coleoptera (32%) and Diptera (9%); the remaining 5% was labeled as unknown. Diet of the eastern red bats was not statistically compared between types of orchards due to the low number of samples.

Of the 131 big brown bats, 79 were obtained from conventional apple orchards, whereas 52 bats came from organic sites. Overall, the diet of big brown bats included five orders of insects. In contrast to the prey eaten by the eastern red bat, Coleoptera alone composed 78.6% of the volume of the diet, followed by Diptera (13.5%), Lepidoptera (1%), Hemiptera (0.9%) and Hymenoptera (0.5%). **In short, this project discovered that the most common bat in Michigan, the big brown bat, eats very few moths (1%) that affect the orchard.**

The percent volume of beetles and flies, the two most common orders, in the diet of big brown bats, were compared as well as overall ordinal diversity and evenness of their diets, between organic and conventional sites. There were no statistical differences between organic and conventional apple orchards for the percent volume of coleopterans ($F_{1, 6} = 0.21$, $P>0.05$) or dipterans ($F_{1, 6} = 0.01$, $P > 0.05$). Mean diversity at the ordinal level was not significantly different ($t_6 = 0.95$; $P = 0.19$) between organic (0.37 ± 0.05) and conventional (0.45 ± .06) sites. Three beetles and one bug within the diet of big brown bats were identified to the level of species. The coleopterans included the spotted cucumber beetle (Diabrotica undecimpunctata – 1.7% of total volume), June bug (Phyllophaga implicita – 1.3%), and Japanese beetle (Popillia japonica – 0.6%; Table 1.23), whereas the hemipteran was the green stinkbug (Acrosternum hilare – 0.9%). About 16.8% of the 131 big brown bats consumed the green stinkbug, whereas 3.1-14.5% of the bats had eaten one of the three species of beetle. Only one of these four species of insect was found in feces produced by any one bat.

The other major part of this project was using DNA testing to identify the type of insects that the bats were eating. Amplification was attempted of mtDNA from 524 fragments in 131 pellets produced by 131 bats. One-hundred-sixty-five (31%) samples of mtDNA from 95 bats were successfully amplified and submitted for sequencing. Of these 58 (35%) matches having ≥ 98% similarity were obtained with sequences of insects.
Comparisons with the reference database allowed identification of 41 (71%) of the 58 matched sequences to species, 5 (8%) to only genus, and 12 (21%) to only family. Forty-nine (84%) of the matches were to taxa within the order Coleoptera; most (37 matches) represented taxa within the family Carabidae, with a few from Elateridae (5), Cerambycidae (4), Chrysomelidae (1), Nitidulidae (1), and Scarabaeidae (1). Orders other than Coleoptera that were identified in the fecal pellets were Diptera (6 matches), Hymenoptera (2), and Ephemeroptera (1). The 41 fragments identified to species were traced to 20 different species. The most commonly identified species was Harpalus pennsylvanicus, a carabid beetle that was documented 15 times.

The other 19 species were detected only 1-3 times each. The 20 species included several important pests, such as mosquitoes (Aedes), the spotted cucumber beetle (Diabrotica undecimpunctata), and pavement ants (Tetramorium caespitum). However, none of the major pests of apples in Michigan – the codling moth, oriental fruit moth, and plum curculio – were found among the fragments that were identified to species.

DISCUSSION

One of the goals of the project was to determine the effect of bat activity on reducing damage caused by codling moth. For this reason, bat activity and damage at organic and non-organic orchards were monitored. Unfortunately, no significant difference of bat activity was noticed between organic and conventional apple orchards in southern Michigan in the number or diversity of insects. Perhaps, a study that examined specific families, genera, or species of flying insects would be able to detect a difference between organic and conventional apple orchards in Michigan, although I could not do so at the level of order.

Coleoptera was the most abundant order of insect found (78.6% volume) in both types of orchards combined, followed by Diptera (13.5%). The other three orders of insects found within the diet of big brown bats were Hemiptera, Lepidoptera, and Hymenoptera, although each contributed ≤ 1% of the volume.

The green stinkbug (Acrosternum hilare) is often a pest in orchards and agricultural fields. Because they are polyphagous, they feed on fruiting bodies of shrubs, trees, grasses, vegetables and fruit, but can survive on weedy hosts. This insect also feeds on stems and foliage and can damage several types of fruit trees, including apple and cherry. The adults use their needlelike mouthparts to obtain the fluids of plants, although these insects can develop a preference for developing seeds and thus become pests on plants such as corn and soybean. The fact that 42% of the big brown bats ate one of these four species of pest indicates the potential value of bats to agriculture in Michigan beyond just apple.

