ANIMAL AND ARTIFICIAL BAIT PREFERENCE OF SILPHIDAE AND A CITIZEN SCIENCE PROJECT ON THE AMERICAN BURYING BEETLE, *NICROPHORUS AMERICANUS*

By

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ANIMAL AND ARTIFICIAL BAIT PREFERENCE OF SILPHIDAE AND A CITIZEN SCIENCE PROJECT ON THE AMERICAN BURYING BEETLE, *NICROPHORUS AMERICANUS*

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Abstract:

Carrion beetles (Coleoptera: Silphidae) utilize vertebrate carcasses for feeding and reproduction. These beetles find carcasses using chemoreceptors located on their antennae which detect volatiles released during decomposition. Surveys for carrion beetles, including the federally endangered American burying beetle, *Nicrophorus americanus* (Olivier), utilize various bait types ranging from whole laboratory rats to parts of chicken that are rotted at warm temperatures for several days. Environmental variability during bait preparation may cause inconsistency which could impact survey outcomes. In this study, capture rates for Silphidae were compared using whole rotten animal baits, rotten chicken and beef parts, commercially available stink baits, and a commercially available chemical. Sampling occurred near Stillwater, OK and in three Nebraska counties. Among bait types, tuna caught the most Silphidae with chicken drumsticks and mice catching less. Among artificial baits, Danny King's Catfish Punchbait® and Strike King® Catfish Dynamite Bait caught more Silphidae than other artificial baits tested. These results emphasize the importance of standardized sampling methods for population estimate studies and conservation. Results suggest that rotted tuna fish and chicken drumsticks can be used as readily available attractive bait for surveys of carrion beetles including *N. americanus*. Entomological citizen science projects are growing with the public interest and ease of access provided by the Internet. Involving children and citizens to participate in the collection of scientific data allows more data to be collected, and provides an educational tool. Insect conservation citizen science projects that demonstrated success include the Monarch butterfly, *Danaus plexippus* (Linneaus) and threatened ladybird beetles (Coccinellidae). With these as a model, a project focusing on the endangered American burying beetle, the Banished Beetle project, was developed. Educational curriculum activities and other materials were created and made available. Participants were encouraged to trap for burying beetles using an artificial stink bait. Four classrooms, two middle schools and two elementary schools in Tulsa, OK, participated in the project, as well as a few citizens through Master Gardeners workshops and Scistarter.org. No burying beetles were captured, but future potential exists if implemented during peak summer burying beetle activity.

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INTRODUCTION

Surveys are an important part of the recovery plan for *Nicrophorus americanus* (Olivier)*,* therefore bait should be standardized. Rotting of whole carcasses or parts of a carcass can fluctuate depending on weather, storage conditions and sources of material. Thus, an artificial bait could improve sampling consistency. In this study, different bait types were tested for attractiveness to Silphidae beetles. *Nicrophorus* beetles were trapped using different baits. This project also used artificial bait to develop a classroom exercise to encourage school children to trap for burying beetles. This curriculum could be incorporated into a global citizen science project educating the public about the American burying beetle and other carrion beetles. A successful citizen science project could help researchers in discovering additional areas where *N. americanus* is present, and significantly update its distribution.

OBJECTIVES

Effect of Bait

1) Determine if commercially available baits can attract burying beetles when compared to commonly used rotten carcasses/carcass parts.
2) Compare capture success using different parts of rotten chicken: whole chicks, drumsticks, chicken thigh, chicken liver, chicken gizzards and hearts were tested.

Citizen Science

1) Develop materials to use at outreach and educational events to teach about the American burying beetle.
2) Develop an experiment for use in classrooms utilizing artificial bait to trap for carrion beetle.

CHAPTER II

LITERATURE REVIEW

Coleoptera: Silphidae

Burying beetles, also called sexton beetles, belong to the order Coleoptera, and the relatively small family Silphidae. Beetles of the family Silphidae are scavengers of decaying organic material and utilize vertebrate carcasses for feeding and reproductive purposes. The Silphidae are divided into two subfamilies: Silphinae and Nicrophorinae. In North America there are 30 described species of Silphidae in eight genera (Anderson and Peck 1985). In total, there are 13 defined genera and 208 species found worldwide. The use of carrion resources varies greatly between the two subfamilies, Silphinae and Nicrophorinae (Ratcliffe 1996).

The life-cycle of Silphinae is more typical of carrion feeding insects. Two adult beetles are attracted to carrion in the environment, mate, and the female will oviposit in the soil nearby. Larvae eclose within 2-7 days and feed on the carcass, go through three larval instars and pupate in the soil for 14-21 days. Particular interest has been paid to the genus *Nicrophorus*, the burying beetles of the Nicrophoriane due to their complex semi-social behavior and bi-parental care. Adult *Nicrophorus* beetles will also meet at a carcass, but before mating the pair will bury a mouse, vole or other appropriately-sized carrion into the ground. They do not compete with Silphinae, which use larger carrion resources. Silphidae provide many ecological services, mainly recycling and removing decaying carrion and reducing fly populations. In turn, removing carcasses from habitats reduces fly populations and bacterial load in the environment, which benefits humans. *Nicrophorus* beetles also transport symbiotic phoretic mites which feed on fly eggs, eliminating potential competition for resources from flies (Anderson and Peck 1985, Ratcliffe 1996).

Nicrophorus Life History

Burying beetles discover a carcass in the environment within two days, but it can happen quickly, within 35 minutes after death (Milne and Milne 1976). The beetles can detect carcasses as far as 3.22 km away using olfactory organs on their antennae and palpi (Scott 1998). Sensillae on both organs are able to detect hydrogen sulfide and cyclic compounds that are released when an animal dies (Dethier 1947). Beetles will travel great distances to discover a carcass; the largest North American species, *Nicrophorus americanus* (Olivier) have been documented to disperse up to 7.24 km/night (4.5 miles) in Nebraska, with one documented movement of 29.19 km (Jurzenski et al. 2011). Once the carcass is located, beetles face strong inter- and intraspecific competition, and the largest and strongest usually win. Male and female burying beetles will initially pair when a male locates a carcass in the environment and emits a pheromone to attract a female. Together, the pair will examine the carcass, crawl underneath it and perform “push ups” to determine its weight. If it is within the correct size range they will continue in the burial process (Milne and Milne 1976). Burying the animal underground helps beetles eliminate competition for their resource, and needs to be done quickly to avoid vertebrate scavengers, and fly oviposition on the carcass (Anderson and Peck 1985).

Beetles will plow through the soil beneath the carrion, causing the carcass to sink into the ground. The carcass is covered by a few centimeters of soil in about 5 to 8 hours. Beetles prepare the carcass by removing the fur or feathers from the carcass and begin to work it into a ball. The furless carcass is formed into a brood ball, and the beetles deposit oral and anal secretions to control and delay decomposition (Trumbo 1990, Hoback et al. 2003, Urbanski et al. 2008, Jacques et al. 2009). The female builds a chamber nearby, where she will lay her eggs. After performing a series of steps to prepare the carcass and the brood ball is formed, beetles will mate. The female will then oviposit, larvae hatch and go though three instars, then pupate in the soil for 13-15 days. Unlike members of Silphinae, *Nicrophorus* parents stay, feed, and protect their young (Anderson and Peck 1985).

Parental Care

Parental care is defined as any form of behavior that appears likely to increase the fitness of the parents' offspring (Clutton-Brock 1991). Parental care has been studied across the animal kingdom, with most studies have been focused on birds, cichlid fishes and mammals (Suzuki 2012). In insects, parental care has evolved in 10 different orders. While maternal care is common in insects, male contributions to care are rare (Tallamy 1994). Insect biparental care has evolved several times independently, and has been associated with nests, and thus prevention of extra-pair copulation (Trumbo 1996).

