A survey of the dung beetles in cattle manure on pastures of an organic and a conventional dairy farm in New York state.

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A SURVEY OF THE DUNG BEETLES IN CATTLE MANURE ON PASTURES OF AN ORGANIC AND A CONVENTIONAL DAIRY FARM IN NEW YORK STATE.

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Dairy is an important part of New York state agriculture. Many dung beetle species live in pasture cattle manure. This study was a survey of the species of beetles (Scarabaeidae, Geotrupidae, Hydrophilidae, and Histeridae) in dairy cattle manure from pastures of two different farms, one conventional and one organic. *Aphodius* species, specifically *A. granarius, A. haemorrhoidalis,* and *A. stercorus* were the most numerous beetles (approximately 21% of the identified beetles), excluding the small, unidentified Hydrophilidae less than 2 mm in length. This contrasts with results of similar studies using the same protocol in North Carolina where *Onthophagus taurus* was the most abundant species of dung beetle on pastures, suggesting that latitude has a an effect on the composition of dung beetle communities.

ACKNOWLEDGEMENTS

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I would like to thank my parents and younger sister, who have always been supportive of my goal to study entomology even if they didn't understand it. My father was also very helpful in reviewing my manuscript as a non-entomologist.

I would also like to thank Joy Tomlinson, Kay Russo, and Sarah Seehaver for their assistance in collecting the beetles.

Finally, I will always be grateful for the love and support I have received from my friends I met through Bill. Without you, I would never have been able to do this at all.

Introduction

Dairy is an important part of New York state agriculture. In 2004 the New York dairy industry generated nearly $2 billion dollars in revenue, accounting for 53.6% of all farm income in New York state (N.Y. Agricultural Statistics, 2005).

Cattle manure on pastures is a nutrient rich resource that supports a diverse community of pest and non-pest arthropods. Only a small percentage of insect species associated with cattle dung are pests, but two of these, the horn fly (*Haematobia irritans* [Linnaeus]) and the face fly (*Musca autumnalis* [DeGreer]) are estimated to cause more than $780 million in losses annually to the national cattle industry (Bertone et al 2005; Floate 2006). Through their feeding habits these flies can cause considerable animal annoyance and/or blood loss, resulting in decreased weight gain and milk production. These decreases significantly raise costs for farmers as they seek to control or repel the flies and mitigate the damage they have done (Drummond, 1987). The face fly can also transmit bovine pink eye, which costs dairy farmers up to $123 million dollars a year to treat (Thomas and Skoda, 1993). Both the face fly and the horn fly breed in cattle manure on pastures and their larvae contribute to the breakdown of the dung pat.

Eight families of beetles have already been reported to live and reproduce in cattle dung pats on pastures in New York state (Valiela 1969). For the purposes of this study all beetles that live in manure are considered "dung beetles". Scarabaeoid beetles in the families Scarabaeidae and Geotrupidae are the most notable of these. These beetles are coprophagic during both the larval and adult life stages (Bertone 2004) and their activities reduce pasture fouling, aerate the soil, recycle nutrients, and compete directly with dung-breeding Diptera for habitat and food resources (Bertone 2004; Bertone et al

2005; Floate 2006). The life history of these beetles can be broken down into three distinct classes: rollers (telecoprids), tunnelers (paracoprids), and dwellers (endocoprids). Rollers, including *Geotrupes* species, form balls of manure which they push from the pat to bury as brood balls. *Onthophagus* species are tunnelers that consume the pat and burrow beneath it to bury brood balls. Dwellers, mainly *Aphodius* species, consume the manure as they tunnel within the dung pat and oviposit in the manure or surrounding soil. Beetles utilizing these last two strategies compete most effectively with dung-breeding flies (Bertone 2004).

Although many papers which explore the beneficial actions of dung beetles on pastures have been published, surveys of North American beetle fauna are rare. Study areas include Texas, Georgia, Florida, North Carolina, South Carolina, South Dakota, and Alberta, Canada (Bertone et al 2005). These studies have shown a significant effect of latitude on the temporal distribution of many species (Bertone 2005). The most recent survey of New York state's cattle manure arthropod community was published in 1969 (Valiela 1969). There exist no published studies on the seasonal distribution of dung beetles in New York state.

Several studies have been published considering the effects of organic farming practices on biodiversity (Bengtsson et al 2005; Maeder et al 2002; Shah et al 2003). Organic farming encompasses a broad range of practices, but its philosophy can be distilled to the prohibition of soluble mineral inputs and synthetic pesticides and use of primarily naturally derived compounds instead (Trewavas 2001). In the context of this study, an important compound prohibited by organic farming regulations is internal parasticides, also known as endectocides. These chemicals are often not completely metabolized and may be excreted into the manure, where they can cause significant and negative effects on dung beetle populations (Floate 2006). Generally, farming biodiversity studies show that organic farming increases the species richness of birds, insects, and plants. It has been noted that while predatory insects responded well to organic farming, this trend did not apply to non-predatory insects (i.e. dung beetles) and pest species (Bengtsson et al 2005).

Materials and Methods

Two dairy farms in New York state, one an organic farm in Tioga county and the other a conventional farm in Tompkins county, were chosen for the study. The two farms were approximately 37 kilometers apart. The farms were selected based on the willingness to participate, without controlling for other factors. The organic farm has been certified organic since 1985.

Fresh cattle dung was collected from pastures at each site. An ice-cream scoop was used to measure out equal amounts of manure, which were then frozen wrapped in paper towels until needed. Trapping occurred on a weekly basis from 17 May 2006 until 30 August 2006 (16 weeks). Two trapping methods were used. Dung beetles were trapped using dung-baited pit-fall traps like those used by Bertone (2005) and collections of manure cores.

The pitfall traps (Fig 1 and 2) were inserted into 4 x 10 inch PVC tubes that had been placed in the ground. These tubes ensured precise and repeated trap placement in addition to preventing soil from collapsing into the hole. Ten traps were placed on pastures on each farm at the beginning of the study (17 May 2006) and were baited with the previously collected frozen dung from the respective farms. On 26 July 2006 an additional ten pitfall traps were placed at each farm, and these were baited with fresh manure collected that day. Twenty-four hours after the pitfall traps were placed, the beetles were collected into plastic bags, labeled according to location, and brought back to the lab to be frozen for later identification.

Using a trowel, dung pat cores (10 per farm) approximately 400 ml in volume were collected from manure on pasture that was selected based on the presence of dung beetle aeration holes (Figure 3). The samples were brought back to the lab where they were placed in a modified Berlese funnel without lights, called an extractor (Figure 4 and 5). At the bottom of the extractor was a jar with 75% ethyl alcohol, which killed and preserved the specimens. After a period of 3 days the manure pat was inspected to be sure all of the beetles were collected. The preserved sample was then stored at room temperature pending identification.

