Summer 2010

Carrion Beetles of the Blackwater Ecologic Preserve: Community Structure Seasonal Patterns and Habitat Use

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CARRION BEETLES OF THE BLACKWATER

ECOLOGIC PRESERVE: COMMUNITY STRUCTURE, SEASONAL

PATTERNS, AND HABITAT USE

by

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B.S. May 2004, Old Dominion University

A Thesis Submitted to the Faculty of
Old Dominion University in Partial Fulfillment of the
Requirement for the degree of

MASTER OF SCIENCE

BIOLOGY

OLD DOMINION UNIVERSITY
August 2010

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ABSTRACT

CARRION BEETLES OF THE BLACKWATER ECOLOGIC PRESERVE: COMMUNITY STRUCTURE, SEASONAL PATTERNS, AND HABITAT USE

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Carrion beetles (Silphidae) are important in the decomposition of carcasses in ecosystems. Two subfamilies, Nicrophorinae and Silphinae, differ in reproductive behaviors. The Nicrophinae, burying beetles, bury small carcasses to serve as food for the adults and their offspring. The Silphinae oviposit near larger carcasses. There is intense competition among all carrion beetles and other carrion feeders for carcasses, and beetle species have evolved seasonal activity patterns that minimize competition, such as when they are active and when they reproduce. Northern Silphidae communities are more diverse than southern communities, probably due to increased competition for carrion in the south.

This research focused on the Silphidae in the Blackwater Ecologic Preserve (BEP), a long leaf pine habitat in southeastern Virginia. One objective was to determine whether the carrion beetle community structure was more similar to the northern or the southern fauna. Northern habitats tend to support habitat generalists and habitat specialists, whereas southern habitats tend to support habitat generalists. A second objective was to determine if carrion beetles of both subfamilies at BEP differ in seasonal patterns as they do in other studies. A third objective concerned beetle response to prescribed burns at BEP with the expectation that open habitat species might

prefer burned areas. Finally, beetle dispersal ability and the effect of different trapping methods on beetle catch were investigated.

Three Nicrophorinae and four Silphinae species were collected at BEP. One Silphinae has a northern distribution but the other species occur throughout the eastern United States. Each species had a distinct seasonal pattern similar to that reported previously. One Silphinae, an open habitat species, was found primarily in burned areas but the other species were collected more frequently in unburned forest. In the mark/recapture study, no marked beetles returned to traps, which is consistent with literature reports that beetles cannot detect carrion beyond a few meters. Three Nicrophorinae species and one Silphinae species were primarily in tree traps. One Silphinae species was abundant in both tree and ground traps, and two Silphinae species were collected exclusively in ground traps. Future studies should include a variety of trapping methods and trap locations.

This is dedicated to my family and friends, but most importantly to my mother. No simple words can describe her. She is my superhero. Without her encouragement and loving support all these years, my higher education would have not been possible. She taught me anything is possible as long as you work for it and never stop until you achieve it. She is my role model and the reason I am who I am. Thank you forever and always, Mom!

ACKNOWLEDGMENTS

I would like to acknowledge all the hard work that was put into this thesis by my committee: Dr. Deborah A. Waller, Dr. John R. Holsinger, and Dr. Kerry S. Kilburn. They were enthusiastic from the beginning and encouraged me when my spark was about to sputter. They took on the extra task of helping guide me through this part of my education and I appreciate all of their time that was dedicated to my thesis. I give my utmost thanks to my main advisor, Dr. Waller.

Dr. Waller is the reason behind my love of beetles. She showed me when I was an undergraduate that insects were not the occasional tiny thing you see skittering across the ground. She taught me, just like birds or mammals, insects too have their place in this world. After taking her entomology class I never quite lost my love of the six legged creatures. From then on I have taken every opportunity to educate anyone who will listen on the importance of these tiny creatures. They, after all, allow us humans to survive.

Dr. Waller has also been the driving force of the completion of my degree. Without her this degree may have not been possible. I would like to thank her for the many hours of guidance and thought put into my research and thesis. Words are never enough to express gratitude and I hope through this research and future research that she knows my life has been forever changed by her.

Last, but definitely not least, I would like to thank my ever faithful research companion, Sarah Scott, without who I might not have gone on to pursue a Master's degree. We spent many of days in the field together sweating and collecting insects as they tried desperately to get away from us. I do not think either one of us will ever forget the fun we had while doing this research.

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CHAPTER I

INTRODUCTION

Carrion is a rare and ephemeral resource. Some species feed on carcasses while others use them for reproduction (Scott 1998). Both vertebrates and invertebrates feed on carrion and there is intense competition for this limited resource (Trumbo 1990). Most species that use carrion have developed strategies to minimize competition (Shubeck 1983).

Carrion beetles are important members of the carrion feeding guild and their evolution has been shaped by both intraspecific and interspecific competition (Scott 1998). Within a community, carrion beetles differ in temporal and seasonal activity (Shubeck 1968, Scott 1998), carrion size preference, and habitat use (Peck 1986, Trumbo and Bloch 2000). In the United States, northern and southern carrion beetle communities differ in species composition and beetle activity patterns (Trumbo 1990). Northern carrion beetle communities are more diverse than southern communities, and tend to include both habitat generalists and specialists, while southern communities lack habitat specialists (Trumbo 1990). Beetle distributions in the southern United States are likely limited by increased competition from flies and ants (Trumbo 1990, Scott 1998).

Almost nothing is known of carrion beetle diversity in long leaf pine habitats. These forests once covered much of the southeastern United States, but are now reduced to about five percent of their previous range (Pitts-Singer et al. 2002). This study was conducted at the Blackwater Ecologic Preserve (BEP), a long leaf pine (*Pinus palustris*) habitat in Isle of Wight County in southeastern Virginia. BEP is an ideal location for

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The journal model for this thesis is *The American Midland Naturalist*.

research on carrion beetles because of its unique attributes. The preserve is subjected to prescribed burns in some areas. The burns allow this northernmost stand of long leaf pine to reproduce (Frost and Musselman 1987) and create a patchwork of different-aged burns. In addition to long leaf pine forest, the preserve also has sections that are deciduous forest, and the Blackwater River borders the preserve. Some of the plant species on the bluff overlooking the river share affinities with northern flora, while long leaf pine is a southern species (Plocher 1999). All of these features allow for a diverse habitat to study the ecology of carrion beetles. Eleven species of carrion beetles that occur in the eastern U.S. might be found at the Blackwater Ecologic Preserve: one species of *Necrophila*, one species of *Necrodes*, two species of *Oiceoptoma* and seven species of *Nicrophorus* (Anderson and Peck 1985, Peck and Kaulbars 1987).

CARRION BEETLE TAXONOMY AND BIOLOGY

Carrion beetles belong to the order Coleoptera and family Silphidae. Beetles in this family tend to be large and range from 10-35 millimeters in length (Anderson and Peck 1985). Most Silphidae eat carrion as larvae and adults (Smiseth and Moore 2002), and both stages also frequently feed on fly larvae that infest carcasses (Steele 1927, Ratcliffe 1972). Carrion beetles are a diverse taxon that plays an important role in decomposition in ecosystems (Wolf 2004). In addition, these insects are studied for their forensic importance (Watson and Carlton 2005). Their presence can help indicate time of death and the location of a crime scene if the body has been moved. These beetles have also been used in poaching investigations (Watson and Carlton 2003).

There are two subfamilies of Silphidae, Silphinae and Nicrophorinae (Anderson and Peck 1985). Subfamily Silphinae has six genera and subfamily Nicrophorinae has only one genus, *Nicrophorus*. The two subfamilies differ in the ways the beetles use the carrion. The Silphinae lay eggs around a carrion source whereas the Nicrophorinae bury carrion and then lay eggs in the buried carcass ball. Nicrophorinae beetles select and bury small carrion sources, effectively eliminating them as potential resources for Silphinae beetles (Scott 1998). However, the Nicrophorinae are occasionally found feeding on larger carcasses (Peck 1986).

The Nicrophorinae are commonly called burying beetles. These species are noted for their bright orange-red colors and large size and have been studied extensively due to their reproductive behaviors (Trumbo 1990, Trumbo 1991). Facultative biparental care is an uncommon reproductive behavior for insects, but male and female *Nicrophorus* take care of their brood together (Rauter and Moore 2002). Males help the females prepare the carrion by burying and stripping it of hair, fur, and feather, and molding a ball for the larvae. Anal and oral secretions from the male and female beetle help keep the carcass moist and free of microbes (Rauter and Moore 2002). Once the eggs have been laid the male often leaves the molded carrion (Anderson and Peck 1985). After the larvae hatch the female regurgitates food for the young for the first few hours after hatching until the larvae begin eating on their own (Anderson and Peck 1985).