Burying beetles in the genus *Nicrophorus* are unique among non-social insects, in displaying facultative bi-parental care. While both parents invest in care of larvae, females tend to care for offspring for a longer period of time (Trumbo 1990). The residency time, how long the parents stay with the offspring, depends on the cost expended with each reproductive bout (Smith et al. 2014). Male *Nicrophorus* protect the larvae from intruders that attempt to kill them or lay their own eggs on the carcass (Trumbo 1990). Together, the parents will regurgitate a carrion meal to their begging young until the larvae are able to feed on the carcass independently (Crook et al. 2008). The male usually leaves the brood chamber after 3-7 days, and the female leaves before the carrion resource is depleted, after about 14 days (Scott and Traniello 1990). Larvae will disperse into the soil, pupate, and emerge about a month after the carcass was initially buried (Anderson and Peck 1985).

American Burying Beetle

The American burying beetle, *Nicrophorus americanus* (Olivier), is a federally endangered species. It is the largest species of the Nicrophorinae beetles in North America and can range from 2.54 cm to 4.57 cm long. The most distinctive feature of this species is the large orange markings on the raised portion of the pronotum. ABB also have orange-tipped clubbed antennae, and facial markings that are sexually dimorphic. Males have a rectangular orange marking on the clypeus, while females have a triangular orange marking on the clypeus (Bedick et al. 1999).

N. americanus was designated as federally endangered by the U.S. Fish and Wildlife Service in 1989, mainly due to a substantial reduction in its distribution (USFWS 2008). Reasons for their decline include habitat loss and fragmentation, decline of the proper- sized carrion, increase in competition for prey, light pollution, and pesticide use. The exact cause of loss remains unknown in part because populations of *N. americanus* have declined drastically, while similar *Nicrophorus* species remain relatively abundant (USFWS 2008).

The most likely explanation for the decline of *N. americanus* is habitat loss as grasslands and forests were converted to farmland, changing the composition of small vertebrates suitable for reproduction. At the same time, an increased number of edge scavengers, mainly raccoons and foxes, resulted in more competition and less available carrion. In addition, since the mid-19th century, two species likely used by *N. americanus*, the passenger pigeon, *Ectopistes migratorius* (Linnaeus) and the greater prairie chicken *Tympanuchus cupido* (Linnaeus), were eliminated from eastern and mid western North America. These birds, which occurred throughout the original range of *N. americanus*, may have once provided ample carrion from natural mortality of chicks (Amaral et al. 1997).

Habitat and Distribution

Between 1900 and 1989, populations of *N. americanus* have disappeared from about 90% of their range, and *N. americanus* now only occur in six U.S. states: Oklahoma, Nebraska, South Dakota, Arkansas, Kansas, and Rhode Island (Figure 1). Five of these states are at the western edge and Rhode Island is at the eastern edge of the beetles' former range (Bedick et al. 1999). Historically, the geographic range of *N. americanus* included over 150 counties in 35 states; however documentation of records across the former range is not uniform. The last specimens collected across the Atlantic seaboard were collected in the 1940s. Since their endangered listing in 1989, survey efforts have increased and *N. americanus* have been discovered in more locations in Nebraska, South Dakota, Arkansas, and Oklahoma (USFWS 2008).

N. americanus is considered a habitat generalist in most literature, although some authors argue that it prefers forests or grasslands (Anderson 1982, Holloway and Schnell 1997). Because *N. americanus* is the largest of the *Nicrophorus* beetles in North America, they need larger carrion for reproductive purposes, ranging from 200 to 300 grams (Kozol et al.1988). Other endangered species like *N. americanus*, often have larger bodies and narrow niches (Diamond 1984). For example, *N. germanicus* in Europe and *N. concolor* in Japan and China are the largest burying beetles in those respective areas, and also suggested to be habitat generalists. Because these species depend on larger carcasses for burial, they require ecosystems with more penetrable soils, which includes mature forests with open understories and humic soils (Anderson 1982).

In field studies of *N. americanus*, when feeding at Camp Gruber Training Site in Oklahoma and at Fort Chaffee Military Reservation in Arkansas, *N. americanus* were found to be habitat generalists. Both of these locations have a diversity of habitat types including grasslands, fallow fields, bottom land forests and oak-hickory forests (Holloway & Schnell 1997). On Block Island, Rhode Island, *N. americanus* have been found across a broad variety of habitats, from shrub thickets to grazed fields. However, this may be indicative of a low diversity of predators in an island environment, and not an indication of habitat preference by *N. americanus* (Crowell 1983). Continued research on habitat distribution of *N. americanus* is essential in the recovery process, allowing for documentation of undiscovered populations, managing current habitats and selecting sites for reintroduction (Creighton et al. 1993). In addition, designation of critical habitat for the persistence and recovery of the species may be possible.

Conservation Efforts

Because *N. americanus* is federally endangered, any transport, possession, sale or unauthorized taking is prohibited. Research methods and management actions are subject to the Endangered Species Act of 1973 - ESA (16 U.S.C. 1531-1544, 87 Stat. 844) (Panella 2013). In 1991 the U.S Fish and Wildlife Service developed a recovery plan for *N. americanus*, which recommended: 1) protect and manage extant populations, 2) maintain captive populations, 3) continue Penikese Island reintroduction effort, 4) conduct studies, 5) conduct searches for additional populations, 6) characterize habitat and conduct vertebrate inventories, 7) conduct additional reintroductions, 8) continue to conduct research into the specie's decline and 9) conduct informational and educational programs (Panella 2013).

When the recovery plan was implemented, *N. americanus* were only known from Block Island, Rhode Island and Oklahoma (Jurzenski et al. 2014). For recovery, the service desired to establish three self-sustaining populations within four geographic areas, the Northeast, Southeast, Midwest, and Great Lakes regions. After this recovery plan was formed, *N. americanus* were found in more locations and with this new data, a species assessment was conducted and is currently being evaluated (USFWS 2008).

Populations of *N. americanus* on Rhode Island are monitored annually utilizing capture, mark and recapture methods (Rathiel et al. 2006). Surveys of *N. americanus* in Oklahoma have expanded the known range to 43 eastern Oklahoma counties (USFWS 2015). *N. americanus* was also found in four nearby counties in Arkansas, 17 counties in Nebraska and Southern South Dakota, as well as four counties in Kansas. Surveys have been done in numerous other states that yielded no *N. americanus*; including Maine, Massachusetts, Michigan, mainland Rhode Island, Long Island New York, New Jersey, North Carolina, Ohio, Louisiana, Tennessee, Florida and Pennsylvania (Amaral et al. 1997). *N. americanus* were raised at the Cincinatto Zoo from 1991-1993 for educational purposes, at the University of Oklahoma for research, and Boston University for reintroduction efforts. The first attempted reintroduction of *N. americanus* was done on Penikese Island, at the tip of an island chain in Massachusetts (Amaral et al. 1997). The Midwest geographic area has estimates of more than 1,000 *N. americanus* individuals in known populations for more than 5 years. Delisting has not been considered because there are no stable populations in the other 3 regions, even with reintroduction efforts (Jurzenski 2012).