Beetle identification was done using The Beetles of Northeastern North America (Downie and Arnett, 1996). Representative specimens of each species were sent to expert Richard Hoebeke (Cornell University) for confirmation.

Results

A total of 11,708 adult dung beetles were caught in 320 manure pat cores (10 per week per farm) and 440 pit fall traps catches (10 per week per farm ant after 24 July, 20 per week per farm). 4,743 beetles were collected from the conventional farm and 6,965 beetles were collected from the organic farm. The most abundant type of dung beetle collected were the small, less than 2 mm, unidentified specimens in the family

Hydrophilidae, accounting for 66% of all beetles collected (Table 1). The most prevalent identified species were in the genera *Aphodius* (23% of identified beetles) and *Sphaeridium* (7.7%).

The data shows a clear difference in effectiveness between the two trapping strategies (Table 2). Approximately 95% of all of the dung beetles collected were collected from the dung pats using the extractors. Other than the volume of beetles collected, the only difference between the two traps was that *O. nuchicornis* was only collected from the pitfalls.

On 27 June 2006, both Tompkins and Tioga counties received record amounts of precipitation. This rain caused the Susquehanna River to overflow. As a direct result of this, the organic farm was flooded, producing standing water over two feet deep. The pitfall traps were arranged around the pasture that was most affected by the flood. While dung pat core collections were made in the field on 26 June and adult beetles were successfully extracted from those samples, it was not possible to collect the samples in the pit fall traps until 5 July (7 days).

Two distinct peaks were observed in total number of beetles collected (Figure 6). As the aforementioned flood occurred between the two peaks, it is possible that the weather and the flood were the causes of the adult beetle population crash. This explanation cannot entirely account for the trends in the data, however. The organic farm was underwater, and it clearly exhibited the greatest crash in total adult beetle populations. This population decline began on 21 June, before the flood on 27 June. The data from the conventional farm further supports the possibility that the dung beetle crash is not entirely due to the flood. The population trends on both farms mirror each other rather closely, but the conventional farm was never flooded. This suggests that the population changes over time may have been due to changes in beetle seasonal distribution.

Upon closer inspection the peaks and valleys in the total beetle population appear to be due primarily to the bimodal distribution of *Aphodius* species over time, supplemented by the bimodal distribution of *Sphaeridium* species (Figure 7). This was true for both the organic and conventional farm (Figure 8). However, the peaks in beetle populations for the *Aphodius* and *Sphaeridium* species appear to be slightly offset between the conventional and organic farms before 12 July 2006. It is interesting to note that although the populations of beetles on both farms appeared to be declining before the flood, the population on the organic farm reached a minimum much faster than that of the conventional farm. This suggests that the flood may have contributed to the speed with which the populations declined.

Eight species of *Aphodius* were collected. The three most common of these were *A. granarius, A. haemorrhiodalis,* and *A. stercorus*. The population trends of *Aphodius* species were very similar between the farms. There was one large peak on the conventional farm on 7 June 2006, with the organic farm peaking a week later. The farms exhibited the same trends from 12 July 2006 until the end of the season (Figure 9).

The different peaks in adult *Aphodius* collected coincided with the peaks of the three most abundant *Aphodius* species (Figure 10). *A. granarius* peaked around 14 June and then dropped off considerably. The second peak in *Aphodius* species occurred around 9 August, and coincided with a spike in the populations of *A. haemorrhiodalis* and *A. stercorus*. These three species appeared to be univoltine.

Three species of *Sphaeridium* were also present, although not in as great a number. There were two distinct peaks in total numbers of *Sphaeridium* species collected on the organic farm. The data demonstrates that the three species collected show a bivoltine distribution (Figure 11). It is not entirely clear whether or not this distribution is due to a population crash caused by the flood (Figure 12). When the data is analyzed by farm, it is clear that the flood on the organic farm dramatically affected the *Sphaeridium* species, a trend that was not mirrored by the conventional farm (Figure 13).

The organic farm exhibits a greater species richness as the relative abundance of the different species is more uniform (Figure 14). Over 50% of all beetles collected from the conventional farm were a single species, whereas a maximum of 26% of all adult beetles collected on the organic farm were the same species.

Conclusions

The recent Bertone study in North Carolina showed several species to be common to all of their trap sites. This 2006 New York state study collected the same species, but their relative abundances were different. The NC study showed *O. taurus* to be the most common beetle collected. In this study *O. taurus* was the most common *Othophagus* species collected, but *A. granarius* was the most common adult beetle collected (excluding small Hydrophilid beetles).

The data from this survey was very similar to that of the 1969 New York state Valiela study, as all of the *Aphodius*, *Sphaeridium*, and *Onthophagus* species collected in that study were also collected in 2006, except for the presence of *O. taurus*. This species was introduced into Florida from the Middle East and Europe in 1970. Therefore, its distribution has expanded since Valiela's study and now includes New York state.

This study was designed to be a 16 week survey of the dung beetle community in cattle manure on dairy pastures of New York state. The average temperature for the duration of the study was 18.2ºC, with an average daily maximum of 24 ºC and an average daily minimum of 12.4 ºC (Eggleston, 2007). A better understanding of the life history and temporal distribution of dung beetles in New York state could be developed by extending the sampling time period. Specifically, a more complete survey would include collecting from early spring to late fall on days that the temperature is above freezing.

It is not possible from this data to determine whether the apparent difference in species richness and diversity between the two farms is due to farming techniques or differences in landscapes, soil type, and the ecology of the surrounding land. The organic farm is located in a hilly region. Some of the samples were collected from pastures bordered by forests. The conventional farm is located in a flat area, with clear-cut pastures, roads, and houses bordering the area samples were collected from. Current research shows that landscape characteristics have a greater effect on the biodiversity of agricultural areas than the type of farming techniques utilized (Bengtsson et al, 2005; Maeder, et. al 2002). The Bengtsson meta-analysis demonstrated that the diversity of non-predatory insects is not affected by farming practices. Our study suggests a need for further investigation into the effect of farming practices on the biodiversity of dung beetles while controlling for differences in landscapes.

A majority of the dung beetles were collected while sampling dung pats. This suggests that the trapping protocol was most effective for collecting dung beetles that live within the pats. The depth to which soil beneath the core was collected was highly variable. This may have led to differential success at sampling the beetles which tunnel beneath the pats, specifically *Onthophagus* species. While this may not be the case with the pitfall traps, the numbers of beetles collected by this method are nearly insignificant. To improve the sampling efficiency of the dung pat core method, soil beneath the manure must also be collected. The optimal depth for this modification would be the depth of brood chambers of local *Onthophagus*. The depth of burrows of *Onthophagus* beetles varies due to soil type, but brood chambers have been found as deep at 18cm below the pat (Bryan 1976). Only pitfall traps collected *O. nuchicornis*. The effectiveness of this species at breaking down dung pats is unknown, but given its relatively low abundance and small size it is likely not as important as other species.

