Developing Sustainable Management Systems for Native Pollinators

Grant # FNE 02-411

Maryann and Jim Frazier
Singing Creek Farm
RR 1, Box 1524
Mt Union, PA 17066
814-542-7291
mxt15@psu.edu

2. Project Goals

The lack of understanding of species diversity, nesting habits, nesting preferences, and pollination benefits to fruit and vegetable production systems by the many native species of bees in Pennsylvania, currently prevents their management and use by growers on an individual farm basis. We propose to take the first steps in developing a sustainable management system with a one-year study to document the diversity and abundance of species of native pollinators visiting brambles on three certified organic farms during the 2002 growing season, and to determine the nesting preferences in different sizes of artificial nesting tubes. We have successfully used such tubes with two solitary bees, *Osmia lignaria (*native) and *Osmia cornifrons* (introduced*)* which are effective pollinator of apples and other rosaceous plants.

Objective 1. Determine the numbers and types of native bees visiting wild and cultivated brambles during the blooming period, and make a first approximation of their potential as effective pollinators. We will collect all bees visiting bramble flowers and identify these to species. We will use pan traps to sample for bees active at times when we are not in the field. Their potential as pollinators will be determined by counting the number of each bee group (honey bees, bumble bees solitary bees) visiting a selected number of flowers during successive10-minute periods at two or more times of the day (early morning, early afternoon, late afternoon) and calculating an index of visitation for comparison among groups.

Objective 2. We will provide native bees with three choices of above ground nesting tube sizes and measure the degree of acceptance of these nesting options. For those species that nest in tubes, we will attempt to follow their development and determine any parasites on them. Acceptance of a tube will permit us to hold the fully developed bees in a refrigerator and delay their emergence until needed for pollination the following season. Nesting options chosen can then be refined further into a grower management system for increasing abundance and use of these native pollinators on a local farm basis.

3. Update information of farm

Singing Creek Farm is located adjacent to 4000 acres of state game lands, and has been largely fallow for the last 12 years making it an ideal site to collect and evaluate native species of bees on wild brambles. We have both black raspberries and blackberries in addition to wine berries, the native "red" raspberry growing abundantly on our farm.

4. Cooperators

New Morning Farm is a well-established organic farm operation located in a secluded area with abundant wild vegetation adjacent to the farm.

Jim and Moie Crawford
New Morning Farm
HCR 71, Box 168B
Hustontown. PA 17229

Village Acres Organic Farm is a well-established organic farm located in a rural area with numerous home sites nearby. The surrounding area is rather well developed with somewhat limited wild vegetation adjacent to the farm.

Roy Brubaker
Village Acres Organic Farm
RR1, Box 209
Mifflinburg, PA 17059

Both cooperators provided access to their raspberry production areas for surveying pollinators and setting up nesting boxes and discussed their management and harvest practices for the variety "Heritage" with us.

5. What was done and how it was done

A. Investigation of the Blue Orchard Mason Bee Nesting Tube Choice on Singing Creek Farm

It is well documented that solitary bees and wasps use a close range orientation flight about 1 meter from the nest entrance to locate and remember landmarks relative to the nest entrance, and then a second orientation flight of about 3 meters distance to locate larger scale landmarks, which are used to locate its nest upon returning from foraging in the field. This led us to question whether presenting nesting tubes in a big bundle in a box as we had done in the previous two years, might make nest tube location more difficult than in natural settings. We thus conducted a preliminary investigation with our stock of overwintered tubes of *Osmia lignaria* from the 2001 season. During the 2001 season, we had observed females often making "mistakes" when trying to locate their own nesting tubes. They would land on the end of a tube and often investigate 3 or 4 tubes, sometimes entering a tube with another female inside, before locating the one that she was actively provisioning. This searching takes time and reduces the overall efficiency of provisioning a nest, which could result in a lower number of offspring per female. While *Osmia* spp. had successfully used our artificial tubes the previous year, we had no idea if this was accomplished at the efficiency of which they are capable.