Trapping Methods

The USFWS recommends the use of baited pitfall traps for *N. americanus* surveys. Pitfall traps consist of a trap cup of at least 0.71-L. similar to a Solo cup, a smaller bait cup, wire and a protective covering. These traps capture *N. americanus* using a bait, and keep them alive in the trap cup until traps are checked by 10:00 or 11:00 A.M (USFWS 2008). The smooth surface of the cups keeps *N. americanus* from climbing out and escaping (Creighton et al. 1993). While 24 oz., or 0.71-L cups for pitfall traps have been favored in the past, 5 gallon, or 8.9-L buckets have also been used, and are now the standard trap used by researchers. The larger size accommodates larger bait, allows for more room for trapped beetles, and improve ventilation (Bedick et al. 2004, Leasure et al. 2012).

The suspended bait cup eliminates beetle contact with bait while also blocking *N. americanus* from escaping with flight. If closed bait is used, a bait cup should be smaller than the trap cup, about the size of a salad dressing cup, and must be suspended above the trap cup using wire looped around or through the cup and secured into the ground is recommended. A cover that is hard and also secured into the ground, such as a nursery plant container with holes on the side is used to protect the trap. The cover provides shade and protects captured *N. americanus* from scavengers and drowning due to rainfall. The lip of the trap cup should be 1.27-1.9 cm above ground level to prevent water from filling the cup during heavy rains (Bedick et al. 2004, USFWS 2015). A wetted sponge can be placed in the bottom of the trap to provide moisture (Bedick et al. 2004).

U.S. Fish and Wildlife protocol for presence/absence surveys of *N. americanus* in Oklahoma recommend modifications of the previously described trap to allow for better performance. Buckets are not inserted in the ground, and are used as above ground traps instead. Buckets are attached to a tree or fencepost, and are covered for weather protection. To cover the trap, a piece of plywood at least 10.16 cm larger than the bucket is used, as well as two 2.54 cm by 2.54 cm wooden sticks to separate the bucket and the wooden cover. After the bucket is covered by the wooden lid, additional weight should be added to the top of the trap, such as soil or rocks, to prevent nearby scavengers or wind from removing the cover (USFWS 2015).

In the past, the U.S. Fish and Wildlife Service's recovery plan for *N. americanus* suggests two different sampling protocols. One method uses a transect of eight pitfall traps with no bait contact over three trap nights (closed bait). The second uses buckets that allow for bait contact over five trap nights (open bait) (Leasure et al. 2012, Butler et al. 2013). The closed bait method uses cups to keep the bait separate from the trap so the beetle does not come in direct contact with the bait. Some studies have suggested that may clog insect spiracles, leading to beetle mortality (Creighton et al. 1993). While the transect method has been used in burying beetle surveys across Arkansas and Oklahoma (Lomolino et al. 1995), most recent trapping surveys in Nebraska used an open bucket technique for five nights; however, this worked in areas with loose deep soils but would be difficult in other substrates. (Bedick et al. 2004). Differences between transect methods and bucket methods make the comparison between capture rates of *N. americanus* difficult (Butler et al. 2013). To accurately compare populations in the future, protocols need to be standardized in the future. The use of a separate bait cup, as opposed to the beetles contacting the bait in the trap is important to develop further as a safe protocol to trap (Butler et al. 2013). *N. americanus* traps must be checked before 10:00 A.M. each morning in Oklahoma, and 11:00 A.M. each morning in Nebraska, to avoid exposure to temperatures over 25° C (USFWS 2011). The pitfall trap design is shown in figure 2.

Bait Usage

The USFWS allows the use of any carrion is efficient in pitfall traps as long as it is the proper size and emits a pungent odor (USFWS 2011). Un-skinned chicken, liver, gizzard and road kill have been used. Fresh bait does not attract *N. americanus*, and needs to be placed outside in a closed container in direct sun for at least a day (USFWS 2011). Typically, bait it rotted outside for 1-3 days, depending on air temperatures (Butler et al. 2013). If daytime temperature is cooler than 30°C, baits should be left out in the sun longer than a day. When bait is rotted outside, the container used should not be filled to capacity, allowing room for gas pressure inside the container as the bait rots (USFWS 2015).

Per trap, about 15-20 grams or 0.5-0.7 ounces of bait is sufficient. Old bait should not be left near the trapping area, as it could distract *N. americanus* from entering the traps. When checking traps, bait should be replaced when it dries, is contaminated by maggots or when it has been consumed with open bait protocols. Typically, in *N. americanus* surveys, whole rotted carcasses are used, with the hair or feathers still intact. Laboratory rats are obtained from online dealers or pet stores, and weigh about 75-374 grams. When using a bait cup; however, smaller rotted pieces of a carcass can be used that do not have skin, hair or organs (USFWS 2015). Current literature shows *N. americanus* researchers continue to use whole rotted carrion, chicken, or other carrion parts (Butler et al. 2013). Bedick 2004 examined effects of bait type on captures and found no differences. To date, no has been documented using an alternative bait type.

Citizen Science Projects in Entomology

Citizen science is the collaboration between researchers and members of the public to answer scientific questions, and work toward a common goal. Many ecological questions are broad and require large data sets collected from wide areas. Researchers alone often cannot gather sufficient data to answer broad scale questions. Thus, citizen scientists can aid research, and provide the "ears, eyes, and data" on a broader scale to add to the information pool (Clarke 2013). With little training and few resources, anyone can provide meaningful contributions to citizen science, from students to the general public, to professional scientists. Citizen science is also a way for teachers to motivate students by getting them involved in research that is relevant. When students conduct their own research, it helps students gain an understanding of science and analytical reasoning skills (Trautmann et al. 2013). Citizen science involving entomological concepts integrate all of the dimensions of the Framework for K-12 Science education, including scientific practices, crosscutting concepts, and disciplinary core ideas (Clary et al. 2012).

Until the late 20th century, researchers wanting to recruit people for survey projects had to place ads in a newspaper. Today, the internet allows easy access to people, which has resulted in the recent explosion of citizen science projects (Clarke 2013). Internet capabilities have also made it possible for anyone to view and use citizen science data. Organized citizen science projects are ongoing and growing in popularity and the Cornell Lab of Ornithology has included a toolkit on their website for developing and editing citizen science projects. (Oberhauser & Prysby 2008, Jordan et al. 2011, Trautmann et al. 2013).

The Cornell user guide recommends following a pattern in developing a citizen science projects, from planning, to implementing, to sharing. When planning a project, it is recommended to describe the project and its audience, then define the goals and anticipated outcome of the project. The guide includes ways to evaluate a project, to examine the study design and data collection techniques so as to achieve the original goal set. The guide recommends spending time recruiting participators and to recruit more than are needed because many will not agree to participate, or not follow through. How data will be reported, either online, by phone or mail should be determined before data collecting begins. There are many ways to share and analyze data depending on the objectives desired (Bonney et al. 2009, Phillips et al. 2014).

While projects can vary in approach, subject and matter, most citizen science projects seek to answer scientific questions and strives to reach a set of goals, either in research, education, conservation or a combination of objectives (Bonney et al, 2009, Phillips et al. 2014). Many citizen science projects are created by professional scientists or organizations hoping to collect data on a particular species or taxonomic group. With the help of citizens collecting data, the geographic range of research collected is much larger than what individual scientists could collect themselves (Trautmann et al. 2013). These data contribute to a larger data set that is used to examine environmental differences or help predict changes that may occur in the future (Clary et al. 2012). Besides collecting data, citizen scientists can also monitor environmental conditions such as water quality, or help to analyze large databases. Other projects collect long term data that goes beyond the lifetime of the original scientist, thus allowing for continuation of data collection and analyses to track long term changes (Trautmann et al. 2013).