Nicrophorinae have a symbiotic relationship with phoretic mites. Almost all *Nicrophorus* carry phoretic mites and the relationship is thought to be mutualistic since the mites eat fly eggs on the carrion that pose problems for reproductive beetles and the beetles transport the mites to food sources (Anderson and Peck 1985). Since phoretic mites are seldom found on Silphinae, these beetles have developed a strategy that avoids fly competition by timing the larval stage of offspring after fly larvae are ready to pupate (Anderson and Peck 1985).

Nicrophorus might have evolved carrion burial in order to decrease fly infestation. Suzuki (2000) found that by burying a carcass 2.4 cm below the soil surface, *N. vespilloides* avoids competition with flies. The mites benefit from the burial of the carcass also, because they reproduce underground along with the Nicrophorinae (Springett 1968).

CARRION BEETLE DISTRIBUTIONS

Seventy species belonging to the genus *Nicrophorus* can be found worldwide with only fifteen species in the U.S. (Peck and Kaulbars 1987). Seven of the fifteen U.S. species might be found in Virginia (Anderson and Peck 1985), including *N. carolinus*, *N defodiens*, *N. marginatus*, *N. orbicollis*, *N. pustulatus*, *N. sayi* and *N. tomentosus* . Three of these species, *N. orbicollis*, *N. pustulatus*, and *N. tomentosus*, are found throughout the eastern United States and can be expected to occur in southeastern Virginia. *N. carolinus* has a southern distribution that reaches the North Carolina/Virginia border. This species has recently been collected in the Great Dismal Swamp in southeastern Virginia (Schwab, personal communication). Three species, *N defodiens*, *N. marginatus* and *N. sayi*, have a northern distribution and can be expected to occur in western Virginia *Nicrophorus americanus*, a species on the endangered species list, used to have a natural distribution that included Virginia, but now is found only in the midwest with one population in Rhode Island (Lomolino et al. 1996).

Of the six genera of Silphinae only three have an eastern United States distribution, *Necrodes*, *Oiceoptoma*, and *Necrophila*. *Necrodes surinamensis* is the only species in the genus and it has a broad distribution throughout the eastern United States (Anderson and Peck 1985). Two species of *Oiceoptoma* occur in the eastern United States; *Oiceoptoma inaequale* is widespread throughout the east, but *Oiceoptoma noveboracense* is a northern species that reaches northern Virginia. *Necrophila americana*, the only species in its genus, is widespread in the east.

Very little research has been conducted on the carrion beetle fauna of Virginia. A study in southwestern Virginia on the insect fauna visiting pig carcasses found the Silphinae species *Oiceoptoma inaequali* and *O. noveboracense*, *Necrodes surinamensis*, and *Necrophila americana* and three Nicrophorinae species, *Nicrophorus marginatus, N. orbicollis* and *N. tomentotus* (Tabor et al. 2005). The two species with northern distributions, *O. noveboracense* and *N. marginatus,* reflect the high altitude and cold climate of that region. Almost nothing is known of the carrion beetles in southeastern Virginia, which might be expected to include species with a southern distribution like *N. carolinus.*

This thesis explored the diversity and seasonal activity of a carrion beetle community in southeastern Virginia in a long leaf pine forest. This habitat shares plant species affinities with both northern and southern geographical regions (Plocher 1999) and it is unknown whether carrion beetles there resemble northern or southern fauna.

This thesis focused on five hypotheses concerning the carrion beetle community at the Blackwater Ecologic Preserve. The hypotheses were centered on community structure, seasonal activity patterns, habitat use including response to prescribed burns, dispersal abilities of the beetles, and the effects of trapping method on beetle catch.

SEASONALITY

Carrion beetles exhibit distinct seasonal activity patterns (Shubeck 1968, Trumbo 1990, Lingafelter 1995, Wolf 2004). Difference in seasonality and temperature preference can allow coexistence of Nicrophorinae in a single habitat if they are active at different times (Wilson et al. 1984). Temperature may affect when Nicrophorinae are active since *N. tomentosus* has been observed flying only on warm nights (Wilson et al. 1984). Different carrion beetle species are active in different parts of the summer according to their reproductive cycles (Shubeck 1968).

Trumbo (1990) noted that Nicrophorinae are more successful in cooler habitats because warmer temperatures favor invertebrate competitors such as ants and flies. Carrion flies can locate a carcass considerably faster than Nicrophorinae. Nicrophorinae are less likely to use a carcass that has been heavily infested by flies (Suzuki 2000). In his North Carolina study Trumbo (1990) found that no mouse carcasses used as bait were taken by beetles for reproduction in late summer, probably because of the increased fly infestation at that time.

The Blackwater Preserve in southeastern Virginia usually experiences long hot summers and mild winters, and seasonal patterns of carrion beetles can be expected to reflect those of southern states like North Carolina.

HABITAT PREFERENCE

Carrion beetles can be habitat generalists or habitat specialists (Shubeck 1983, Lingafelter 1995). Trumbo (1990) compared his study in North Carolina with a study conducted in Michigan and concluded northern habitats tend to have both habitat specialists and habitat generalists whereas southeastern habitats support habitat generalists. Trumbo and Bloch (2000) noted *Nicrophorus* species gain possession over more carcasses in habitats with closed canopies. Sikes and Raithel (2002) suggested that vegetation changes associated with deforestation might have been a contributing factor that led to the decline of the endangered *Nicrophorus americanus*.

Fragmented habitats can be detrimental to carrion beetle diversity (Sikes and Raithal 2002, Wolf 2004). The fragmentation caused by a burn may result in fewer larger-bodied beetle species, including habitat specialists like *N. orbicollis* (Trumbo and Bloch 2002). However, there is little information on carrion beetle activity in burned habitats.

Long leaf pine, once common in the southeastern United States, is now restricted to approximately 5% of its original range (Pitts-Singer et al. 2002). Carrion beetles were likely common and widespread in this fire-dependent habitat, but little is known about how carrion beetles respond to fire.

An open canopy increases surface temperature which speeds up the decomposition of a carcass (Trumbo 1990). This can be unfavorable for carrion beetles due to increased competition from other carrion fauna. Burned habitats should resemble open canopy habitats and might be avoided by carrion beetles.

BEP comprises several types of floral communities that vary from largely open canopy to closed canopy (Frost and Musselman 1987). Burned areas in the long leaf pine savannah at BEP create open canopy forest that differs markedly from the closed interiors of unburned forest. Therefore, species of carrion beetles that are habitat specialists in forests might be less likely found in burned sites. The research described in this thesis sampled beetles at the preserve in areas subjected to prescribed burning and areas where burns never occur to assess the effect of fire on carrion beetles. Carrion beetle density and diversity was expected to be greater in unburned than in burned sites. Higher numbers of beetles should be found in the unburned locations because the extra ground and vegetation coverage provides protection from predators and may also lower decomposition rates.

DISPERSAL

Locating carrion is very important for the survival of the Silphidae (Ikeda et al. 2007). Carrion beetles use their antennae, which are covered with olfactory receptors, to help them to locate carrion by detecting its unique blend of chemical cues. Dimethyl sulfide, dimethyl disulfide, and dimethyl trisulfide have been isolated as the attractants in carrion for *Nicrophorus vespillo* and *N. vespilloides* (Kalinova et al. 2009).

Carrion beetles are likely to fly distances greater than one kilometer in a single evening to find food (Trumbo and Bloch 2000). Nicrophorinae have been reported to fly up to 3.22 kilometers in pursuit of carrion (Rintoul et al. 2005). However, Raithel et al. (2006) observed marked *Nicrophorus americanus* beetles were more likely to be recaptured in traps located near the release point, and Shubeck (1968) found that carrion beetles cannot detect carrion beyond a few meters depending on the wind conditions. The present study tested carrion beetles' ability to find a food source from a distance by capturing beetles at a bait, marking them and releasing them at a location 315 – 1440 meters away from the trapping locations. Since carrion beetles are known to fly long distances to find carrion sources, marked Silphidae beetles should be able to fly from the release spot back to a trapping location.

TRAPPING METHOD

Numerous investigators have trapped carrion beetles by using various traps and baits (Shubeck 1968, 1970, 1983, Trumbo 1990, Trumbo and Bloch 2002, Wolf 2004, Ulyshen et al. 2007), but little attention has been focused on whether a given trap design influences the species collected. Some studies suggest that suspended traps capture different species than those on the ground (Shubeck 1970, Ulyshen et al 2007).

Carrion beetles are expected to be more easily captured in ground than tree traps. Carrion is naturally more prevalent on the ground than on a tree, which may be the case if a tree dwelling animal dies in a nest or hole of the tree. Also, all Nicrophorinae and two Silphinae are brightly colored and should therefore be better protected from predators on the ground where vegetation and detritus provide cover. In addition, the bait in a ground trap would be easier to use for reproductive purposes, especially for the Nicrophorinae that bury carrion by digging under the carcass until it is far enough in the ground to cover with dirt. This study used two different trapping methods at BEP, a tree trap and a ground trap, and compared the catch results.