Another improvement to the trapping protocol could also be made. Dung beetles fly to manure. The pitfall traps are effective at sampling ambulatory arthropod species. However, flying insects could land directly on the bait on top of the trap, never making it down to the collection chamber. Another method of trapping beetles using bait, called "flight interruption traps", could perhaps be a better field trapping protocol. To use these traps, fresh manure would be collected and placed on a hard plastic surface. Netting would be placed around the bait to prevent beetles from accessing the manure. A tray full of salt-water, or some other aqueous preservative, would be placed around the bait under the netting. A dung beetle's reaction to colliding with a surface while flying is to immediately drop to the ground. The beetles would fly towards the bait, hit the netting, and then drop into the liquid where they would be preserved until collection the next day.

More research needs to be conducted on the relationship between dung pat characteristics, such as age, moisture, and nutrient content, and their relation to dung beetle assemblage. Some of the dung pats collected in a week from a single farm had hundreds of adult beetles in them, whereas other samples collected under the same conditions had very few adult beetles. As the same search criteria were used to collect all of the samples, without further data about the characteristics of each dung pat this disparity remains unexplained. It is clear that moisture content and sun exposure play a part in attracting and maintaining dung beetle populations (Vessby, K., 2001; Christensen, C.M. and Dobson, R.C., 1976). Additionally, the samples were not taken by the same person every day of the study. It is possible that some of the trends in the data are caused by differences between individuals in their ability to select good dung pats.

It is unclear from this data whether dung beetles are a viable bio-control option for manure reproducing pasture flies. The most abundant dung beetles were the small Hydrophilidae ("small unknowns"), less than 2 mm in size. Their activity in manure is currently unknown. The next most abundant species of dung beetles was *A. granarius*. This is also a small beetle, approximately 4mm in length. Despite their abundance, they likely do not compete much with the fly larvae because they do not need as much manure to complete their development as other larger beetles.

This study was a valuable tool to update the body of knowledge concerning the species of dung beetles present on cattle manure in pastures on New York state dairy farms. Additional research should be conducted to specifically address the impact of conventional and organic farming methods on biodiversity of dung beetles, the influence of topography on beetle distributions, the effect of manure characteristics on the assemblage of dung beetles, and an assessment of possible sampling bias due to trapping protocol.

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Figure Captions

Figure 1: An unassembled pitfall trap used to catch adult dung beetles from pastures on New York state dairy farms.

Figure 2: An assembled and baited pitfall trap of the kind used to capture adult dung beetles from pastures on New York state dairy farms.

Figure 3: Dung pat with dung beetle aeration holes, meeting the requirements for dung pat core samples, collected beetles from pastures on New York state dairy farms.

Figure 4: Modified Berlese funnel without lights used to collect adult dung beetles from cattle dung pat core samples.

Figure 5: Modified Berlese funnel rack used to process samples of cattle dung pat cores.

Figure 6: Total adult dung beetles collected from cattle manure on pastures of an organic and a conventional dairy farm in New York state.

Figure 7: Total number of adult dung beetles of the three most abundant genera collected from cattle manure on pastures of an organic and a conventional dairy farm in New York state.

Figure 8: Temporal distribution of the three most abundant genera of adult dung beetles collected from cattle manure on pastures of an organic and a conventional dairy farm in New York state. The top figure (8A) represents the temporal distribution of beetles by species on the organic farm, while the bottom figure (8B) is from the conventional farm.

Table 1: Species of adult dung beetles collected from manure in pastures on an organic and a conventional dairy farm in New York state arranged by family, genus, and species in descending order of relative abundance.

Table 2: Percentage of total adult dung beetles collected from manure in pastures with each type of trap on an organic and a conventional dairy farm in New York state.