Monarch Watch, a research program based at the University of Kansas is a successful outreach program, continuing original monarch tagging efforts dated as far back as 1952 (Burns 2012). Monarch Watch's mission statement provides the public with information on biology and migration of Monarch butterflies, as well as using Monarchs as a subject to further primary and secondary education. Monarch Watch also has an interactive website full of information, classroom tools and projects, as well as events such as tagging and planting Milkweed plants. Monarch butterfly populations are declining due to loss of habitat. The key to creating habitat for Monarchs and conserving the species is restoration of milkweeds as a national priority (Monarch Watch 2015). Planting milkweeds all over the U.S. isn't feasible for scientists without help, and that's where citizen scientists can be impactful. Involving the public in a project like this has the potential to engage participants to plant milkweed plants, making a difference in future Monarch populations. Monarch Watch, along with educational tools on their website, gained funding from Monsanto in 2015 which enabled the project organizers to offer 100,000 free milkweed plugs for large scale restoration projects (Monarch Watch 2015).

Monarch Watch is not the only citizen science project devoted to Monarch butterflies. The Monarch Larva Monitoring Project focuses on Monarch distribution and abundance during the breeding cycle (Oberhauser & Prysby 2008). Monitoring sites are chosen and described, including milkweed density and then monitored for monarch larvae. Other activities associated with monarch larvae are optional, such as estimating parasitism rates and observing milkweed aphid distribution. Training materials, field guides, data sheets and other resources are all available on the website. To date, 1301 sites have been monitored in 43 U.S. states (Monarch Larva Monitoring Project 2015). There are multiple other successful monarch projects with more specific locations. The Southwest Monarch Study examines breeding patterns and migration of Monarch butterflies in Arizona and the Southwest U.S. Their mission is to encourage Monarch butterfly conservation by tagging Monarchs, monitoring milkweed populations, and providing education programs. Over 300 citizen scientists have tagged thousands of Monarchs since 2004. This data has significantly helped determine the status of monarchs in Arizona. Data forms, identification tools and tagging instructions are available on the website (Southwest Monarch Study 2015).

The Western Monarch Count has participants collect data on monarch populations during their overwintering stage, with the Western Monarch Thanksgiving Count. Data were collected for over 15 years with the help of citizens. Monarch counters sign up to become involved and are given instructions on how to monitor an area. Data and maps are included on the website (Xerces Society 2016).

Other Lepidoptera-centered projects include Butterflies and Moths of North America (BAMONA) and Project Butterfly WINGS. Butterflies and Moths of North America, hosted by the Butterfly and Moth Information Network, aims to collect and provide access to quality data of butterflies and moths for North America, from Panama to Canada. Citizen scientists participate by taking photographs of these insects and submitting their observations. These contributions have added to an ongoing database of butterfly and moth image galleries. BAMONA adds to the data set with species profiles and maps displaying point data (Lotts and Naberhaus 2015). Project Butterfly WINGS, hosted by the Florida Museum of Natural History, asks participating youth to help scientists determine the abundance of butterfly species as part of a long term monitoring project. Instructions for monitoring butterflies can be found in the 4H WINGS project book, and ID sheets and more information can be found on the Project Butterfly WINGS website (Florida Museum of Natural History 2015).

One very successful citizen science project in entomology is the Lost Ladybug Project. This project started in 2000 when Cornell researchers teamed up with 4H Master Gardeners to conduct surveys on ladybird beetles across New York. Graduate students started to help by developing ladybird beetle survey projects for children and working with a few elementary schools to test these techniques in the field. In 2006 an 11 year old discovered a nine-spotted ladybug, *Coccinella novemnotata* (Herbst), that had not been collected in the U.S. in the previous 14 years. With this discovery, the Lost Ladybug Project was funded by NSF and launched into a larger project. The project now has a website with instructions for citizen scientists to collect lady beetles, take pictures and send them in to add to a growing map of data. The Lost Ladybug website also includes many resources for lady beetle identification, lesson plans and literature.

As of April 26, 2015, the project had generated 31,097 lady beetle records from contributors (Lost Ladybug Project 2015).

The Lost Ladybug Project's proposal to NSF had three objectives, (1) a website that includes an integrated education program on biodiversity and classification, as well as a way to participate and interact with a ladybird beetle database; (2) create a group of trained volunteers to make use of the educational resources and facilitate surveys, and (3) to create one of the largest and most accessible biological databases. The group designed their project modeled on other successful citizen science projects including FrogWatch, Christmas Bird Count, and FeederWatch. On a broader scale, the Lost Ladybug Project strives to foster an appreciation for the natural world in children, primarily ages five to eleven. Using ladybugs as a charismatic and easy to catch subjects, the project can teach children about the scientific process, biodiversity and conservation (Lost Ladybug Project 2015).

An additional ladybird beetle project, The Buckeye Lady Beetle Blitz, is a project initiated in 2009 at Ohio State University, which quantifies ladybird beetle abundance and diversity. Participants watch a training video online and are mailed a toolkit with sampling supplies and identification cards. Once specimens are mailed back, DNA tests are performed on ladybird beetles collected (The Ohio State University Gardiner Lab 2016). Conventional scientific surveys sample ladybird beetles on a limited spatial and temporal scale. Thus, data obtained through citizen scientists provide vital information, and an opportunity to gather observations of rare species (Losey et al. 2012).

Bees (Family: Apidae) are another insect group which the public has focused on. Bumble Bee Watch is a collaborative effort between members of the Xerces society and citizen scientists to conserve North America's bumble bees. Participants are asked to take pictures of bumble bees, upload them to the website, utilize simplified field guides and attempt to identify the bee. Experts then verify species identification. The website includes an interactive map, and uploaded photos from participants (Bumble Bee Watch 2016).

The Great Sunflower Project also focuses on pollinators and has over 100,000 members. The public can be involved by counting bees while monitoring a garden or other habitat. Cumulative results over the past eight years are displayed on the website (The Great Sunflower Project 2015). A different take on a bee project is ZomBee Watch, based at San Francisco State University Department of Biology. ZomBee Watch is a citizen science project tracking the honey bee parasite, *Apocephalus borealis* (Brues), also known as the Zombie fly. The name of this project comes from the "zombie-like" behavior of honey bees when they are parasitized by the Zombie fly. Objectives of this project are to discover locations of Zombie flies parasitizing honey bees, to observe the strange behavior of bees flying away from the hive at night, and to encourage citizen scientists to make a contribution to the knowledge of honey bee health (ZomBee Watch 2012).

In addition to conservation, the general public is concerned about migration and biodiversity. The Migratory Dragonfly Partnership, formed in 2011, asks its participants to monitor the spring and fall migrations of dragonflies in North America. This information helps researchers determine distance traveled and directs them to where the dragonflies emerged as adults. The project also serves to promote conservation of wetlands where these dragonflies began life. The partnership asks volunteers to monitor ponds for dragonflies, using data sheets and identification tools on their website. The Partnership also developed a mobile dragonfly identification app. The dragonfly app is synced with the BirdsEye® app to encourage bird watchers to report dragonflies as well (Migratory Dragonfly Partnership 2016).

National Moth Week is a week long global event to spread awareness about biodiversity. It began in 2012 by the Friends of the East Brunswick (NJ) Environmental Commission. During the specified week in July, volunteers can join or host their own moth party and search for moths outside at night using an outdoor light, a sheet and a sugary bait. Participants are encouraged to upload pictures of the moths observed. In 2015, National Moth Week was successfully celebrated in all 50 states for the 3rd consecutive year. Their website offers kids coloring activities, moth event listings and more resources (National Moth Week 2015).