SUMMARY OF HYPOTHESES AND PREDICTIONS

1. Species of carrion beetles at BEP will be more similar to the species found in the southern United States than in more northern habitats.

2. Carrion beetles at the preserve will exhibit seasonal patterns that differ among species and show similar seasonal patterns to southern carrion beetle communities.

3. Carrion beetles will differ in habitat use according to species. In particular, forest species should avoid burned habitats which may differ in temperature, humidity and light levels from unburned forest.

4. Beetles will travel long distances to find carrion, and they should return to sites of collection when released at hundreds of meters away.

5. Tree traps should capture different carrion beetle species than ground traps, and the Nicrophorinae should favor ground traps.

CHAPTER II

METHODS

STUDY SITE

All field research for this study was conducted at the Blackwater Ecological Preserve (BEP) in Isle of Wight County, Virginia. The preserve comprises 128 hectares of land in southeastern Virginia, which contains the northernmost community of long leaf pine (Frost and Musselman 1987). The preservation of long leaf pine requires parts of the preserve to be burned to clear the substrate. This allows seed germination and the grass stage of the longleaf pine to take root. The first controlled burn of the preserve was in January 1986 (Frost and Musselman 1987) with the last burn during the study period occurring in Spring 2007.

Table 1 lists the eight trapping locations used for the study, including four burned sites and four unburned sites. Trapping locations that were considered burned were burned in the past and were again burned at some point during the study period. Coordinates for each trapping location are included and were found using GPS (B. Miller, personal communication). Trapping locations were picked at random based on if the location was burned or not burned. A map of the trapping locations shows approximately where on the preserve location was.

Table 1.—Trapping locations, burned/unburned status, and location coordinates.

Trapping location	Burned or Unburned	Coordinates
B1	Burned	N 36° 49.095' W 076° 51.116' ± 3.962m
B2	Burned	N 36° 49.310' W 076° 51.101' ± 4.572m
U1	Unburned	N 36° 48.804' W 076° 51.256' ± 6.706m
U2	Unburned	N 36° 49.524' W 076° 51.337' ± 5.182m
B3	Burned	N 36° 49.419' W 076° 51.116' ± 5.182m
B4	Burned	N 36° 49.129' W 076° 51.103' ± 5.486m
U3	Unburned	N 36° 49.468' W 076° 51.686' ± 5.791m
U4	Unburned	N 36° 49.431' W 076° 51.322' ± 5.791m

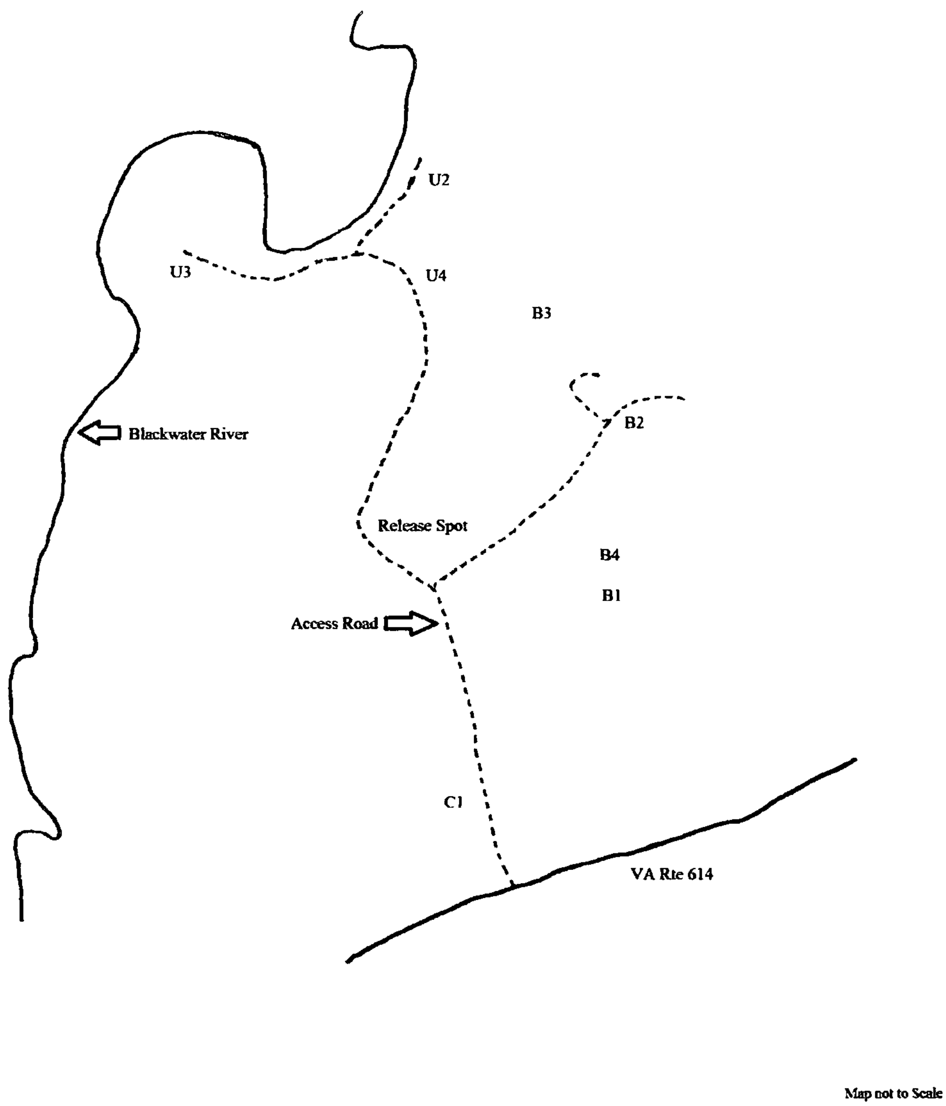

Fig. 1.—Trapping location schematic.

TRAPPING PROTOCOL

For each trapping event, a set of four trapping locations was baited with one trap per trapping location. Each set consisted of two burned and two unburned trapping locations. The sets were alternated during the experiment to sample both sets evenly. B1 and B2 of set 1 were burned and U1 and U2 of set 1 were unburned. The B3 and B4 of set 2 were burned and U3 and U4 of set 2 were unburned. The number of times each set was trapped throughout the twenty-five month experiment is displayed in Table 2.

Traps were set on day one and beetles were collected on day four and day eight. All carrion beetles in the trap on day four were collected from the trap and keyed to species level. Temperature and humidity readings using a Scientific Fisher thermometer were recorded during each setting or collection of the traps. On day eight, after all carrion beetles were identified, the trap was removed from the trapping location. Pieces of beetles (eleytra, head, etc.) were not included in counts, only beetles that were alive or, if dead, mainly intact. Voucher specimens were kept of each beetle species and deposited in the Old Dominion University Entomology collection.

Table 2.—Number of times the traps were set during each year out of a possible twelve months. Each set consisted of two burned and two unburned trapping locations with one trap per trapping location.

	First Year (July 2005 – June 2006)	Second Year (July 2006 – June 2007)	Third Year (July 2007 – October 2007)
Set 1	5	7	1
Set 2	11	5	2
Number of months the trap were set out of twelve months	**10 months**	**11 months**	**4 months**

TRAP TYPES

Two different trap types were used for the experiment, the tree trap and the ground trap. Tree traps were used July 2005 through June 2006, and ground traps were used July 2006 through June 2007. Both traps were used simultaneously July 2007 through October 2007.

Ground Trap

The ground trap had a wooden frame with wire mesh stapled around the frame (Fig. 2). The dimensions of the trap were 50.8 x 25.4 x 22.9 centimeters. There was a 15.2 centimeter diameter hole cut in the bottom with a plastic funnel covering the hole so insects could crawl or fly into the trap, but could not easily get back out. Another 15.2 centimeter diameter hole was cut in the top of the trap to allow for collection of the insects in the trap.

The bait can held sixty grams of bait. The bait can for the ground trap was made out of an empty 210 milliliter cat food can with four holes drilled in the sides. The holes were drilled for securing the bait can to the trap. The can was suspended underneath the hole in the bottom of the funnel with bungee cords. The bait used was a mixture of Jack Mackeral and Friskies Mixed Grill canned cat food. Jack Mackeral was mixed with Friskies Mixed Grill in a ratio of five to two parts. Each trap type was baited with 60 grams of room temperature cat food/ mackerel mixture. The bait was measured to the nearest gram using Good Cook electronic food scale and placed in a clean, empty cat food can for the ground trap or in the bottom piece of the tree trap.

The bait cans were placed in a plastic Ziploc bag and the tree traps were placed in a cooler to prevent utilization of bait by Dipterans before the experiment. The ground traps were assembled at each site.