The sex ratios of bats captured can potentially tell us about the environment. The hypothesis of this project was that adult female big brown bats would be more common in organic orchards than in conventional farms, since there is no synthetic chemicals being used and potentially more diverse population of insects. The sex ratios of adult big brown bats, however, did not differ between types of orchard, nor did the ratio of reproductive to non-reproductive adult females. Although these predictions were not upheld, this is not surprising because they were predicated on an assumed difference in the insect community between organic and conventional sites. As the light-trapping revealed, the total abundance of insects and the abundance of the five most common orders of insects did not differ between types of orchards even though the conventional orchards were using synthetic pesticides. Availability of prey, therefore, was similar in organic and conventional apple orchards, so there was no reason for energetically stressed females to favor one type of orchard over the other.

Future studies examining this question should consider a larger sample of orchards and a concomitant paired design. Factors to consider in a paired design could be size of the orchard and especially elements of the surrounding habitat, such as use of adjacent land, size of neighboring woodlands, distance to the nearest pond or stream, and location of known roosts-all are factors that can influence the activity of bats. Furthermore, identification of insects to taxonomic levels below the order should increase the chances of detecting significant differences in the abundance and diversity of prey. Failure to find more activity of bats and insects in organic orchards in my study suggests that the presence of synthetic pesticides alone does not deter adult bat activity in a major way and the differences between organic and conventional apple orchards, if they exist, are subtle and /or clouded by other variables and that more sophisticated field and statistical techniques will be required to document their existence.

This project used molecular techniques to study the diet of the big brown bat, one of the most common bats in North America and it resulted in identification of 41 fragments to species, 5 to only genus and 12 to only family. Descriptions of foods eaten by this species, based on visual analysis, consistently indicated that the big brown bat preys mainly on beetles.

One of the goals of this project was to determine whether bats in orchards of southern Michigan were consuming the most species pests of apples, the codling moth, oriental fruit moth, and to a lesser degree the plum curculio. Based on molecular analysis of 58 fragments of prey from 40 bats, I could find no evidence that bats captured in apple orchards were preying on these species. Two of these pests are moths, and the earlier results of theis showed that big brown bats do not include a large number of moths in their diet, compared with beetles. Thus, this projects failure to document the presence of these three pests in the diet of the big brown may be based on the general rarity of moths and curculionid beetles in the overall insect population in the Michigan environment. Although, the authors of this project are not aware of any bat that preys heavily on curculionids, some North American bats, such as the Brazilian free-tailed bat (Tadarida brasiliensis), hoary bat (Lasiurus cinereus), and eastern red bat (Lasiurus borealis), consume many moths on a daily basis, and perhaps the codling moth and oriental fruit moth fall prey to the bats more commonly in regions of the country where these moth eating species are abundant such as western United States.

Although this project was unable to document that these bats are consuming the pests of most concern to apple growers in Michigan, it was able to show that big brown bats do eat insects that are of economic concern, such as mosquitoes. Mosquitoes in an organic orchard can be a major worker health risk if not controlled. Dipterans typically form a small portion of the diet of the big brown bat, perhaps because of the usual small size of these insects, but other research has found mosquitoes in the diet of big brown bats in Georgia. Using the DNA-based technique, this project found three culicids: Aedes excrucians, A. trivittatus, and A. vexans. A. vexans is a vector of arthropod-borne viruses, such as eastern and western equine encephalitis, West Nile virus and deadly rabbit virus (myxomatosis), as well as the nematode known as canine heartworm (Dirofilaria immitis). Big brown bats could potentially help reduce the risk of farm workers from contracting these diseases by lowering the mosquito population.

Besides the culicids, another dipteran, the crane fly (Nephrotoma erebus: Tipulidae), was identified based on its DNA. The larvae in this insect, which are called leatherjackets due to their tough brownish skin, live in the soil, where they attack the roots of grasses, such as those found in residential lawns, in spring. The adults do not feed and only emerge for mating and laying eggs, making them available as prey for bats.

Research in and near orchards in the dryer western United States has shown that a greater percentage of the bats diets coming from codling moth.

PROJECT IMPACTS

The preliminary nature of this project resulted in no economic benefit. The monitoring of the bat and insect activity did not result in any change to pest management inputs. The establishment of the bat houses may result in future benefits, but this cannot be quantified at this time.

OUTREACH

Unfortunately, due to the results of this research project the outreach component had to be altered. The results did not earn this project a session at any of the Midwest's grower seminars or conferences. The results did not encourage collaborating researchers to promote implementation of bat houses for pest control in apple orchards.

Country Mill Farms, however, adapted the outreach component to include over 15,000 school children have a short school house lesson where they learn how apples grow. Part of that lesson is a session about "good bugs and bad bugs" in which the children learn how bats can eat a wide variety of bugs. After the school house lesson the children receive a hayride one of the stops is the bat houses. The students learn the importance of creating and saving habitat for mammals such as bats so that they can do their job and not become extinct.

PROGRAM EVALUATION

Thank you for having a well-run program. Is it possible to have more material from the projects available online so that they can be downloaded directly from your website (www.sare.org)? For example, PowerPoint Presentations from the projects, etc.