The Pieris project takes a different approach and instead of looking at a species in need of conservation, it attempts to gain information on *Pieris rapae* (Linnaeus), a very abundant, introduced butterfly species. By collecting data on this butterfly, changes in the environment can be studied and reveal how this species might interact with other species. This project started in 2014 and over 1,400 butterflies have been collected from 30 U.S. states and 17 different countries. The website offers collection instructions and up to date maps of current data. Educational materials will be added soon (The Pieris Project 2016).

Cricket Crawl, in 2009, asked participants to observe cricket and katydid calls in New York city. Information on different sounds made by different crickets was provided, along with data sheets. A results map is included on the website, and new locations of the Common True Katydid, *Pterophylla camellifolia* (Fabricus), were discovered, a species which was once abundant and thought to be absent currently on Staten Island (Discover Life 2012). Another Orthoptera-based project is Camel Cricket Census, based at North Carolina State University.

This project gathered photos and specimens of camel crickets inside homes to better understand the distribution of native and nonnative camel crickets. Citizen science collaboration resulted in the publication, “Too big to be noticed: cryptic invasion of Asian camel crickets in North American houses” (Epps et al. 2014, Robb Dunn Lab 2014).

Firefly Watch was started in 2008 and is hosted by the Museum of Science in Boston, Mass. Participants are asked to search for fireflies in their backyard during the summer, and to include information on the habitat where surveys take place. The Firefly Watch website includes data sheets, current data maps, and educational videos. This project has contributed to research regarding firefly diversity and biology that was previously unknown. Flashing patterns and geographic distribution of the firefly genus *Photinus* can be updated with this new information (Lloyd 1966, Museum of Science 2016).

The School of Ants project, based in laboratories at both North Carolina State University and University of Florida, involves citizens in documenting ant species around schoolyards and backyards. Ants have been collected all over the U.S. and some interesting findings have been made, including the discovery of a species that had not been found for 70 years. The School of Ants project has class activities and modules in addition to the instructions on participating in ant collection (School of Ants 2011).

University of Minnesota’s Forest Extension Service runs Wasp Watchers, a project detecting smokey-winged beetle bandit wasps, *Cerceris fumipennis* (Say). These wasps prey on Emerald Ash Borers (EAB), *Agrilus planipennis* (Fairmaire) can be used as an early detection tool of the invasive species. Wasp Watchers asks volunteers to find *C. fumipennis* habitat, likely at baseball fields, to report sightings and to turn in EAB specimens from *C. fumipennis* nests.

Identification tools and information on the importantance of biosurveillance of these wasps to monitor EAB are available on the Wasp Watcher's website (University of Minnesota 2015).

Bugs in Our Backyard is an educational outreach program encouraging K-12 students and other volunteers to explore the diversity of insects and plants in their backyard. Modules are offered to target and learn about specific bugs, such as the soapberry bug, milkweed bug, stinkbug, or insects in general. All citizen contributed data are added to a collaborative research project, and results are available on the website (Bugs in Our Backyard 2016).

While these entomology citizen science examples have been mainly a way for researchers to collect data, citizen science research can include a variety of different approaches. Most are considered a contributory approach, in which participants collect and submit data under guidance of an organization. Other approaches are collaborative and co-created, where participants are more involved in the project and help analyze data or even help develop the project (Bonney et al, 2009, Phillips et al. 2014) A comprehensive list of entomology citizen science projects is shown in Table 1.

LITERATURE CITED

Amaral, M., A. Kozol, T. French. 1997. Conservation status and reintroduction of the endangered American burying beetle. Northeastern Naturalist 04:121–132.

Anderson, R.S. 1982. Resource partitioning in the carrion beetle (Coleoptera: Silphidae) fauna of southern Ontario: ecological and evolutionary considerations. Can. J. Zoo. 60: 1314–1325.

Anderson, R. S. and S.B. Peck. 1985. The insects and arachnids of Canada part 13: The carrion beetles of Canada and Alaska (Coleoptera: Silphidae and Agyrtidae). Agriculture, Canada, Ottawa.

Bedick, J. C., B. C. Ratcliffe, W.W. Hoback, and L.G. Higley.1999. Distribution, ecology and population dynamics of the American burying beetle *Nicrophorus americanus* Olivier (Coleoptera: Silphidae) in south-central Nebraska, USA. J. Insect Conserv. 3: 171–181.

Bedick, J. C., B.C. Ratcliffe, and L.H. Higley. 2004. A new sampling protocol for the endangered American burying beetle, *Nicrophorus americanus* Olivier (Coleoptera: Silphidae). Coleopt. Bull. 58: 57–70.

Bugs in Our Backyard. 2016. Retrieved from https://www.bugsinourbackyard.org.

Butler, S. R., R. Harms, K. Farnsworth-Hoback, K. Koupal, J. Jurzenski, and W.W. Hoback. 2013. Standardized capture rates of the endangered American burying beetle, *Nicrophorus americanus* Olivier (Coleoptera: Silphidae) using different trap protocols. J. Insect Conserv. 17: 607–613.

Bumble Bee Watch. 2015. About. http://www.bumblebeewatch.org.

Burns, L.G. 2012. Citizen scientists: be a part of scientific discovery from your own backyard. Published by Henry Holt and Co., New York, NY.

Clarke, C. 2013. Be the change: saving the world with citizen science.

Clary, R., J. Wandersee, J. Guyton, and M. Williams. 2012. Citizen science in your own backyard. The Science Teacher, 79: 51–57.

Clutton-Brock, T. H. 1991. The Evolution of Parental Care. Princeton University Press. 352 pp.

Creighton J.C., C.C. Vaughn and B.R. Chapman. 1993. Habitat preference of the endangered American burying beetle (*Nicrophorus americanus*) in Oklahoma. The Southwestern Naturalist. 38: 275–306.

Crook, T.C., T. Flatt and P.T. Smiseth. 2008. Hormonal modulation of larval begging and growth in the burying beetle *Nicrophorus vespilloides*. Anim. Behav. 75: 1–77.

Crowell, K L. 1983. Islands-insight or artifact?: Population dynamics and habitat utilization in insular rodents. Oikos 41:442–454.

Diamond, J. M. 1984. Historic extinctions: a rosetta stone for under-standing prehistoric extinctions, pp 824-862 in P. S. Martin and R. G. Klein, ed. Quaternary extinctions: a prehistoric revolution. University of Arizona Press, Tucson.

Discover Life. 2012. NYC Cricket Crawl. Retrieved from http://www.discoverlife.org/cricket/.

Dethier, V.G. 1947. The role of the antennae in the orientation of carrion beetles to odors. Journal of the New York Entomological Society. 55: 285–293.

Epps M.J., H. L. Menninger, N. LaSala, and R.R. Dunn. 2014. Too big to be noticed: cryptic invasion of Asian camel crickets in North American houses. PeerJ eCollection 2:525.

Florida Musuem of Natural History. 2015. Project Butterfly WINGS. Retrieved from https://www.flmnh.ufl.edu/wings/aboutWINGS.asp

Hoback W.W., A.A. Bishop, J. Kroemer, J. Scalziti and J.J. Shaffer. 2003. Differences among antimicrobial properties of carrion beetle secretions reflect phylogeny and ecology. J. Chem. Ecol. 30: 719–729.

Holloway, A.K., and G. D. Schnell.1997. Relationship between numbers of the endangered American burying beetle *Nicrophorus americanus* Olivier (Coleoptera: Silphidae) and available food resources. Biol. Conserv. 81:145–152.