We investigated if females of *Osmia lignaria* would choose tubes close together (no space between the tubes), spaced tubes (tubes with dowel rods of equal diameter placed between tubes) or spaced tubes with the addition of colored markings that would offer additional visual cues for close orientation flights. Using a box with three compartments we placed 30 overwinterd *Osmia lignaria* nesting tubes (potential of about 180 bees emerging) in the middle compartment and we placed next to them 30 empty tubes bundled together without space between the tubes. In the compartment below we place 30 tubes with dowel rods of equal diameter between the tubes acting as spacers and in the compartment above we placed 30 tubes with dowel rod spacers and orientation makings. The bees emerging in the middle compartment would thus have equal access to the three choices of tubes upon returning from their initial foraging flights. We counted the number of tubes of each group occupied at the end of a 30 day period.

Figure 1. Three combinations of tube spacing and colored marks for the Blue Orchard Mason Bee to Provision in 2002. Middle compartment with30 tubes of overwintered bees (left), and 30 tubes without spacers (right);30 tubes with spacers (bottom) and 30 tubes with spacers and orientation markings (top).

B. Diversity and abundance of pollinators visiting raspberries on three farms

The **diversity** of pollinators visiting raspberries at the three different farms was determined by collecting at least one of every type on bramble flowers during each farm visit. Different colored pan traps were also used to sample pollinators at times when we were not physically at the farms. The **abundance** of pollinators visiting brambles was determined by counting the number of bees visiting a set number of bramble flowers (15 for most counts) during successive10-minute periods during each farm visit. This was done 6 times at mid- morning and 6 times in early afternoon on three different visits to each farm. These results were summarized as the Index of Visitation for each bee group.

Singing Creek Farm has no cultivated brambles, so all collections were taken on only wild brambles. While we had hoped to survey mainly wild red raspberries (wine berries), a late frost greatly reduced the flowering of these wild berries. We were however able to sample pollinators on blackberries and black raspberries which did not seem to be affected by the late frost. Wild brambles flowered throughout June.

Both cooperating farms had cultivated red raspberries (var. "Heritage"). These berries are managed by cutting the canes to the ground early in the season, allowing the canes to grow back and then flower and fruit continuously from mid-July until frost. We were struck by the fact that this management practice shifts the flowering time of cultivated raspberries completely away from the time when wild raspberries are flowering. Because cultivated berries are blooming almost a month later than wild berries, we would not expect to see the same species present in both situations especially since most of the specialized bees that we observed on wild berries are only active for about 6-8 weeks.

Figure 2. Two solitary bees observed visiting cultivated raspberries during our field visits in 2002. Left is *Melissodes bimaculata* (Lepeletier); right is Au*gochlorpsis spp*

Developing Sustainable Management Systems for Native Pollinators

Grant # FNE 02-411

PART II

C. Nesting Tube Choices on Two Organic Production Farms

Three nesting boxes were placed at the plant canopy height by fixing them to the tops of trellis poles near the ends and one near the middle of selected rows at the two farm sites with cultivated berries. Each box was made up of three compartments and each compartment held approximately 100 nesting tubes of one of three different diameters: (cardboard straws available from Jonesville Paper Tube Corp.; sizes 5/16"x 6", 3/16"x 6" and 1/8"x 6"). The position of the different sized tubes was randomized in the three compartments in each box. Based on our earlier finding of *Osmia lignaria's* preference to nest in tubes with space between the tubes and orientation markings, we set up the nesting boxes with equal sized spaces between the rows of tubes and added red, yellow, and blue orientation markings. This was done in all three compartments. The progress of filling the tubes was assessed at each farm visit, and pictures were taken of the species actively filling the tubes.

Figure 3. Nesting box showing the three types of tubes with colored orientation markings. Left, close up view of the box, right, view showing box at canopy height near the end of a row.

Figure 4. A large Leafcutter bee, *Megachile pugnata* Say, provisioning large tubes at New Morning Farm during 2002. None of these bees were observed to be visiting raspberry flowers during our observation time.