Figure 1


Figure 2

Figure 3

Figure 4

Figure 5

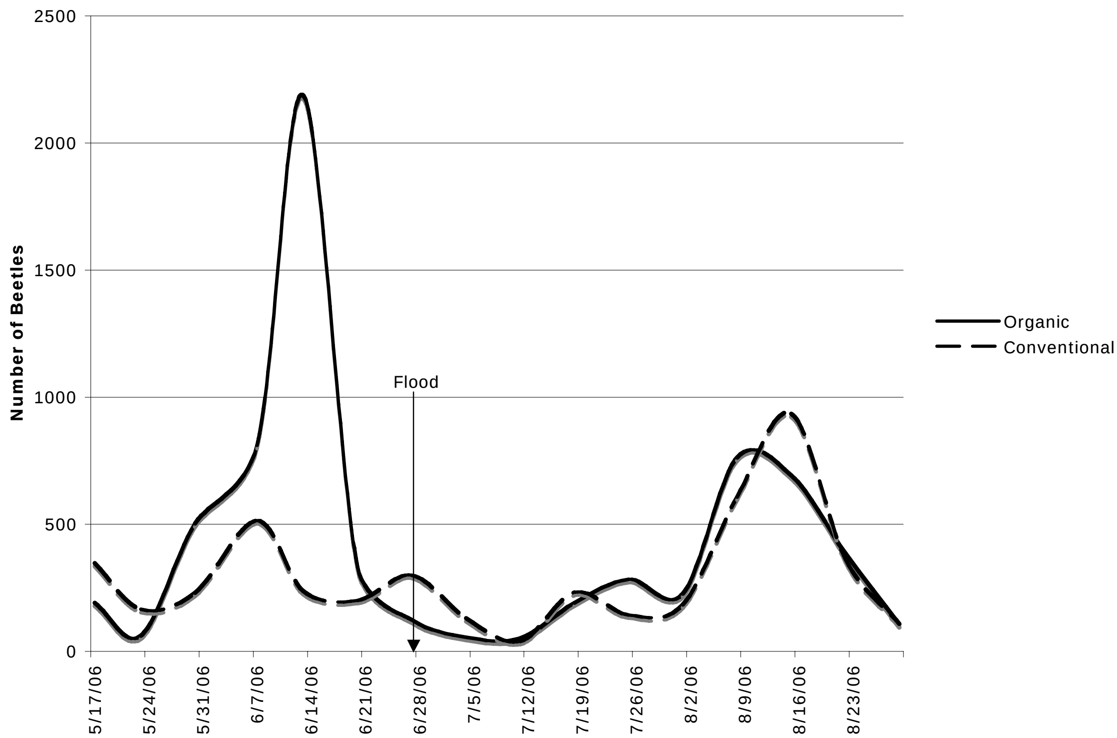
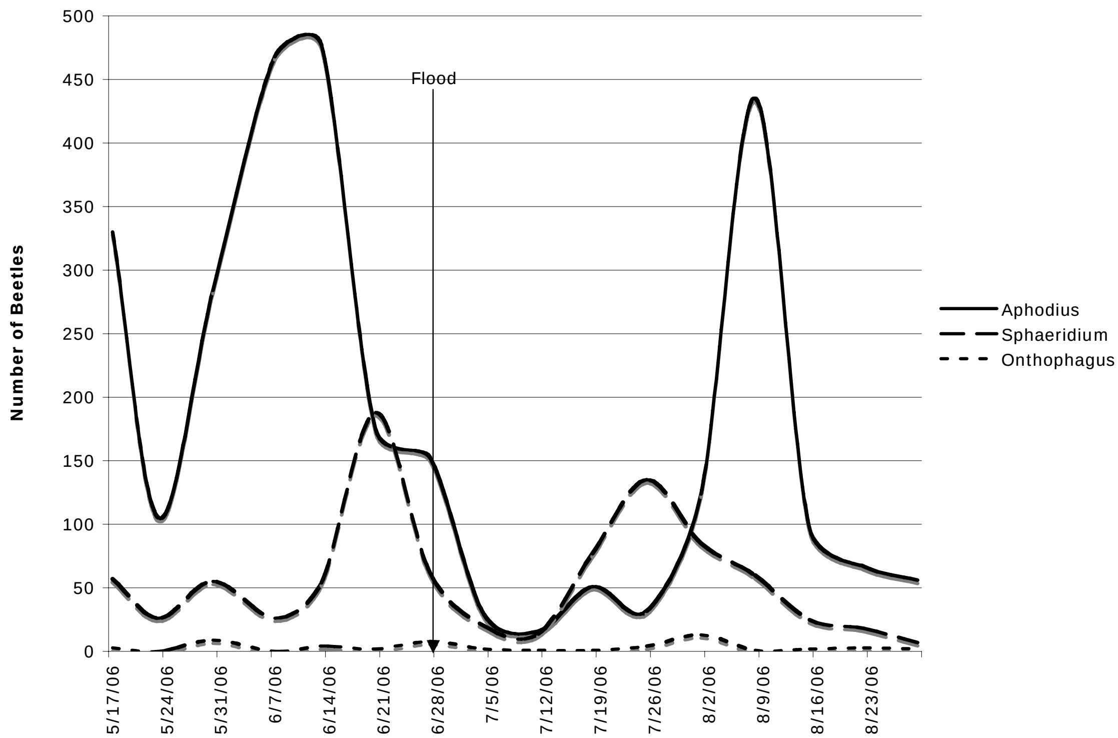

Number of Beetles
2500
2000
1500
1000
500
0
Flood
Organic
Conventional
5/17/06
5/24/06
5/31/06
6/7/06
6/14/06
6/21/06
6/28/06
7/5/06
7/12/06
7/19/06
7/26/06
8/2/06
8/9/06
8/16/06
8/23/06

Figure 6


Number of Beetles
500
450
400
350
300
250
200
150
100
50
0
Flood
5/17/06
5/24/06
5/31/06
6/7/06
6/14/06
6/21/06
6/28/06
7/5/06
7/12/06
7/19/06
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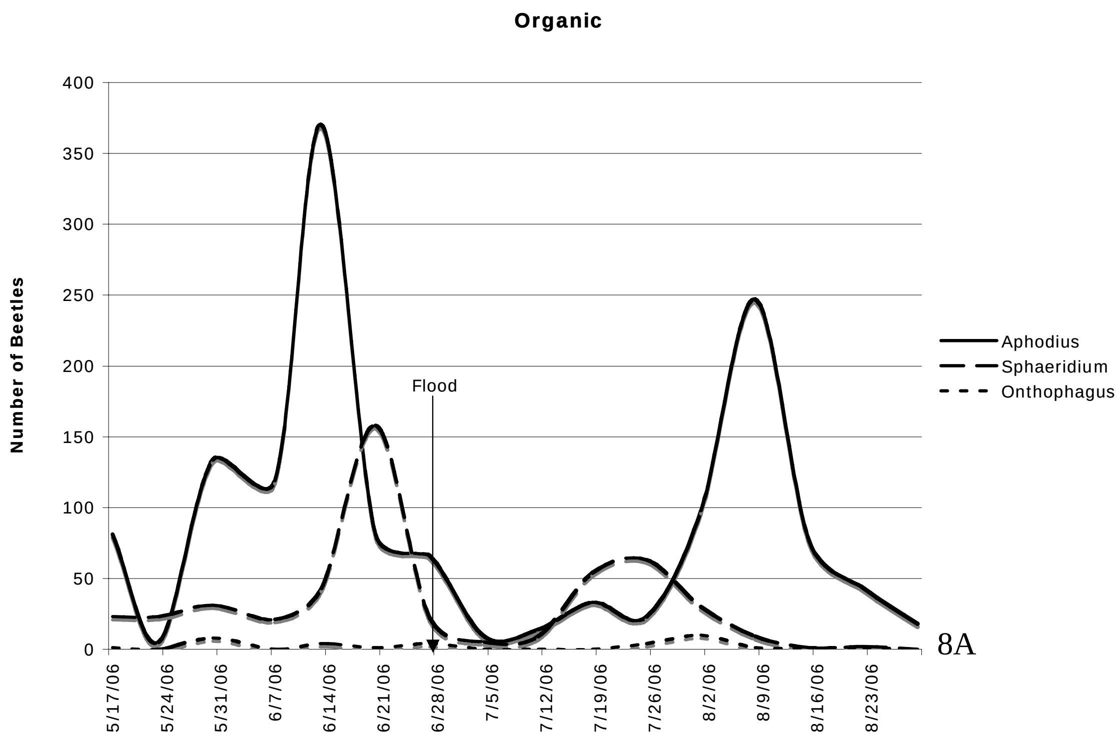
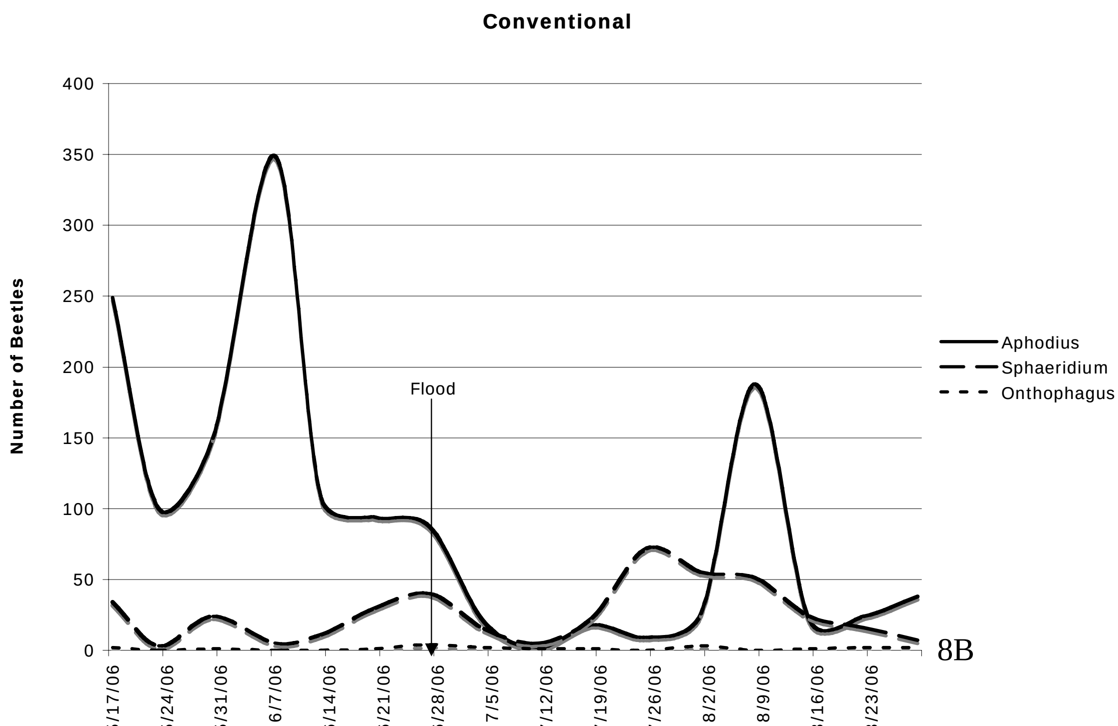
8/2/06
8/9/06
8/16/06
8/23/06
Aphodius
Sphaeridium
Onthophagus