Jacques B.J., A. Akahane, M. Abe, W. Middleton, W.W. Hoback and J.J. Shaffer. 2009. Temperature and food availability differentially affect the production of antimicrobial compounds in oral secretions produced by two species of burying beetle. J. Chem. Ecol. 35: 871–877.

Jordan, R., S. Gray, D. Howe, W. Brooks, and J. Ehrenfeld. 2011. Knowledge Gain and Behavioral Change in Citizen-Science Programs, Conserv. Bio. 25:1148-1154.

Jurzenski, J., D. G. Snethen, M.L. Brust, and W.W. Hoback. 2011. New records of carrion beetles in Nebraska reveal increased presence of the American burying beetle, *Nicrophorus americanu*s Olivier (Coleoptera: Silphidae). Great Plains Research, 21: 131-43.

Jurzenski, J.D., C.F. Jorgensen, A. Bishop, R. Grosse, J. Riens, and W.W. Hoback. 2014. Identifying priority conservation areas for the American burying beetle, *Nicrophorus americanus* (Coleoptera: Silphidae), a habitat generalist. Systematics and Biodiversity. 12: 149–162.

Jurzenski, J. 2012 Factors affecting the distribution and survival of endangered American burying beetles, *Nicrophorus americanus* Olivier. PhD Dissertation, University of Nebraska-Lincoln.

Kozol, A. J., M. P. Scott, and J. F. A. Traniello. 1988. The American burying beetle, *Nicrophorus americanus*: studies on the natural history of a declining species. Psyche 95:167–176.

Leasure, D. R., D. M. Rupe, E. A. Phillips, D. R. Opine, and G. R. Huxel. 2012. Efficient new above-ground bucket traps produce comparable data to that of standard transects for the endangered American burying beetle, *Nicrophorus americanus* Olivier (Coleoptera: Silphidae). Coleopt. Bull. 66:209–218.

Lloyd, J.E. 1966. Studies on the flash communication system in *Photinus* fireflies. Museum of Zoology, University of Michigan 130: 1-95.

Lomolino, M. V., J. C. Creighton, G. D. Schnell, and D. L. Certain. 1995. Ecology and conservation of the endangered American burying beetle (*Nicrophorus americanus*). Conserv. Bio. 9: 605–614.

Losey, J. E., L. Allee, and R. Smyth. 2012. The Lost Ladybug Project: Citizen spotting surpasses scientist's surveys. Amer. Entomol. 58: 22–24.

Lotts, K., and T. Naberhaus. 2015. Butterflies and Moths of North America. http://www.butterfliesandmoths.org.

Migratory Dragonfly Partnership. 2015. About MDP. http://www.migratorydragonflypartnership.org/index/welcome.

Milne L.J. and M. Mile. 1976. The social behavior of burying beetles. Scientific American. 235: 84-89.

Monarch Larva Monitoring Project (MLMP). 2015. http://www.mlmp.org.

Monarch Watch. 2015. About Us, www.monarchwatch.org.

Museum of Science. 2016. Firefly Watch. Retrieved from https://legacy.mos.org/fireflywatch.

National Moth Week. 2015. National Moth Week Global Citizen Science, http://nationalmothweek.org.

Oberhauser, K.S., and M.D. Prysby. 2008. Citizen Science: Creating a Research Army for Conservation, Amer. Entomol. 54 (2):103-105.

Panella, M.J. 2013. American Burying Beetle, Species Conservation Assessment for The Nebraska Natural Legacy Project. Nebraska Game and Parks Commission, Lincoln, NE.

Ratcliffe, B. C. 1996. The carrion beetles (Coleoptera: Silphidae) of Nebraska. Bulletin of the University of Nebraska State Museum 13:1–100.

Rathiel, C.J., H.S. Ginsberg, M.L. Prospero. 2006. Population trends and flight behavior of the American burying beetle, *Nicrophorus americanus* (Coleoptera: Silphidae), on Block Island, RI. J. Insect Conserv. 10: 317–322

Scott, M.P. & J.F.A. Traniello. 1990. Behavioural and ecologi- cal correlates of male and female parental care and reproductive success in the burying beetle, *Nicrophorus orbicollis*. Animal Behav. 39: 274–283.

Scott, M. P. 1998. The ecology and behavior of burying beetles. Annual Review of Entomology, 43: 595-618.

Smith, A. N., C.B. Mark, and J. C. Creighton. 2014. Residency time as an indicator of reproductive restraint in male burying beetles. Ed. T. M. Jones. PLoS ONE 9.10: e109165. PMC.

Tallamy D.W. 1994. Nourishment and the evolution of paternal investment in subsocial arthropods. In: Hunt JH, Nalepa CA, Editors. Nourishment and Evolution in Insect Societies. pp. 21–56. Westview Press.

The Great Sunflower Project. 2015. Retrieved from http://www.greatsunflower.org.

The Ohio State University Gardiner Lab. 2016. Buckeye Lady Beetle Blitz. Retrieved from http://ale.cfaes.ohio-state.edu/outreach/buckeye-lady-beetle-blitz-blbb.

The Pieris Project. 2016. Retrieved from http://www.pierisproject.org.

Rob Dunn Lab. 2014. Camel Cricket Census. Retrieved from http://robdunnlab.com/projects/camel-cricket-census/.

School of Ants. 2011. Retrieved from http://www.schoolofants.org.

Southwest Monarch Study. 2015. Retrieved from http://www.swmonarchs.org.

The Lost Ladybug Project. 2016. Retrieved from http://lostladybug.org.

Trautmann, N, J. Fee, and T.M. Tomasek. 2013, Citizen Science: 15 Lessons That Bring Biology to Life. 6-12, National Science Teachers Association, Arlington, VA, USA.

Trumbo, S.T. 1996. Parental care in invertebrates. Advances in the Study of Behavior 25: 3–51.

Trumbo, S.T. 1990. Interference competition among burying beetle (Silphidae, *Nicrophorus)* Ecol. Entomol. 15:347–355.

The Lost Ladybug Project. 2015. About Us. http://www.lostladybug.org/about.php.

Phillips, T. B., M. Ferguson, M. Minarchek, N. Porticella, and R. Bonney. 2014. User's Guide for Evaluating Learning Outcomes in Citizen Science. Ithaca, NY: Cornell Lab of Ornithology.

University of Minnesota. 2015. Wasp Watchers Program. Retrieved from http://www.myminnesotawoods.umn.edu/eab/waspwatchers/.

Urbański, A, E. Czarniewska, E. Baraniak, and G. Rosiński. 2008. Developmental changes in cellular and humoral responses of the burying beetle *Nicrophorus vespilloides* (Coleoptera, Silphidae). J. Insect Physiol., 60: 98-103.

U.S. Fish and Wildlife Service. 2008. American burying beetle (*Nicrophorus americanus*) 5 year review: Summary and Evaluation. New England Field Office. Concord, NH.

USFWS (U.S. Fish and Wildlife Service) 2011. American burying beetle *Nicrophorus americanus* survey guidance for Oklahoma. Tulsa, Oklahoma.

USFWS (U.S. Fish and Wildlife Service). 2015. American burying beetle *Nicrophorus americanus* Oklahoma presence/absence live-trapping survey guidance.

Xerces Society. 2016. Western Monarch Count Resource Center. Retrieved from http://www.westernmonarchcount.org.

ZomBee Watch. 2012. Retrieved from https://www.zombeewatch.org.

TABLES AND FIGURES

Table 1. Comprehensive list of current entomology citizen science projects by taxon and university/organization affiliation.