The entire trap was secured to a metal oil drip pan, which also had holes in it to allow drainage of rain water, with bungee cords (Fig. 3). The trap was then staked to the ground using plastic tent stakes for added stability. Leaf litter was added to the metal pan to help prevent the pan from heating up. This procedure was used each time the ground trap was set.

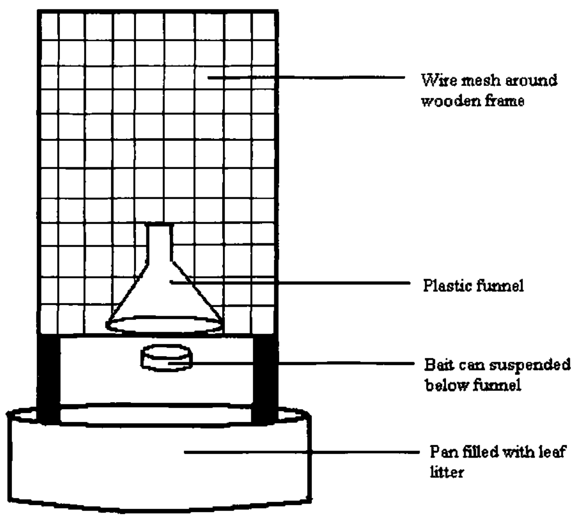

Fig. 2.—Ground trap schematic.

Fig. 3.—Ground trap.

Tree Trap

The tree trap was made from a 500 milliliter plastic water bottle (Fig. 4). The bottle was cut in two places dividing the bottle into three pieces. The bottom piece had four 0.7 centimeter diameter holes placed equidistant, which were punched using a paper hole punch. The holes were punched to allow bait odor to escape the bottle. This bottom piece held sixty grams of bait, which was the same as the bait used for the ground trap. The middle piece also had four 0.7 centimeter diameter holes punched into the side of it and plastic canvas mesh was attached to this piece using four brass brads. The mesh prevented beetles from getting caught in the bait. There were two 0.7 centimeter diameter holes punched in the top of the middle piece and a string was attached to the bottle to secure the bottle to the tree. The middle piece was then taped to the bottom piece and the top piece was taped to the middle piece.

The tree trap was tied to a tree 152 centimeters from the bottom of the tree and a metal cage was placed around the trap using plastic flagging (Fig. 5). This procedure was used every time the tree trap was set.

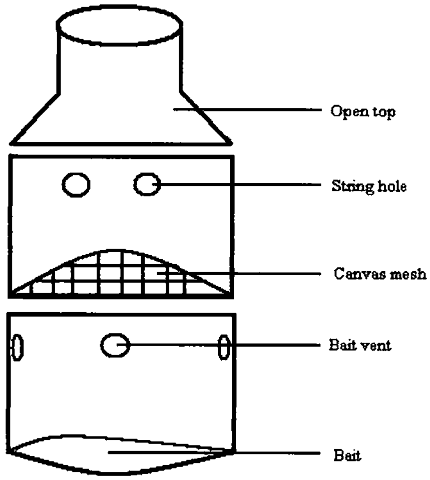

Fig. 4.—Tree trap schematic.

Fig. 5.—Tree trap with wire cage.

MARK/RECAPTURE OF *NECROPHILA AMERICANA*

Mark/ recapture tests were used to determine dispersal distances of *Necrophila americana* (Table 3). *N. americana* was used for the test since this species was readily abundant at the time of the mark/recapture study and appeared to have no habitat preference. Three mark/recapture trials were conducted *Necrophila americana* beetles were collected and marked from three trapping locations, released from a common release point, and recaptured at traps from the set of initial capture. The distance from the release point to each trapping location is in Table 6. The four ground traps were set on day one (Sunday).

Table 3.— Mark/recapture test of *Necrophila americana.*

Date beetles marked & released	Number of beetles marked	Collected from	Color marked	Recapture Locations	Date traps checked
June 6, 2007	10	U2	blue	B1, B2, U1, U2	June 10, 13, 17
July 18, 2007	10	B4	blue	B3, B4, U3, U4	June 22, 25, 29
July 18, 2007	4	U3	yellow	B3, B4, U3, U4	June 22, 25, 29

Table 4.—The distance in meters between each trapping location and the release point. An asterisk denotes locations in burned habitat.

Trap location	Distance from release point
*B1	524m
*B2	824m
U1	315m
U2	1270m
*B3	1079m
*B4	548m
U3	1440m
U4	990m

A lab test showed that the fingernail polish marking did not harm the *Necrophila americana* beetle and the marking lasted two weeks (Fig 6).

Fig. 6—Marked *N. americana* beetles in lab experiment to test the longevity of fingernail polish on a beetle.

After marking, all marked beetles were released from the designated release point. Day eight (Sunday) the traps were checked for any marked beetles and the bait was replaced with new bait. Any unmarked beetles were marked and released from the release spot. Day eleven (Wednesday) the traps were checked again for marked beetles. On day eleven all unmarked beetles were keyed and recorded, but not marked. Day fifteen (Sunday) the traps were checked for any marked beetles and all unmarked beetles were keyed and recorded.

TRAPPING METHOD

Tree traps and ground traps were set out simultaneously at each set of trapping locations for approximately two weeks at a time during the months of July, August, September, and October 2007. Using a tape measure the ground traps were set 152 centimeters away from the base of the tree the tree trap was tied to.

At each location, a tree trap was tied on the north side of the tree (the tree was marked with flagging and used during entire experiment) with yarn at a height of 1.5 meters north of the base of the tree. A wire cage was placed around the tree trap to prevent the trap from being taken off the tree or falling off the tree. A ground trap was set 152 centimeters north of the base of the tree.

During the trapping method test, the bait was replenished on day eight (Sunday) since the trapping event was two weeks long. The traps were set out on day one, checked on day four, and collected on day eight (typically Sunday, Wednesday, Sunday).

DATA ANALYSIS

A three-factor analysis of variance was used to examine the effects of trap type (tree versus ground trap), habitat type (burned versus unburned) and beetle species (for the seven species collected) on number of beetles collected over the study in the eight trapping locations from June 2005 – June 2007. A separate three-factor analysis of variance was performed for the comparison between tree and ground trap types when both were set out simultaneously in burned and unburned habitats from July - October 2007. The three factors were trap type (tree versus ground trap), habitat type (burned versus unburned) and beetle species (for the seven species collected). Temperature and relative humidity throughout the study were analyzed separately using two-factor analyses of variance. The two factors were habitat (burned versus unburned) and season (four levels for the four seasons studied: Winter = January-March, Spring = April-June, Summer = July-September and Fall = October-December).

CHAPTER III

RESULTS

SPECIES DIVERSITY

Carrion beetles from both subfamilies collected from June 2005 through October 2007 are shown in Table 5. Silphinae were the most numerous with four species present at the preserve. Three species of Nicrophorinae were collected.

Table 5.—Number and species of beetles found in each subfamily of the family Silphidae throughout the study June 2005- October 2007

Subfamilies	Species	Number
Nicrophorinae	*Nicrophorus orbicollis*	250
	Nicrophorus pustulatus	66
	Nicrophorus tomentosus	183
Silphinae	*Necrodes surinamensis*	16
	Necrophila americana	246
	Oiceoptoma inaequale	184
	Oiceoptoma noveboracense	163

Necrodes surinamensis was the least frequently collected with only sixteen specimens collected during the twenty eight month study.

SEASONALITY

The seasonal patterns for all species collected during the study period of July 2005 through June 2006 are depicted in Figure 7. During the late summer months of July, August, and September (average temperature 30.8°C and average humidity 59.9%), *N. orbicollis* at 158 beetles was the most common beetle collected in the tree trap. *N. americana* came in as the second most abundant species found during the same three months with 64 beetles collected. Forty four *N. tomentosus* beetles and thirty three *N. pustulatus* were collected from the tree trap during these hot months. *N. surinamensis* was collected thirteen times during the three months with *O. inaequale* and *O. noveboracense* not collected during the first three months of the study.

The next three months during the late fall and early winter, October, November, and December (average temperature 17.5°C and average humidity 47.2%), in 2005 showed a decrease in beetle abundance with the decrease in temperature. *N. orbicollis* continued to show the most abundance with 46 beetles collected. *N. tomentosus* was not far behind with 37 beetles collected from the tree trap. Only three *N. pustulatus* beetles were collected, and the four species of the subfamily Silphinae were not collected at all during these three months.

The winter months, January, February, and March (average temperature 14.5°C and average humidity 44.2%), in 2006 saw no beetle activity. No beetles of any species were found during this period.

A slight increase in beetle abundance was observed in spring, April, May, and June (average temperature 24.9°C and average humidity 42.8%), 2006. Again *N. orbicollis* was found more often than the other species with four beetles collected. The other two species of subfamily Nicrophorinae were found equally at three beetles a piece. One *N. americana* was collected while *N. surinamensis* and *O. inaequale* were not trapped during these warmer months. *O. noveboracense* was collected for the first time twice during this period.