Figure 7



8A



8B

Figure 8

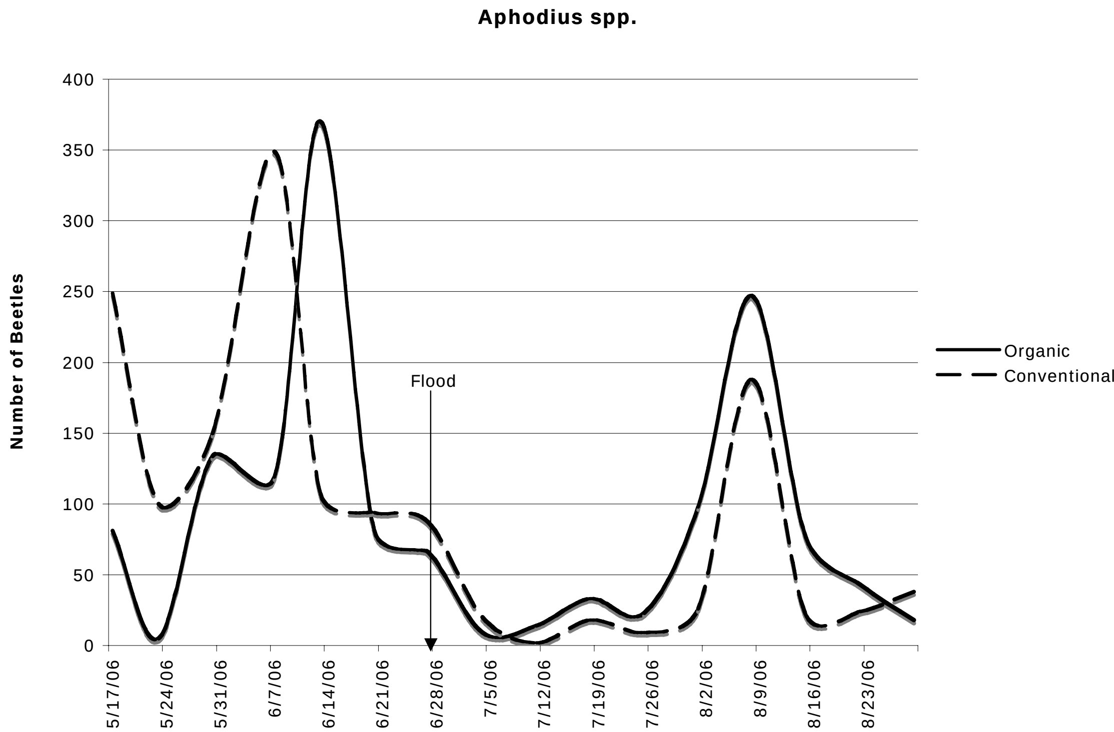

Aphodius spp.
Number of Beetles
400
350
300
250
200
150
100
50
0
Flood
5/17/06
5/24/06
5/31/06
6/7/06
6/14/06
6/21/06
6/28/06
7/5/06
7/12/06
7/19/06
7/26/06
8/2/06
8/9/06
8/16/06
8/23/06
Organic
Conventional