Taxon	**Common Name**	**Project Title**	**Location/Organization/University**
Apis mellifera	Honey bee	Zombee Watch	San Francsisco State University
Apis sp., Bombus sp.	Honey bees and bumble bees	Bee Spotter	University of Illinois
Bombus sp.	Bumble bee	Bumble Bee Watch	Xerces Society
Cerceris fumipennis	Smoky winged beetle bandit wasp	Wasp Watchers	University of Minnesota
Coccinellidae	Ladybugs	The Lost Ladybug Project	Cornell University, NY
Coccinellidae	Ladybugs	Buckeye Lady Beetle Blitz	Ohio State University
Coccinellidae	Ladybugs	Spot a Ladybug	University of New Hampshire
Curculionidae: Scolytinae, Platypodinae	Bark and ambrosia beetles	Backyard Bark Beetles	University of Florida
Danaus plexipus	Monarch butterfly	Southwest Monarch study	Arizona
Danaus plexipus	Monarch butterfly	Monarch Watch	University of Kansas
Danaus plexipus	Monarch butterfly	Western Monarch Count	Xerces Society
Danaus plexipus	Monarch butterfly	Monarch Larva Monitoring Project	University of Minnesota
Danaus plexipus	Monarch butterfly	Journey North	Annenberg Foundation
Danaus plexipus	Monarch butterfly	Big Garden Milkweed Butterfly Count/Monarch Butterflies Help	Tampa, FL
Danaus plexipus	Monarch butterfly	Project Monarch Health	University of Georgia
Desmocerus palliatus	Elderberry longhorned beetle	Where is the Elderberry Longhorned Beetle?	Drexel University, PA
Drosophila suzukii	Spotted wing drosophila	Spotted Wing Drosophila Monitoring Network Program	North Carolina State University
Elaphrus sp.	Marsh ground beetle	Where is the Elaphrus Beetle?	Drexel University, PA
Euwallacea sp	Polyphagous shot hole borer	SCARAB (Scientific Collaboration for Accessible Research About Borers)	UC Riverside, CA
Hymenoptera	Bees	The Great Sunflower Project	San Francsisco State University
Hymenoptera	Bees, wasps	Native Buzz	University of Florida
Hymenoptera	Ants	School of Ants	North Carolina State, University of Florida
Hymenoptera	Ants	Bay Area Ant Survey	California Academy of Sciences
Hymenoptera	Bees	Bee Hunt	National Biological Information Infrastructure, National Science Foundation
Jadera haematoloma	The red-shouldered soapberry bug	Bugs in Our Backyard	Colby College, ME
Lampyridae	Firefly	Firefly Watch	Musuem of Science, Boston, MA
Lepidoptera	Moths	National Moth Week	Friends of the East Brunswick (NJ) Environmental Commision
Lepidoptera	Butterflies	Project Butterfly WINGS	Florifa Museum of Natural History
Lepidoptera	Butterflies	Michigan Butterfly Network	Kalamazzo Nature Center
Lepidoptera	Butterflies	Los Angeles Butterfly Survey	Natural History Musueam Los Angeles, CA
Lepidoptera	Butterflies	Illinois Butterfly Monitoring Project	Illinois
Lepidoptera	Butterflies and moths	Butterflies and Moths of North America (BAMONA)	Butterfly and Moth information Network
Lycaeides melissa samuelis	Karner blue butterfly	Karner Blue Butterfly Survey	Wisconsin Department of Natural Resources
Nicrophorus americanus	American burying beetle	The Banished Beetle Project	Oklahoma State University
Odonata	Dragonfly	Migratory Dragonfly Partnership	Xerces Society
Odonata	Dragonfly	Illinoise Odonate Survey	Illinois
Odonata	Dragonfly	The Dragonfly Swarm Project	The Dragonfly Woman blog
Orthoptera	Cricket, katydid	Cricket Crawl	New York city
Pieris rapae	Cabbage white butterfly	The Pieris Project	University of Notre Dame, IN
Pyrrhalta viburni	Vibernum leaf beetle	Vibernum Leaf Beetle Project	Cornell University, NY
Rhaphidiphoridae	Camel cricket	Camel Cricket Census	North Carolina State University

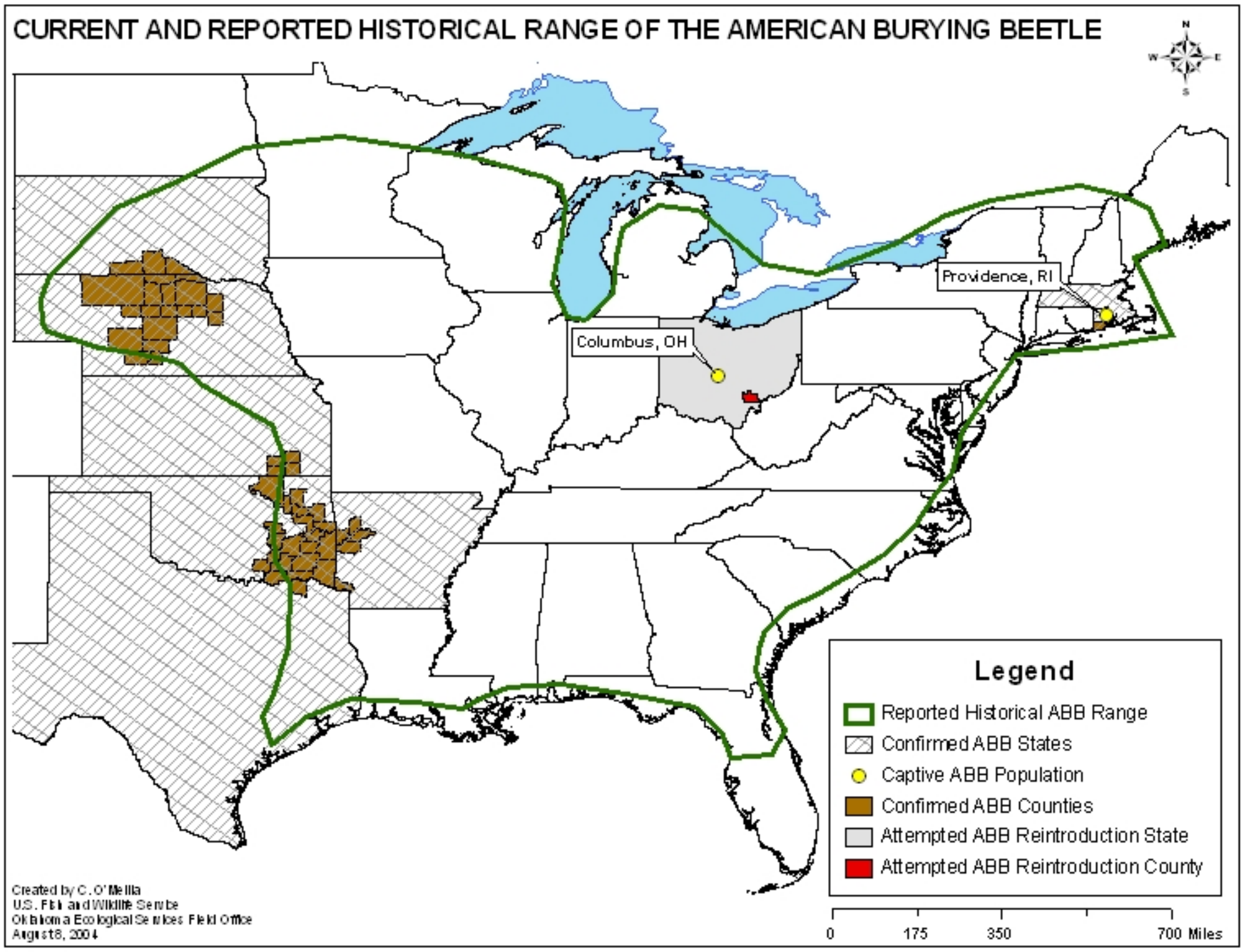

Figure 1. Distribution map of the past and present populations of *Nicrophorus americanus* (Olivier), as well as reintroductions (USFWS 2015).