Overall for the study period July 2005 through June 2006 the most beetles were collected during the first three months, only the burying beetle species were collected in October, November, and December, no beetles were collected in the following three months, and only twelve beetles collected in the last months of the study.

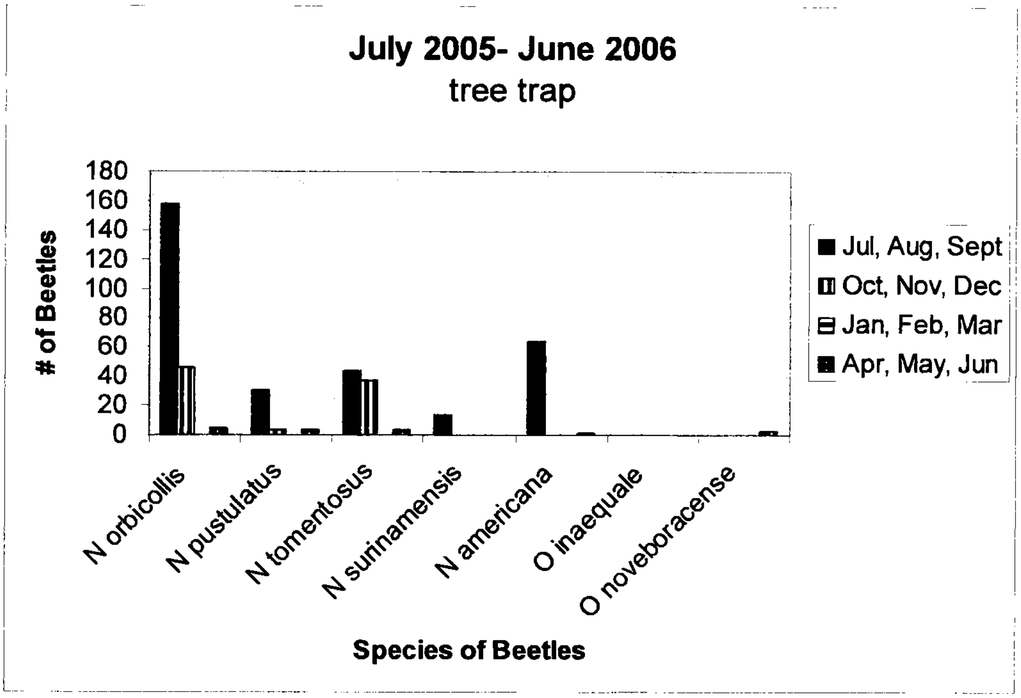

Fig. 7.—Number of each species collected using the tree trap method during July 2005 through June 2006 and grouped into three month intervals to show seasonal patterns.

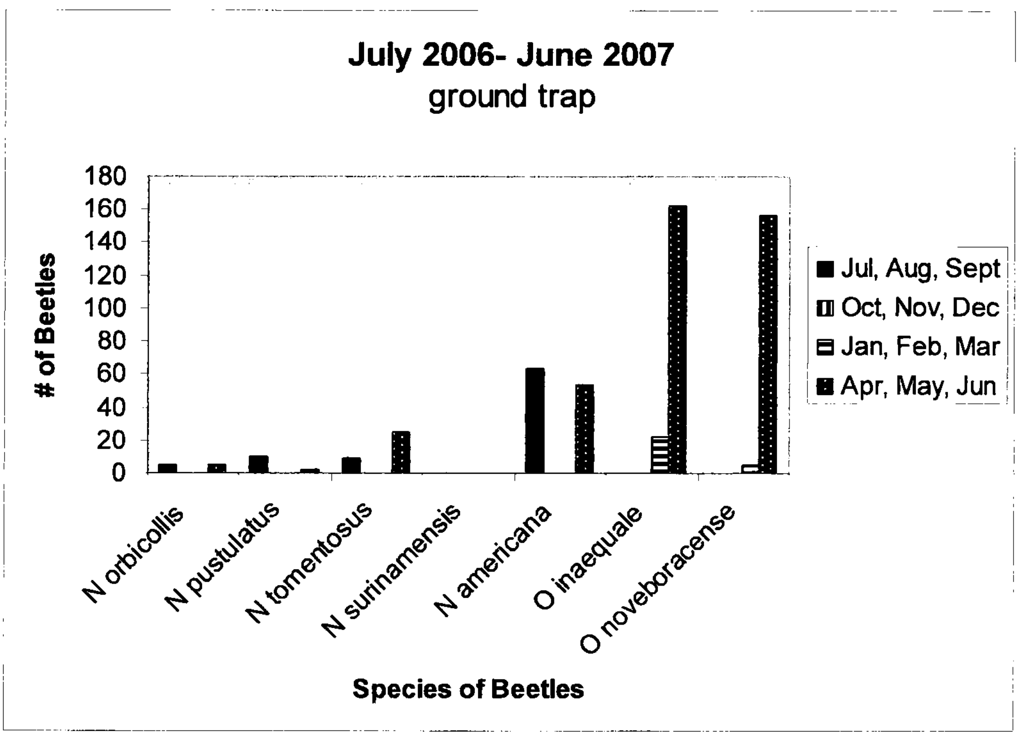

Fig. 8.—Number of each species collected using the ground trap during July 2006 through June 2007 and grouped into three month intervals to show seasonal patterns.

The beetles collected during the sampling period of July 2006 through June 2007 are depicted in Figure 8. Only the ground trap was used during this sample period. During the first three months of this study year, July, August, and September (average temperature 31.7°C and average humidity 50.0%), *N. americana* was the most abundant at sixty three beetles collected. *N. pustulatus* was the next most common beetle found at ten beetles with nine *N. tomentosus* beetles collected during this period. Five *N. orbicollis* beetles were collected while no *N. surinamensis*, *O. inaequale*, and *O. noveboracense* beetles were found.

No beetles were collected during the following three months of October, November, and December (average temperature 16.3°C and average humidity 41.4%).

In the next period, January, February, and March 2007 (average temperature 13.2°C and average humidity 47.6%), only twenty two *O. inaequale* and five *O. noveboracense* beetles were collected.

The last three months of the sampling period, spring April, May and June 2007 (average temperature 26.7°C and average humidity 48.1%), showed an increase in beetle activity. *O. inaequale* and *O. noveboracense* were the most commonly collected at 162 and 156, respectively. *N. americana* were the next commonly collected beetles with fifty three found. *N. tomentosus* were the most common Nicrophorinae to be collected at twenty five beetles. For the Nicrophorinae species, there were five *N. orbicollis* and two *N. pustulatus* beetles collected during April, May, and June, 2007. The Silphinae *Necrodes surinamensis* was not collected in the trap at anytime during the sampling period of July 2006 through June 2007, when only the ground trap was used.

Overall for the study period July 2006 through June 2007 *N. americana* was the most commonly collected beetle in the first three months, no beetles were collected in October, November, or December, 27 beetles of the two *Oiceoptoma* species were collected in January, February, and March, and the last three months saw an increase in beetles collected, especially in the two *Oiceoptoma* species.

HABITAT PREFERENCE

More silphids were found in the unburned habitats than in the burned habitats. Out of the 1108 beetles collected from June 2005 through October 2007, 304 (27%) were collected from traps located in burned areas of the preserve and 804 (73%) beetles were collected from unburned areas of the preserve. The three-factor ANOVA revealed significant differences in numbers of beetles found in burned versus unburned habitats ($F = 9.814$, $p = 0.0024$, $df = 1,84$). Beetle species did not differ significantly in number ($F = 1.873$, $p = 0.0949$, $df = 6,84$), probably due to the variation in numbers collected from different traps. There was no significant interaction between burned/unburned habitat and beetle species collected ($F = 1.255$, $p = 0.2873$, $df = 6,84$). These results show that most beetle species were more common in unburned habitats.

Greater abundance of beetles in unburned habitats was not due to differences in temperature or humidity. There were no significant differences in temperature or humidity in burned versus unburned sites (temperature: $F = 0.815$, $p = 0.3674$, $df = 1, 318$; humidity: $F = 0.007$, $p = 0.9354$, $df = 1, 293$). However, there was a significant difference among seasons for both temperature and humidity (temperature: $F = 109.101$, $p = 0.0001$, $df = 3, 318$; humidity: $F = 3.821$, $p = 0.0104$, $df = 1, 293$).