Figure 9

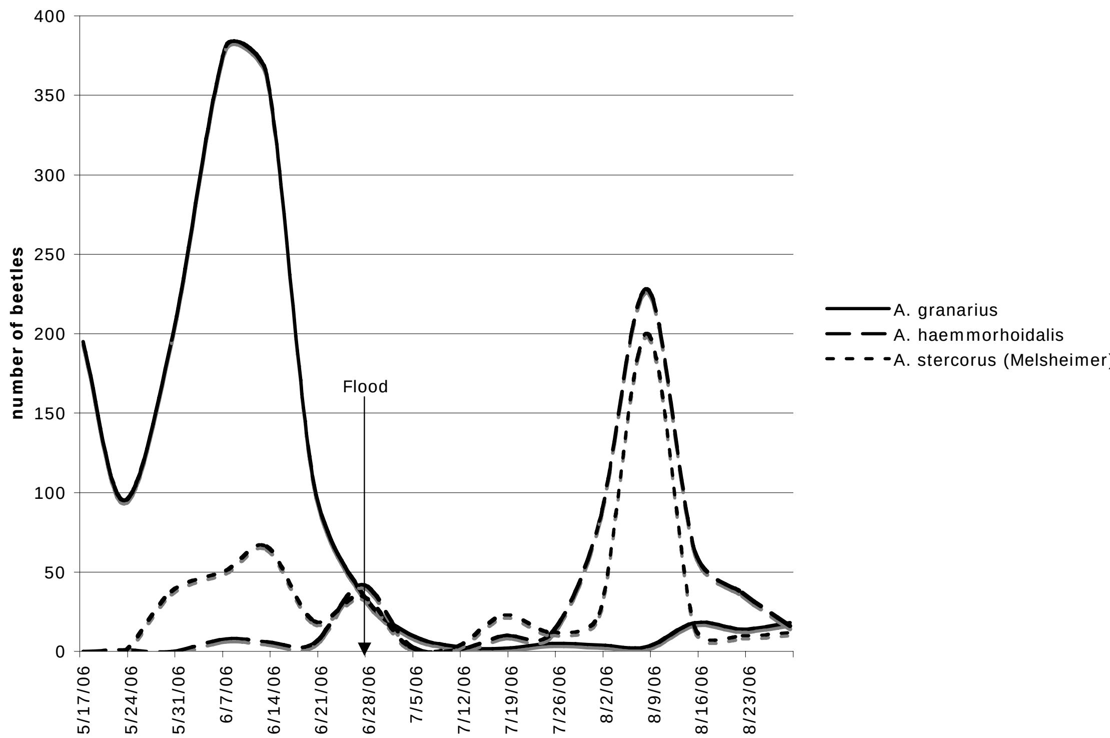
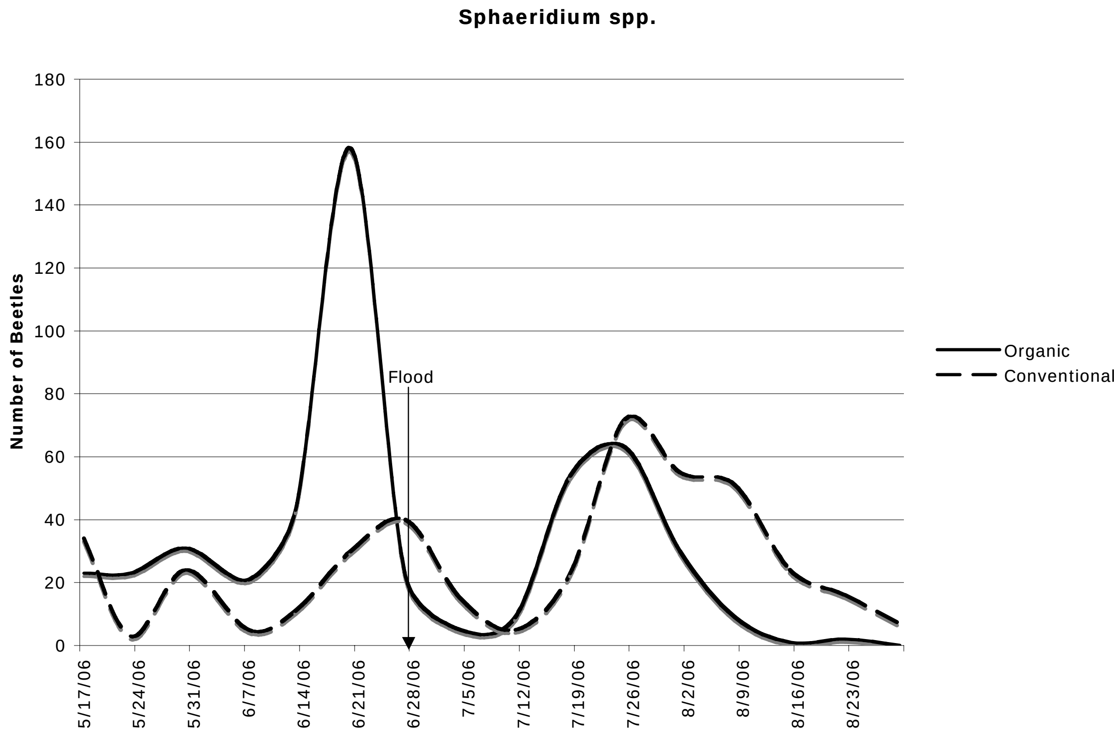

number of beetles
400
350
300
250
200
150
100
50
0
Flood
5/17/06
5/24/06
5/31/06
6/7/06
6/14/06
6/21/06
6/28/06
7/5/06
7/12/06
7/19/06
7/26/06
8/2/06
8/9/06
8/16/06
8/23/06
A. granarius
A. haemmorhoidalis
A. stercorus (Melsheimer)

Figure 10



Sphaeridium spp.
Number of Beetles
180
160
140
120
100
80
60
40
20
0
Flood
Organic
Conventional
5/17/06
5/24/06
5/31/06
6/7/06
6/14/06
6/21/06
6/28/06
7/5/06
7/12/06
7/19/06
7/26/06
8/2/06
8/9/06
8/16/06
8/23/06