6. Results and Accomplishments

Investigation of the Blue Orchard Mason Bee Nesting Tube Choice on Singing Creek Farm

Table 1. Number of Tubes Chosen by Blue Orchard Mason Bees during a 30 day Period in 2002 at Singing Creek Farm. Put in field April 1, 2002.

Date	Old tubes (also w/o spacers)	No spacers between tubes	Spaced tubes	Spaced with orientation markings
5/3/02	0	5	7	11
6/3/02	1	9	18	22

The tubes were counted on two dates; May 3rd and June 3rd. Twice as many bees nested in the spaced tubes as in the non-spaced tubes and the highest number nested in the spaced tubes with orientation markings. Whether this higher number of filled tubes was due to a true preference by the bees or simply an increased efficiency by locating the correct nesting tubes in less time by the females is not clear, however, these results did encourage us to use spaced tubes with orientation marks in our on-farm nesting tube choice experiment. In addition, we observed several females returning from foraging by landing directly on the tube which she was provisioning and immediately going inside. We did not observe any females searching for a tube entrance, once they had landed as we had seen the previous season on tubes without such spacers.

B. Diversity & Abundance of Pollinators Visiting Raspberries on Three Farms

Pollinator Diversity

A total of 126 bee specimens were collected during the months of June and July at the three different locations. These included bees from 13 different genera in 6 different families. All of these were curated and identified to genus. Individuals were identified as separate species but the species identifications are still underway. Our cooperators who are world experts on bee systematics will confirm species identification over the next 12 month. We would like to continue to build this collection over time to develop a complete synoptic collection of pollinators of brambles in Central PA.

Pollinator diversity varied greatly among the three farms. From the collections and identifications of bees shown in Tables 2-4 several differences can be seen. Bees visiting brambles on Singing Creek Farm during wild raspberry bloom in June included 10 species from 7 genera from 6 families. The majority of the bees were from the family Megachilidae, genus *Osmia*. This includes the two well-known species that are specialists on plants of the Rosaceous family and are widely used as pollinators in Japan and the western U.S, as well as a third *Osmia* species. We had held a group of *Osmia cornifrons* (the Japenses horn-faced bee) under refrigeration for several weeks and pulled them out May 30. 2002. The high number of these bees seen foraging on brambles were undoubtedly these bees. We also found bees of a different genera in each of the families Colletidae and Adrenidae. In both cases, bees of these genera are known to be specialists on Rosaceous plants. Thus at least 4 species from 3 families known to specialize on Rosaceous pollen were found on wild brambles on Singing Creek Farm, that were not seen on the other two farms a month later during cultivated berry blooming. Also, noticeably absent were wild honey bees.

Table 2. Diversity of Bees on Wild Raspberries at Singing Creek Farm, June, 2002.

Family	Genus	species
Megachilidae (leafcutter and mason bees)	*Osmia*	*cornifrons*
		lingaria
		?
	Megachile	?

Halictidae	*Lasioglossum*	?
Anthophoridae	*Nomada*	?
Andrenidae	*Andrena*	?
		?
Colletidae	*Hylaeus*	?
		?
Apidae honey & bumble bees	*Bombus*	?
6 families	**7 genera**	**11 species**

Bees visiting red raspberries on the Village Acres Farm during bloom in July included 8 species in 7 genera in 4 families. The majority of the bees observed were honey bees presumably from the hives kept nearby on the farm. During these observations in July, we saw none of the solitary bee species known to specialize on Rosaceous pollen that had been seen earlier on wild raspberries (above). None of the colored pan traps at the plant canopy height, or on the ground level caught significant numbers of bees

Table 3. Diversity of Bees on Cultivated Raspberries "Heritage," Village Acres Organic Farm, July, 2002

Family	**Genus**	**species**
Megachilidae (leafcutter and mason bees)	*Megachile*	?
Halictidae	*Augochlorpsis*	?
	Lassioglassum	?
Apidae (honey and bumble bees)	*Bombus*	?
		?
	Apis	*mellifera* honey bee
Anthophoridae	*Melissodes*	*bimacula?*
	Nomada	
4 families	**7 genera**	**8 species**

Bees visiting red raspberries on the New Morning Farm during bloom in July included at least 12 species in 10 genera in 4 families. The great majority of bees were bumble bees. While we saw a greater diversity of bees here than on the other farm, there were very few honey bees, and none of the species known to specialize on Rosaceous pollen seen on wild berries (above). On one two dates, a very large number of solitary squash bees were collected in blue pan traps placed at the bottom of the rows, early in the morning. None of the other colored pan traps caught significant numbers of bees at the canopy height.