Both trap styles, ground and tree, were set in burned and unburned trapping locations throughout the study. The three-factor ANOVA revealed that there was no significant difference in tree versus ground traps ($F = 0.685$, $p = 0.4101$, $df = 1,84$), probably due to the variation in numbers of specimens collected from different traps. There was a significant interaction between tree versus ground collection and beetle species collected ($F = 4.994$, $p = 0.0002$, $df = 6,84$) and a significant interaction between tree versus ground collection and burned versus unburned location ($F = 6.167$, $p = 0.015$, $df = 1,84$). Overall, fewer beetles were collected from the ground traps set in burned locations. Fifty three percent of the beetles collected during the entire study were found in the ground traps, with 73% of ground trap beetles found in the unburned locations of the preserve (Fig. 8). Of the beetles collected in the tree traps 235 (21%) beetles were found in the burned locations and 290 (26%) were found in the unburned locations (Fig. 9).

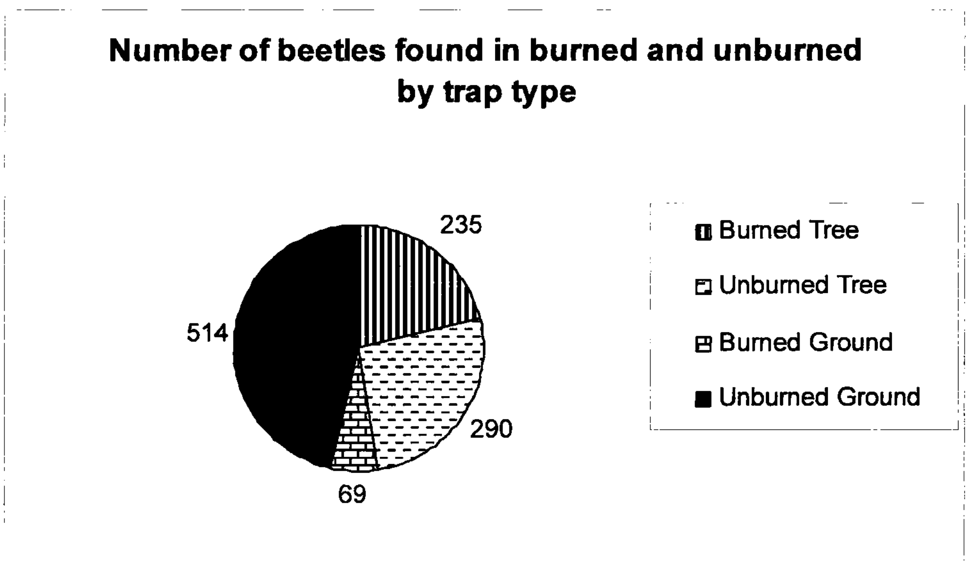

Fig. 9.—Number of beetles found in burned or unburned habitat separated by trap type during the study, June 2005-October 2007.

Three of the four species collected from the subfamily Silphinae were collected more often in unburned areas than burned areas as were beetles from the subfamily

Nicrophorinae, but the three species from this subfamily were also found in high numbers in the burned locations (Fig. 10).

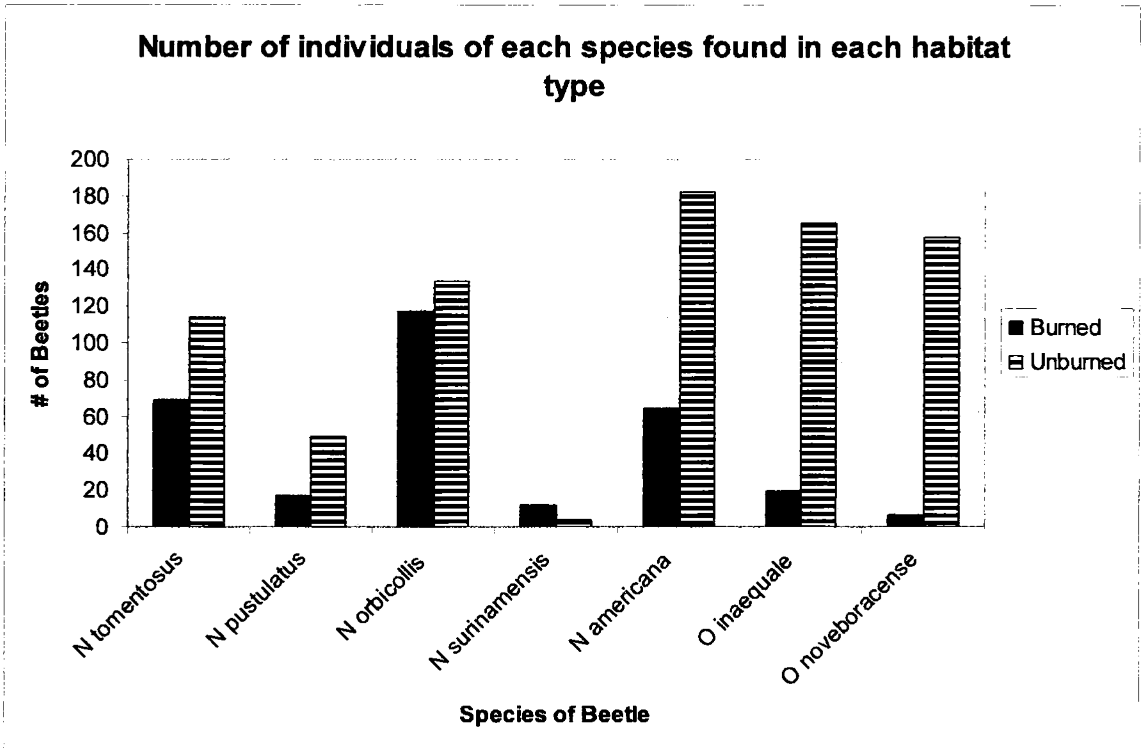

Fig. 10.—Number of individuals of each species found in each habitat type for the entire study period.

MARK/RECAPTURE OF *NECROPHILA AMERICANA*

None of the twenty four *N. americana* marked beetles returned to any traps set.

TRAPPING METHOD

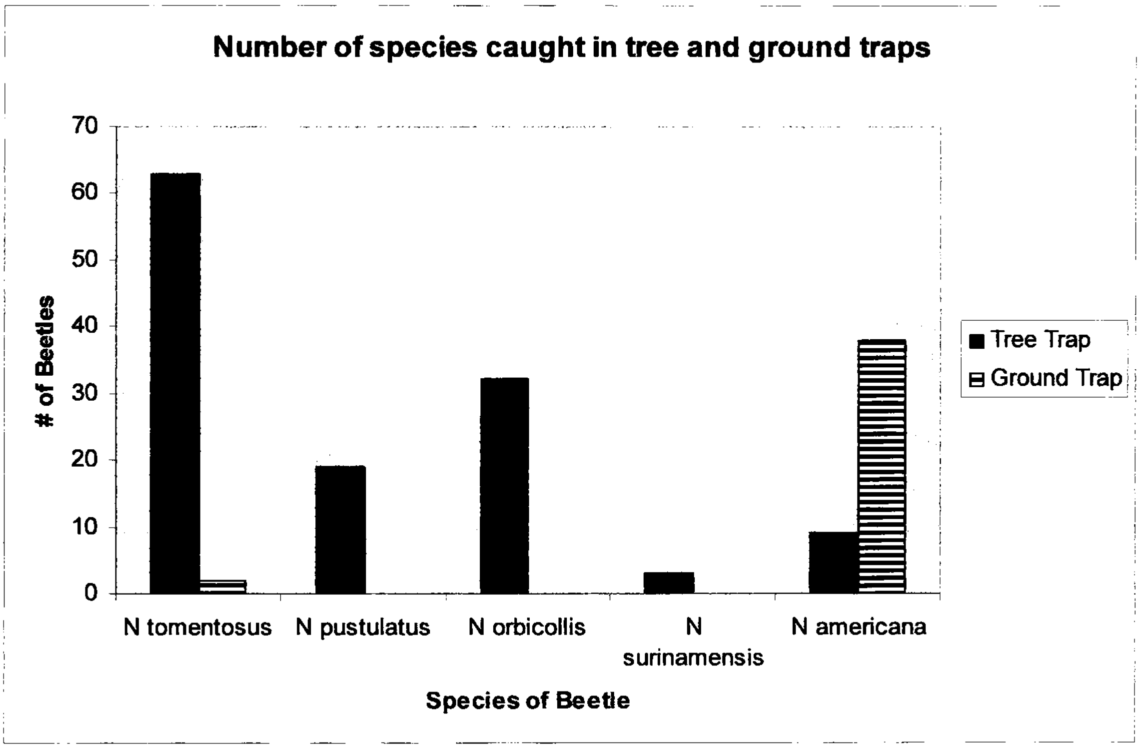

Fig. 11.—Number of species caught in tree and ground traps for the study period of July 2007-October 2007 when both traps were set out simultaneously.