Figure 11

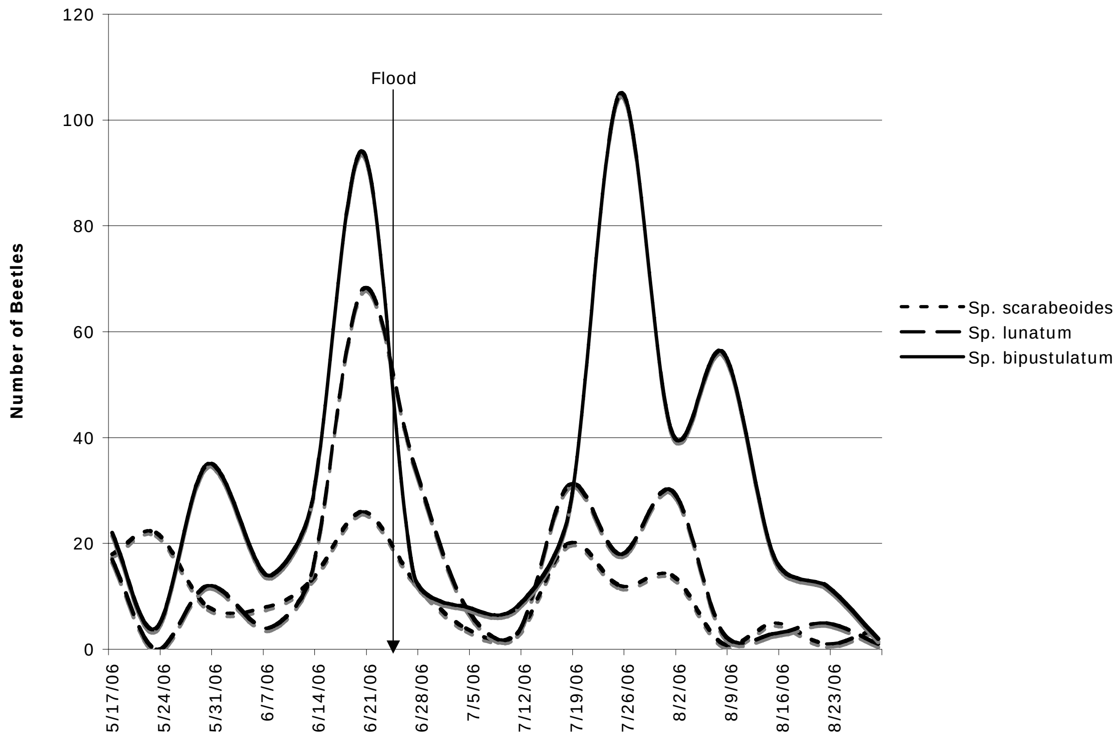
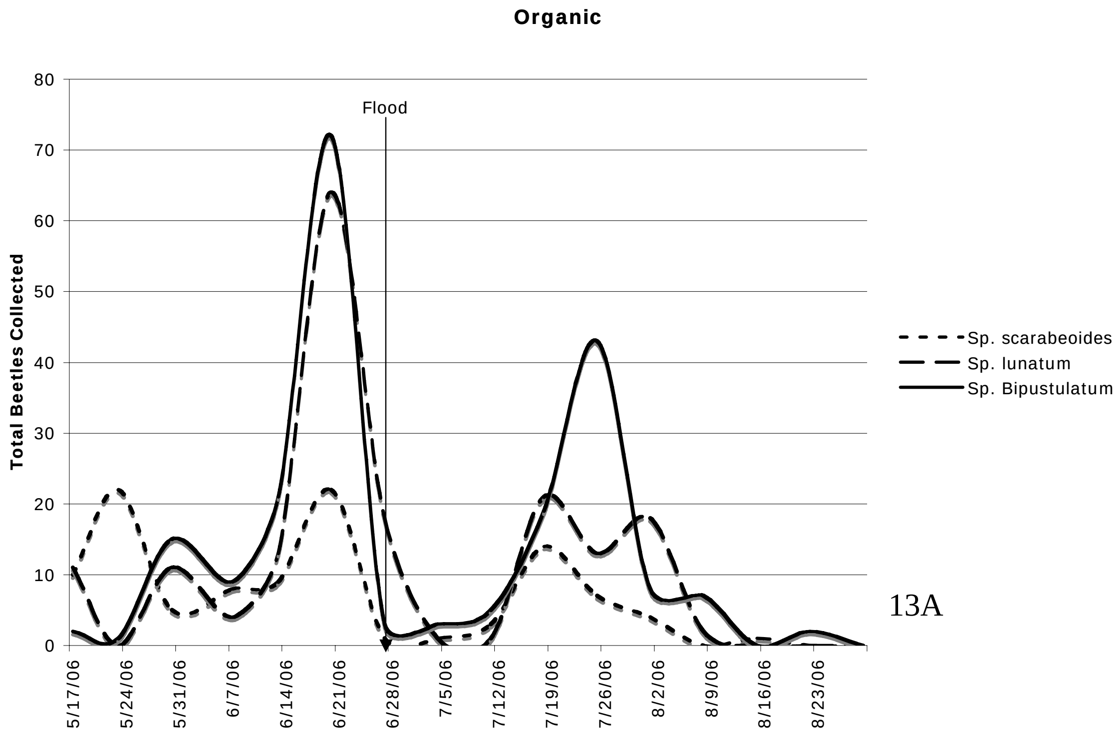
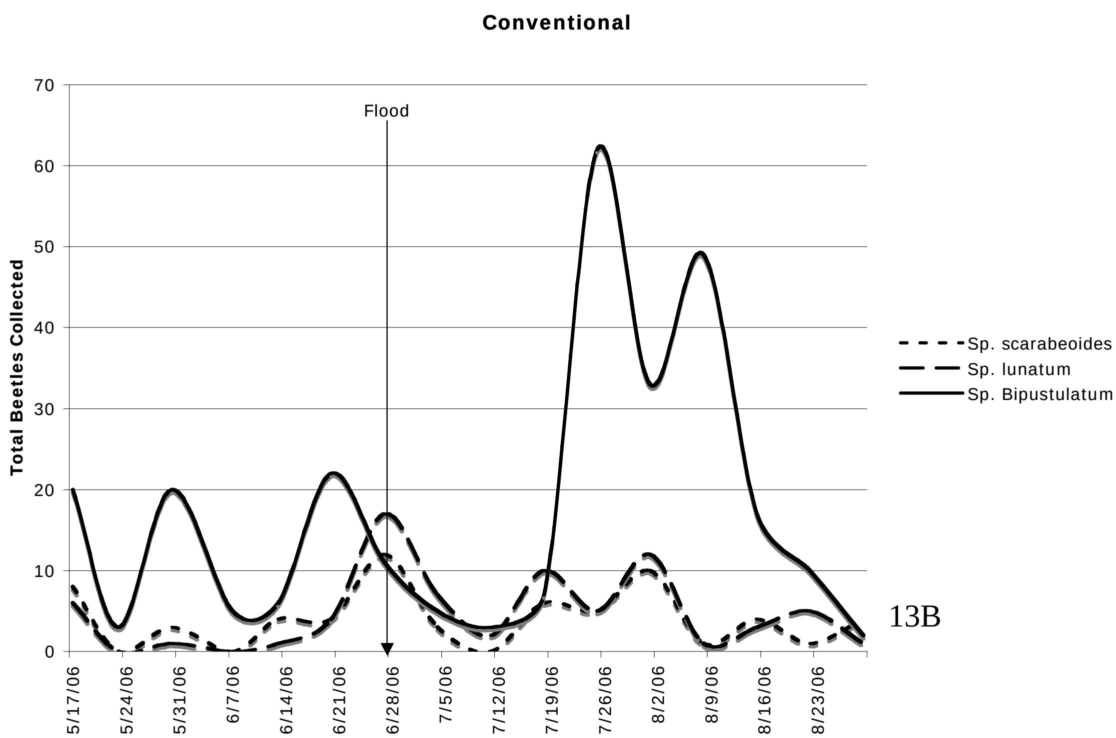

120
100
80
60
40
20
0
Flood
Number of Beetles
5/17/06
5/24/06
5/31/06
6/7/06
6/14/06
6/21/06
6/28/06
7/5/06
7/12/06
7/19/06
7/26/06
8/2/06
8/9/06
8/16/06
8/23/06
Sp. scarabeoides
Sp. lunatum
Sp. bipustulatum