Table 4. Diversity of Bees on Cultivated Raspberies "Heritage," New Morning Farm, July, 2002.

Family	Genus	species
Megachilidae (leafcutter and mason bees)	*Megachile*	?
	Chelostoma	?
Halictidae	*Lasioglossum*	?
	Nomada	?
	Augochlorpsis	?
	Agopostemon	?
Apidae (honey bee and bumble bees)	*Bombus* (bumble bees)	*perplexus*
		impatients
		?
	Apis	*mellifera* honey bee
Anthophoridae	*Xylocop* (carpenter bees)	*virginica*
	Melissodes	*bimacula*
4 families	**10 families**	**12 species**

Pollinator Abundance

Pollinator abundance also varied greatly among the three farms. While flower visitation counts were not made on wild raspberries due to late frost that appeared to reduce flowering (see below *Specific Site Conditions*), pollinators were collected on wild blackberries and wild black raspberries on Singing Creek Farm. We collected a high number of *O. cornifrons*. These bees originated from a population that we had overwintered from 2001, held in refrigeration and placed in the field May30th. We also collected a number of *O. lignaria (*horn-faced bees) and another *Osmia* species that were naturally occurring.

The initial visit to the Village Acres Farm was at the beginning of raspberry bloom (July 10). Flowers and pollinators were few. During the second two visits, the number of flowers increased. While the numbers of bumble bees and solitary bees remained about the same, the number of honey bees foraging increased significantly. A calculation of the index of visitation shows that honey bees were providing the highest visitation to flowers on the second two dates compared to all solitary bees and all bumble bees seen. This index shows that honey bees were visiting flowers 1-2 times per hour during the later dates.

Table 5. Abundance of Bees Visiting Raspberries "Heritage" Blooms on Village Acres Farm, July, 2002

Date and Time	Bee Group[a]	No. of visits/ No. of flowers observed	Index of visitation[d]	Total Bees Observed	Notes
7/10; AM counts made between 10:00-10:40[b]	BB	32/82	0.4	10	light bloom
	HB	15/82	0.2	5	4 colonies on site
	SB	9/82	0.1	6	
7/10; PM counts made between 2:30-3:00	BB	41/82	0.5	10	light bloom
	HB	13/84	0.2	4	4 colonies on site
	SB	11/84	0.1	7	
7/17; AM counts	BB	45/90	0.5	15	

made between 9:00- 9:30	HB	95/90	1.1	38	4 colonies on site
	SB	10/90	0.1	6	
7/17; PM counts made between 1:00-1:30	BB	13/90	0.1	6	
	HB	83/90	0.9	36	4 colonies on site
	SB	7/90	0.1	5	
7/24;AM counts made between 10:00–11:00[c]	BB	19/90	0.2	12	
	HB	208/90	2.3	92	4 colonies on site
	SB	15/90	0.2	10	
7/24; PM counts made between 1:00-2:00	BB	18/90	0.2	9	
	HB	154/90	1.7	76	4 colonies on site
	SB	14/90	0.2	11	

a BB= bumble bee; HB= honey bee; SB=solitary bee
b six counts-15 minute counts were made by two individuals
c six count-15 minute counts were made by one individual
d index of visitation = # of visits/flower/hr.

Table 6. Abundance of Bees Visiting Raspberry Flowers "Heritage" on New Morning Farm, July, 2002.