The following five beetle species were collected during the trap type preference study conducted July –October 2007: 65 (39%) *Nicrophorus orbicollis*, 19 (11%) *N. pustulatus*, 32 (19%) *N. tomentosus*, 3 (2%) *Necrodes surinamensis* and 47 (28%) *Necrophilia americana* (Fig. 11). *N. tomentosus* was collected 63 (50%) times, *N. pustulatus* 19 (15%) times, *N. orbicollis* 32 (25%) times, *N. surinamensis* 3 (2%) times, and *N. americana* 9 (7%) times in the tree trap. *N. tomentosus* was collected 2 (5%) times and *N. americana* was collected 38 (95%) times in the ground trap.

A three-factor analysis of variance revealed no significant difference in beetle numbers in tree versus ground traps (F = 3.4, p = 0.701, df = 1, 60) or in burned versus unburned sites (F = 0.001, p = 0.9819, df = 1, 60), or among beetle species (F = 1.453, p

= 0.2279, df = 4, 60). However, there was a significant interaction between tree versus ground trap and beetle species (F = 2.881, p = 0.03, df = 4, 60). An examination of the data reveals that the Nicrophorinae species *Nicrophorus orbicollis*, *N. pustulatus*, *N. tomentosus*, and the Silphinae species *Necrodes surinamensis* were found most frequently in tree traps and the Silphinae species *Necrophila americana* was found most frequently in ground traps. This mirrors the behavior of *Necrophila americana* during the entire study when it was found twice as frequently in ground traps as in tree traps.

CHAPTER IV

DISCUSSION

SPECIES DIVERSITY

BEP included a mixed assemblage of both northern and eastern carrion beetle communities. One of the southern Nicrophorinae species *Nicrophorus carolinus* was not collected at BEP, but the northern Silphinae species *Oiceoptoma novaboracense* was present in collections. The other species found at the preserve, including the Nicrophorinae, *Nicrophorus orbicollis*, *N. tomentosus*, and *N. pustulatus* and the Silphinae species *Necrodes surinamensis*, *Necrophila americana* and *Oiceoptoma inaequale* are all distributed throughout the eastern United States and can be expected to occur in the south and the north. The most common species at the preserve was the Nicrophorinae, *Nicrophorus orbicollis*, which is very abundant in other areas as well (Trumbo 1990). The Nicrophorinae, *N. pustulatus* was collected in small numbers compared to the other two Nicrophorinae, *N. orbicollis* and *N. tomentosus*, and this is typical for this species (Ulyshen et al. 2007). In North Carolina, Trumbo (1990) could not trap the hard to trap *N. pustulatus* in the field although the study area is within the beetle's range.

SEASONALITY AND HABITAT USE

The following species accounts discuss the seasonal patterns and habitat use of the species collected at the preserve with reference to their known seasonality and habitat preference in other areas. In general, seasonal patterns of different silphid species at BEP are consistent with those reported elsewhere. Habitat use by different species at the preserve was also consistent with literature reports. Those species that are known to prefer forested habitats were most common in unburned sites while species that prefer open habitats were either more common in the burned sites or frequented both burned and unburned habitats.

Nicrophorus orbicollis

In the current research, *N. orbicollis* was active primarily in the late summer and into the fall. *Nicrophorus orbicollis* is active from March to August in prairie habitats in the Midwest (Rintoul et al. 2005). Trumbo (1990) found *N. orbicollis* is dominant on small carcasses from April to September in woodlands of piedmont North Carolina. In Michigan, Wilson et al. (1984) found *N. orbicollis* to be active in the middle of summer.

At the Blackwater Preserve, *N. orbicollis* was the most abundant carrion beetle and it was collected primarily in tree traps, with equal distribution in burned and unburned trapping locations. Scott (1998) observed that *N. orbicollis* inhabits moderately wet hardwood forests while Anderson and Peck (1985) found these beetles are found in both open and forested habitats, but more often in the forest. Trumbo (1990) captured *N. orbicollis* only in traps placed in a woodland habitat.

Nicrophorus pustulatus

At BEP, *N. pustulatus* was active late summer and into the fall. Trumbo (1990) observed *N. pustulatus* was not found on a mouse carcass used as bait in the field of a North Carolina, but in the lab *N. pustulatus* bred on a carcass over one hundred grams. Tabor et al. (2005) did not find *Nicrophorus pustulatus* in a study in southwestern Virginia, although it likely occurs in that region.

Collections of this species at the Blackwater Preserve were most common in tree traps, especially in the unburned habitats. No specimens were caught in ground traps in the burned locations. According to Rintoul et al. (2005), *Nicrophorus pustulatus* prefers wooded habitats over open habitats. Anderson and Peck (1985) trapped a limited number of specimens in forested habitats. This species has been collected high in the canopy (Ulyshen et al. 2007).

Nicrophorus tomentosus

In the current study, *N. tomentosus* was found in similar numbers in the late summer and in the fall. *Nicrophorus tomentosus* is generally active late summer into early fall (Scott 1998) and is considered diurnal, unlike most Nicrophorinae (Anderson and Peck 1985). Wilson et al. (1984) focused their study on interspecific competition among carrion beetles in Michigan and found *N. tomentosus* was active during the day and mimics the flight of a bumble bee to reduce predation. *N. tomentosus* is an autumn breeder with a late emergence in July (Wilson et al. 1984).

In a study conducted in North Carolina's piedmont, Trumbo (1990) found that *N. tomentosus* was the predominant species on small carcasses in October. In the North Carolina study *N. tomentosus* was found to be flying by mid June, but was not immediately reproductively active (Trumbo 1990). The variance of when this species is active as well as other species in this genus may show Nicrophorinae communities have adapted their reproductive success based on the local habitat (Wilson et al. 1984). Anderson and Peck (1985) found these beetles overwinter in the third instar larval phase and pupate the following spring. In their Michigan study Wilson et al. (1984) suggested the reproductive diapause in *N. tomentosus* and reproductive activity late in the year evolved from competition with *N. orbicollis*.

In this study, most specimens were commonly collected at tree traps in both burned and unburned site and in ground traps primarily in the unburned locations. *N. tomentosus* seems to prefer open habitats (Rintoul et al. 2005). Anderson and Peck (1985) described this species as "eurytypic" and believes this is due to their late emergence.

Necrodes surinamensis

In the present study, this species was rare and was collected only from tree traps, with the majority of collections from burned habitats, unlike the other species in this study. Its activity in burned areas corresponds with its reputed preference for open habitats (Rintoul et al. 2005).

In this study, the species was active July through September with a few collections in October. *N. surinamensis* overwinter as adults and are nocturnal (Anderson and Peck 1985). The Silphinae species *Necrodes surinamensis* was observed to be active in May and July, but not in June in a study in a Kansas prairie (Rintoul et al. 2005). In Nebraska adults emerge in early April (Anderson and Peck 1985).

Necrophilia americana

In this study *N. americana* was active from April through September. The Silphinae species *N. americana* emerge as adults in late March and usually reproduce between late May and mid-July (Anderson and Peck 1985). There is only one generation per season (Anderson and Peck 1985). This species is considered diurnal (Shubeck 1983).

At the Blackwater Preserve, *N. americana* was collected in both tree and ground traps in both the burned and the unburned trapping locations. It was most common in ground traps in unburned sites and least abundant in ground traps in burned sites. Rintoul et al. (2005) observed *N. americana* in open, undisturbed, and tallgrass prairie sites in Kansas, although it is thought that they prefer oak-hickory forests. Anderson and Peck (1985) found this species in mesic, open habitats.

Oiceoptoma inaequale

In the current study, this species occurred in low numbers in January through March and was most abundant April through June. This species is diurnal (Shubeck 1971). The Silphinae species *O. inaequale* is reproductively active in early spring with adults emerging as early as February (Anderson and Peck 1985). Eggs are laid in February and March with only one generation per year (Anderson and Peck 1985).

In the present study, *O. inaequale* was present only in ground traps with the majority of collections in unburned habitats. Rintoul et al. (2005) observed *O. inequale* prefer riparian woodlands and Anderson and Peck (1985) noted these beetles seem to be found only in deciduous forest habitats.

Oiceoptoma noveboracense

In this study, *O. noveboracense* made its first appearance in early spring, January through March, and it was most abundant in April through June. It was absent from collections during the summer and fall. The Silpinae species *O. noveboracense* usually emerges as adults in late February (Anderson and Peck 1985). There is only one generation with oviposition occurring around April to May (Anderson and Peck 1985). These beetles are diurnal (Shubeck 1971).

In the present study, this species was collected only in ground traps and it was most frequently found in unburned habitats. *O. novaboracense* seems to prefer riparian woodlands in prairie habitats (Rintoul et al. 2005) and forested habitats (Anderson and Peck 1985).

HABITAT PREFERENCE

The carrion beetles collected at the preserve preferred the unburned habitats over the burned habitats. Only the Silphinae species *Necrodes surinamensis* was collected seventy five percent of the time (12 beetles collected) in the burned habitats and this species is known to prefer open habitats over forests (Rintoul et al. 2005).