Figure 12

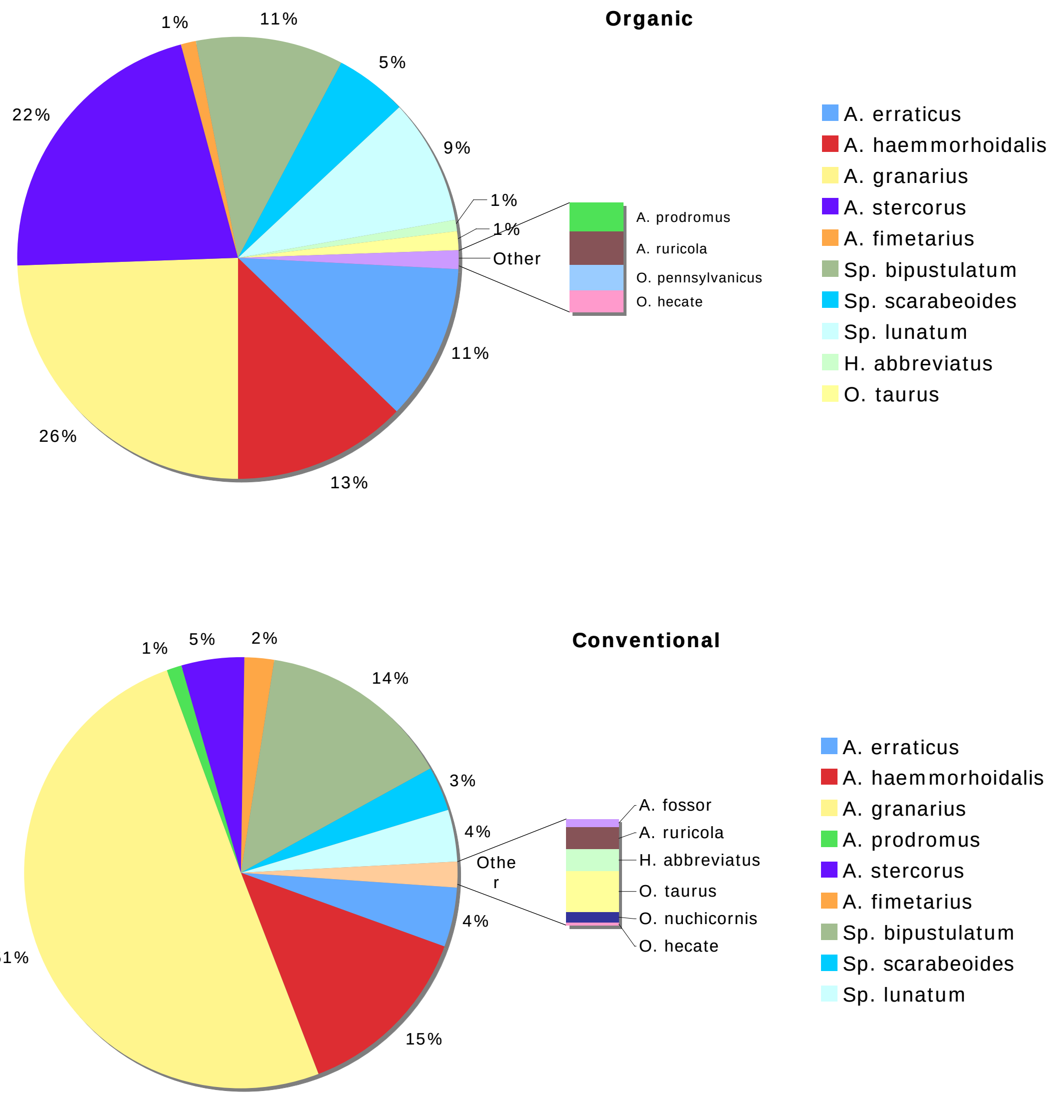


13A



13B

Figure 13



Organic
1%
11%
5%
22%
9%
1%
1%
Other
A. prodromus
A. ruricola
O. pennsylvanicus
O. hecate
11%
26%
13%
A. erraticus
A. haemmorhoidalis
A. granarius
A. stercorus
A. fimetarius
Sp. bipustulatum
Sp. scarabeoides
Sp. lunatum
H. abbreviatus
O. taurus
Conventional
1%
5%
2%
14%
3%
4%
Othe
r
4%
51%
15%
A. fossor
A. ruricola
H. abbreviatus
O. taurus
O. nuchicornis
O. hecate
A. erraticus
A. haemmorhoidalis
A. granarius
A. prodromus
A. stercorus
A. fimetarius
Sp. bipustulatum
Sp. scarabeoides
Sp. lunatum

Figure 14

	Absolute number	Relative Abundance (%)
Scarabaeidae		
Aphodius		
A. granarius (Linnaeus)	1450	12.38
A. haemorrhoidalis (Linnaeus)	515	4.40
A. stercorus (Melsheimer)	511	4.36
A. erraticus (Linneaus)	308	2.63
A. fimetarius (Linnaeus)	66	0.56
A. prodromus (Brahm)	29	0.25
A. ruricola (Melshiemer)	17	0.14
A. fossor (Linnaeus)	3	0.03
Onthophagus		
O. taurus (Schreber)	37	0.32
O. pennsylvanicus (Harold)	7	0.06
O. hecate (Panzer)	7	0.06
O. nuchicornis (Linnaeus)	4	0.03
Hydrophilidae		
Sphaeridium		
S. bipustulatum (Fabricius)	485	4.14
S. lunatum (Fabricius)	252	2.15
S. scarabeoides (Linneaus)	172	1.47
Small unknowns	7816	66.78
Histeridae		
Hister		
H. abbreviatus (Fabricius)	28	0.24
Geotrupidae		
Geotrupes		
G. semiopacus (Jekel)	1	0.01

Table 1

	Extractor	Pit Fall/Fresh	Pit Fall/Frozen
Small Unknown	95.6%	0.3%	4.1%
A. erraticus	94.2%	0.3%	5.5%
A. granarius	88.6%	0.3%	11.1%
A. haemorrhoidalis	96.7%	0.4%	2.9%
A. prodromus	86.2%	0.0%	13.8%
A. stercorus	99.2%	0.4%	0.4%
A. fimetarius	98.5%	0.0%	1.5%
A. fossor	100.0%	0.0%	0.0%
A. ruricola	52.9%	5.9%	41.2%
Sp. bipustulatum	99.8%	0.0%	0.2%
Sp. scarabeoides	98.8%	0.6%	0.6%
Sp. lunatum	96.0%	0.8%	3.2%
O. taurus	70.3%	2.7%	27.0%
O. pennsylvanicus	42.9%	0.0%	57.1%
O. nuchicornis	0.0%	25.0%	75.0%
O. hecate	71.4%	28.6%	0.0%
G. semiopacus	100.0%	0.0%	0.0%
H. abbreviatus	85.7%	7.1%	7.1%
Percentage of total beetles	94.8%	0.4%	4.8%

Table 2