Date and Time	Bee Group[a]	No. of visits/ No. of flowers observed	Index of visitation[d]	Total Bees Observed	Notes
7/20; AM counts made between. 10:30-11:00[b]	BB	172/90	1.9	67	
	HB	7/90	0.08	4	
	SB	80/90	0.9	40	
7/20; PM counts made between. 1:30-2:00	BB	240/90	2.6	93	
	HB	10/90	0.1	5	
	SB	70/90	0.8	42	
7/24; AM counts made between. 10:00- 11:15c	BB	173/90	1.9	58	Temp. low 70's
	HB	2/90	0.02	2	
	SB	41/90	0.5	33	
7/24; PM counts made between 1:00-2:15[c]	BB	129/90	1.4	64	
	HB	11/90	0.1	7	
	SB	78/90	0.9	50	
7/31; AM counts made between 10:00–11:00	BB	93/90	1.0	45	
	HB	11/90	0.1	7	
	SB	63/90	0.7	43	
7/31; PM counts made between 1:00-2:00***	BB	137/90	1.5	79	
	HB	30/90	0.3	14	
	SB	44/90	0.5	32	

a BB= bumble bee; HB= honey bee; SB=solitary bee
b six 10-minute counts were made by two individuals
c six 10-minute counts were made by one individual
d index of visitation = # of visits/flower/hr.

Bumble bees were by far the most abundant pollinators of raspberries on the New Morning Farm. This farm had the greatest diversity and density of pollinators and the highest visitation rates to flowers. The index of visitation shows that bumblebees were visiting flowers much more frequently than either honey bees or solitary bees.

From the data above a conservative estimate of the number of bee visits per day can be made by averaging the number of morning and afternoon visits per hours and multiplying by six (conservative estimate of the number of hours per day that bees forage on brambles). For instance the index of visitation for bumble bees on 7/24 (from Table 6) was 1.9 in the morning and1.4 in the early afternoon. The average visitation per hour was 1.7 visits x 6 (hrs. of foraging per day) = 10.2 visits/flower/day by bumble bees. This can be done for individual bee groups, such as bumble bees or for two or more bee groups combined. Published rates for adequate pollination of raspberries by honey bees recommended 5-15 visits/flower over 3 days.

C. Nesting Tube Choice on Two Organic Farms

Table 7. Number of Nesting Tubes Chosen by Bees on Two Organic Farms in 2002

Farm/ Box #		Small Tubes	Medium Tubes	Large Tubes	Date set out in field
Village Acres 7/24[a]	1	0	2	22	5/13
	2	0	0	0	7/17
	3	0	0	0	7/17

New Morning	**1**	27	48	6[b]	5/13
7/31	**2**	4	0	0	7/20
	3	0	0	0	7/20

a date tubes counted
b many tubes had bees working in them but were not completely filled

At each farm, the two boxes that were set out at the earliest dates were inhabited. The other four, were for the most part, unused. At Village Acres Farm, many of the large tubes that were sealed with mud were empty. The filled tubes were inhabited by a solitary wasp of the family Sphecidae. These wasps are carnivores and their cells were each filled with caterpillars. Only the two medium-sized tubes were used by a small leafcutter bee that was also observed to be visiting raspberry flowers during this provisioning time.

On the New Morning farm 48 of the 50 medium tubes, 27 small tubes, and 6 large tubes were inhabited, for the most part by the large leafcutter bee *Megachile pugnata.* However , none of these bees were seen foraging on raspberry flowers during their time of collecting pollen.

7. Specific site conditions

Singing Creek Farm has no cultivated brambles but an abundance of wild black berries, black raspberries, and red raspberries. It was our intention to compare pollinator diversity and density on wild red raspberries to those of cultivated red raspberries. Unfortunately due to an untimely frost, the flowering of wild red raspberries was minimal and we were unable to collect reliable data from wild red raspberries. However in preparation for this work we did collect pollinators visiting wild blackberries and black raspberries and feel that these are fairly representative of pollinators of brambles in general at this time of the year. We did not collect abundance data (flower visitation counts) on these berries. Multiple years of collecting data would insure that we have a complete list of all native species visiting wild brambles and is a goal of future efforts.