Many factors could contribute to the preference for the unburned locations. The openness of the burned areas could have increased the chance of predation. Although temperature and humidity conditions can potentially influence the choice of habitat, these did not differ significantly at the preserve for the burned and the unburned areas. An open canopy, which characterizes burned sites, can potentially increase soil surface temperature and speed up decomposition of the carcass (Trumbo 1990), and these factors might have influenced preference for unburned habitats. Scott (1998) observed smaller species of the Nicrophorinae dig in damp soil and larger Nicrophorinae bury in dry, sandy soils. Burned habitats at the preserve might have differed in soil type that made them less favorable to the Nicrophorinae species in this study.

Some species that prefer open habitats and might have frequented burned sites, like the Nicrophorinae, *Nicrophorus marginatus*, were not collected at the preserve. Trumbo and Bloch (2000) observed that development and fire suppression can cause a decline in *Nicrophorus marginatus* populations in the Midwest. Given that BEP is not fire suppressed and *N. marginatus* has a distribution that includes southeastern Virginia, *N. marginatus* should have been collected at BEP. A possible reason why this beetle was not found at the preserve could be the increased development in southeastern Virginia since the earlier studies were conducted. Forest fragmentation caused by urbanization has lead to a decline in burying beetle diversity in other areas (Wolf and Gibbs 2004).

DISPERSAL

No beetles returned to the bait traps following marking and release. The release location of the marked beetles might have been too far for the beetles to locate the baited traps. Although carrion beetles can travel large distances (Rintoul et al. 2005), they might not be able to detect bait odors beyond a few meters. Shubeck (1968) did not get a significant return of marked beetles when they had to travel more than one meter to a baited trap. Random wandering was believed to be the reason why some beetles were recaptured in Shubeck's (1968) study in New Jersey, and it may be the method most carrion beetles use to locate carrion.

TRAPPING METHOD

Beetles species differed in their use of tree and ground traps. The Nicrophorinae species *Nicrophorus orbicollis*, *N. pustulatus* and *N. tomentosus* and the Silphinae species *Necrodes surinamensis* were collected primarily from tree traps during the entire study and also during the test of preference for trap type in 2007. The Silphinae species *Necrophila americana* occurred in both tree and ground traps both throughout the study and during the trap type preference test, but it was much more abundant in the ground trap during the test. The Silphinae species *Oiceoptoma inaequale* and *O. novaboracense* were collected exclusively from the ground trap.

The Nicrophorinae might have found the ground trap unsuitable for carrion burial. Beetles were collected in the ground trap if they flew up into the funnel after finding the bait. However, instead of flying up once they located the bait, the beetles could crawl out of the trap. If the Nicrophorinae found the bait but could not bury it because of the floor of the trap, the beetle may have left the trap. Wilson et al. (1984) suggested that Nicrophorinae intent on reproduction may ignore strong bait odors when they are in search of a carcass suitable for oviposition. In contrast, the tree trap was constructed so that Nicrophorinae could not get out of the trap once they were in.

During the study some Nicrophorinae were found in the bottom part of the tree trap floating in the bait. Other Nicrophorinae were discovered chewing on the string that anchored the tree trap to the tree during collections. Before the wire cages were put around the tree trap, the beetles were able to chew through the string and cause the tree trap to drop to the ground where the beetles could then walk out of the trap. Once the cages were placed around the trap the traps were always in place when collected even if the string was chewed.

In a pilot study conducted by Wilson et al. (1984), the same proportion of *Nicrophorus* species was found in suspended pitfall traps as in ground pitfall traps, which indicates that the location of the trap was not a factor. Ulyshen et al. (2007) found *Nicrophorus pustulatus* in traps suspended fifteen meters or more above the ground in Georgia.

Species of the subfamily Silphinae do not bury carcasses for reproduction, so this might explain why these beetles were found in high numbers in the ground traps. In the test of the tree trap and the ground trap *Necrophila americana* was primarily collected from the ground trap.

The Silphinae species *O. inaequale* and *O. noveboracense* were not collected in either trap during this preference test period, July 2007 – October 2007, probably because they are not usually active at that time of year. However, when these two species were collected previously they were collected primarily from the ground traps when they were set from July 2006 to June 2007.

Silphinae beetles were seen mating near the baited traps. *N. americana* did enter both tree and ground traps, and several Silphinae larvae were collected from a tree trap. The larvae were raised in the laboratory and were keyed to *N. americana.* It is unknown why *Oiceoptoma inaequale* and *O. novaboracense* were never collected from tree traps.

Species that were collected from ground traps were found primarily in unburned trapping locations. Possibly the absence of litter in the burned areas and the protection litter provides made the ground traps unsuitable for the beetles the unburned habitats. In contrast, tree traps were visited by several species in both the burned and unburned trapping locations.

SUMMARY AND CONCLUSION

Overall, this study found that the carrion beetle fauna of the Blackwater Ecological Preserve contains species that are widely distributed in the eastern United States and one species, *Oiceoptoma novaboracense*, with a more northern distribution. The seasonal patterns these species exhibit are consistent with their seasonal activities reported from other locations. This is the first study to examine carrion beetle species' responses to prescribed burns in a long leaf pine forest and the results revealed a preference for unburned forest in all species except *Necrodes surinamensis*. The mark-recapture results supported the reports in the literature that indicate beetles cannot locate carrion at a distance. The comparison of trap types provided strong evidence that the type of trap utilized can influence capture results and that investigators should use a variety of trap types to sample carrion beetle faunas most accurately.

Future studies of the carrion beetle fauna should include multiple trap types set at different heights in order to sample the entire community for preference of trap height, which may be indicative of how the beetles discover carcasses. Prescribed burning also needs further research to examine possible effects on the carrion beetle community. Since soil type is important to the Nicrophorinae, the impact of fire on soil needs to be further examined. The soil may get hot enough if the prescribed burn is conducted in the winter that it kills the overwintering carrion beetles. A good constructed mark/recapture study conducted with pre-determined distances and several different marked species could help determine how far carrion beetles travel for a food source.

Finally, continuing to conduct research at sites like BEP is very important because it provides baseline data for global climate change and for fire restoration projects. These studies help to show how essential fire is to fire suppressed communities as well as show how species move from habitat to habitat in response to change.

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APPENDIX A

DATES TRAPS WERE SET, COLLECTED, AND TYPE OF TRAP SET

	Date Traps Set	Date Traps Collected	
Set 1	7/12/2005	7/13/2005, 7/20/2005,7/24/2005	Tree trap
	7/24/2005	7/27/2005, 7/31/2005	Tree trap
	7/31/2005	8/3/2005, 8/7/2005	Tree trap
	8/7/2005	8/10/2005, 8/14/2005	Tree trap
	5/16/2006	5/18/2006, 5/21/2006	Tree trap
	7/11/2006	7/13/2006, 7/16/06	Ground trap
	9/13/2006	9/17/2006, 9/29/2006	Ground trap
	12/17/2006	12/20/2006	Ground trap
	2/19/2007	2/26/2007	Ground trap
	4/9/2007	4/16/2007	Ground trap
	6/3/2007	6/6/2007, 6/10/2007, 6/13/2007, 6/17/2007	Ground trap
	8/19/2007	8/22/2007, 8/26/2007, 8/29/07, 9/2/2007	Both traps
Set 2	8/14/2005	8/17/2005, 8/21/2005, 8/24/2005, 8/28/2005	Tree trap
	8/28/2005	8/31/2005, 9/4/2005	Tree trap (wire cage installed)
	9/4/2005	9/7/2005, 9/11/2005, 9/14/2005	Tree trap
	9/14/2005	9/17/2005, 9/21/05, 9/25/2005	Tree trap
	9/25/2005	9/29/2005, 10/2/2005, 10/16/2005	Tree trap
	10/16/2005	10/23/05, 10/30/2005, 11/6/2005, 11/13/2005	Tree trap
	11/13/2005	11/20/2005, 12/11/2005	Tree trap
	1/8/2006	1/15/2005	Tree trap
	3/12/2006	3/19/2006	Tree trap
	4/9/2006	4/16/2006	Tree trap
	6/13/2006	6/15/2006, 6/18/2006	Tree trap (ground trap trial)
	8/1/2006	8/3/2006, 8/6/2006	Ground trap
	10/25/2006	10/29/2006, 11/1/2006	Ground trap
	1/24/2007	1/28/2007	Ground trap
	3/19/2007	3/21/2007 (picked up WS due to prescribed burn), 3/26/2007	Ground trap
	5/6/2007	5/12/2007	Ground trap
	7/22/2007	7/25/2007, 7/29/2007	Both traps
	9/23/2007	9/26/2007, 9/30/2007, 10/3/2007, 10/7/2007	Both traps

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