8. Economic findings; Conclusions of Economic Importance

a) Commercial production of red raspberries (var. 'Heritage') that cuts back canes in the Spring to promote synchronous blooming in late July through frost, shifts the bloom period beyond the normal emergence of many native Rosaceous-specializing solitary bees, thus eliminating them as pollinators.

b) A sampling of three organic farms in central PA in 2002 confirmed the absence of wild honey bees as pollinators of wild and commercial raspberries, and verified the presence of several Rosaceous-specializing native solitary bee species on wild brambles.

c) Adequate insect pollination for commercial raspberry production is essential, and can be achieved by either providing honey bee colonies at 2-3 hives/acre, or by verifying that wild bumble bees occur in sufficient numbers.

d) We propose that observing the visitation rate to raspberry flowers holds the potential to make a conservative estimate of the adequacy of pollination by honey bees, bumble bees, or solitary bees individually or in combination. This method combines published honey bee pollination rates with the current observations, and allows the grower to make immediate adjustments if needed.

e) We have successfully managed *Osmia cornifrons* and *Osmia lignaria* in nesting boxes with cardboard tubes and over wintered them with refrigeration to time their emergence for apple bloom in May and wild raspberry bloom in June. Refinements for minimizing the build-up of parasites or predators attacking nest boxes, and determining the maximum refrigeration-periods for holding adults are needed. With these improvements, we feel this system holds good potential for becoming a sustainable management system for these solitary bees for raspberry growers of all sizes, as well as meeting the special demands of high tunnel production .

9. What we hope to do next

a) Because bee populations can vary from year to year and because the data collected on wild was incomplete, we would like to complete the diversity and density studies on wild brambles and cultivated raspberries for two additional years. In addition to helping us verify these results, it would also allow us to build a complete collection of pollinators of brambles in Pennsylvania. This collection could be expanded over time to include all pollinators of brambles in the Northeast.

b) We have had success holding *Osmia cornifrons* under refrigeration at 1-2°C for an additional month past the time they would normally emerge. In the western U.S., *Osmia lignaria* have been "held back" in this way to provide additional pollinators for rape and other crops. We would like to try to hold groups of *both O cornifrons and O lignaria* under refrigeration to determine if we can successfully time their emergence with the bloom of red raspberries in late July into August. If so, this could provide raspberry growers with an additional managed specialized pollinator of brambles that would be available during later bloom. This will also tell us if we can make these bees available for high tunnel production of raspberries during both early Spring and later in the Fall production windows.

c) Improve artificial nesting (habitat) boxes for native pollinators. Do spaced nesting tubes with orientation markings make individual females more efficient, and if so, can solitary bee populations be built-up more quickly by providing nesting boxes by spacing tubes and providing orientation markings? Can the boxes be used to redue the build up of parasites or deter predators?

d) Determining pollination visitation rates. Due to a variety of factors that influence the diversity and abundance of bramble pollinators including: variations in habitat surrounding farms, the absence of wild honey bee colonies, and the management practices that results in delayed blooming and thus the absence of pollinators that specialize on Rosaceous plants, we hope to identify an easy field technique that would allow growers to determine if pollinator visitation to their crop is optimal. We think that the Index of Visitation could be used to extrapolate the degree of total flower visitations over the effective life of the blooms and thus give a good approximation of the efficiency of pollination deriving from the bees observed. Whether these are bumble bees, honey bees, or solitary bees, this would be a quick method to determine if sufficient pollination is taking place during the early blooming period. If not, then adjustments could be made, and if adequate, then so much the better, but at least the grower would know the status of pollination, and not guess or forget about it altogether.

10. How do we plan to continue to use these practices

During the 2003 calendar year we will be in England on sabbatical (Imperial College, Wye Campus). Upon our return in 2004 we hope to continue our efforts to develop a sustainable management systems for native pollinators of brambles by working to accomplish the objectives above in item #9 through the submissio of a new 2-year project.

11. Explain what you did for your outreach program

As a result of this work, we plan to submit at least two articles to leading fruit growing publications in the Northeast. Please see the draft of the first article attached here.

James Frazier and Maryann Frazier February 27, 2003