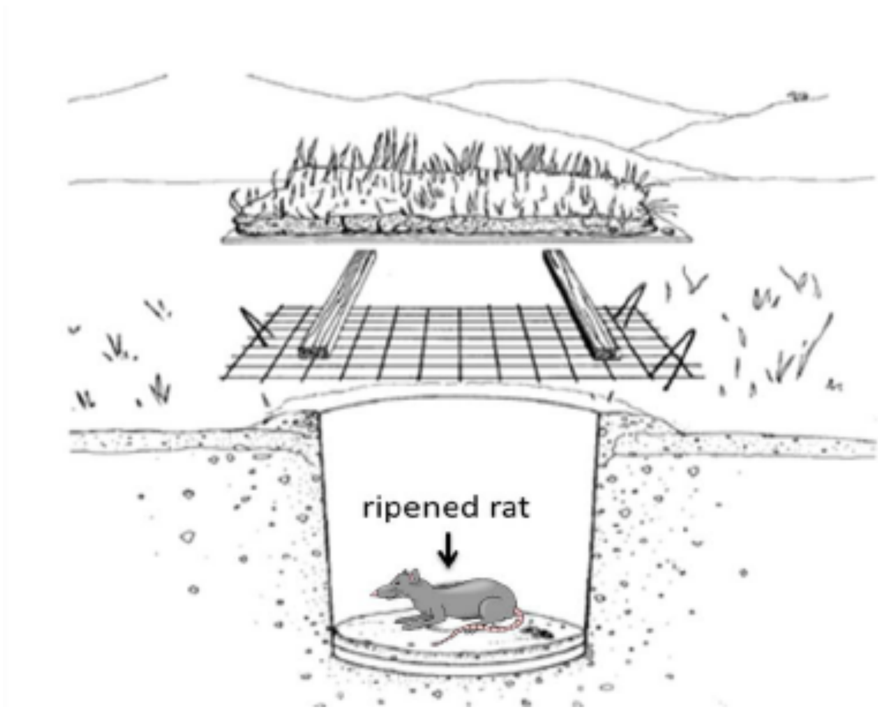

Figure 2. 18.9 L (5 gallon) bucket pitfall trap with plywood cover designed to attract carrion beetles using open bait consisting of a rotten rat (Bedick et al. 2004, USFWS 2015).

CHAPTER III

ANIMAL AND ARTIFICIAL BAIT PREFERENCE OF SILPHIDAE

ABSTRACT

Carrion beetles (Coleoptera: Silphidae) utilize vertebrate carcasses for feeding and reproduction. Beetles find these carcasses using chemoreceptors located on their antennae which detect volatiles released during decomposition. Surveys for carrion beetles, including the federally endangered American burying beetle, *Nicrophorus americanus* Olivier, utilize liver, chicken drumsticks or whole carcasses that are rotted at warm temperatures for several days. Because of environmental variability, consistency of bait is not possible and it likely has substantial effects on survey outcomes. In this study, I compared various types of animal bait to determine effects on capture rates. I also tested capture rates for commercially available artificial baits. All bait types captured carrion beetles and the use of baits for up to three days did not influence capture rates. All types of rotten baits captured more *Nicrophorus* beetles than artificial baits. Among parts of a chicken, chicken drumsticks caught significantly more beetles than other parts of the chicken. Rotten tuna fish and chicken drumsticks caught significantly

more Silphidae than rotten mice or other bait types. In this study, bait type was shown to influence capture rates of carrion beetles, including *N. americanus* and commercially available artificial baits were not found to offer suitable alternatives to rotten animal baits.

INTRODUCTION

Carrion beetles in the family Silphidae use vertebrate carcasses either for reproduction, for nutrients, or both. These beetles play a vital role in decomposition and nutrient cycling, and in turn reduce the amount of flies that would otherwise develop on the carcass. The Silphidae have two subfamilies, the Silphinae, which lay eggs on or near decaying carcasses, where larvae feed on maggots and the Nicrophorinae that have a more complex behavior of burying the carcass to use for reproductive purposes (Anderson and Peck 1985, Scott 1998).

Burying beetles in the genus *Nicrophorus,* discover a carcass with chemoreceptors in their antennae, attract a mate, and together bury the carcass if it is of a desirable size (Scott 1998). The beetles go through a series of steps during which they bury the carcass and remove the fur or feathers and then coat the carcass with secretions to delay decomposition and preserve the carrion so it can be used for raising offspring (Hoback et al. 2003). Once larvae hatch, both parents will remain on site to protect the carcass and their offspring (Anderson and Peck 1985). The seven species of *Nicrophorus* in North America practice niche partitioning where different species exhibit differences in seasonal and daily activity and use variable sizes of carcass for reproduction (Anderson 1982, Anderson and Peck 1985). The largest North American species is the American burying beetle, *Nicrophorus americanus* (Olivier).

The American burying beetle once occurred in 35 states and three Canadian provinces (Bedick et al. 1999, USFWS 2008) but has disappeared from more than 90% of its historic range, and now occurs in six U.S. states: Nebraska, South Dakota, Oklahoma, Arkansas, Kansas and Rhode Island (USFWS 2015). Because of range reduction, *N. americanus* was listed as an endangered species in 1989 and the U.S. Fish and Wildlife Service developed a recovery plan in 1991 (USFWS 2015).

Because burying beetles are attracted to carrion, USFWS recommends the use of baited pitfall traps for *N. americanus* surveys (USFWS 2015). In most studies, a pitfall trap consists of 18.9-L (5-gal) bucket, a smaller bait cup, and protective covering. A closed bait method, keeping bait inside a container, eliminates direct beetle contact with bait (Butler et al. 2013, Creighton et al. 1993). The bait container is constructed with a screen cap, to allow for scent dispersal (Jurzenski et al., 2011). Since 2008, most pitfall trap surveys have used commercially available whole laboratory rats, *Rattus norvegicus* (Berkenhaut). Rats are thawed and aged for 3-7 days before being used as bait, depending on temperature and other weather conditions (USFWS 2008). The U.S. Fish and Wildlife protocol states during trapping efforts, bait should be replaced when it appears dried out, is full of maggots, or no longer emits a pungent odor. There is not a specific protocol on how often to change the bait in relation to its effect on beetle capture (USFWS 2015).

Although rats have become the recent standard, many types of bait have been successfully used, including laboratory rats and mice, road kill of various animals, including opossum, badger, house cat, raccoon, birds, reptiles, fish or parts of an animal such as chicken drumsticks or gizzards and beef liver (Bedick et al. 2004, Backlund et al. 2008, Leasure et al. 2012). Bedick et al. (2004) found that captures with laboratory rats were comparable to captures using other carrion. However, no study to date has reported on the effectiveness of commercially available artificial baits nor directly compared captures among animal parts.

In this study, I tested the effects of bait type by comparing captures of Silphidae among whole animal, animal parts, and artificial baits. I sampled in areas of Oklahoma and Nebraska where *Nicrophorus* and other Silphidae vary in abundance. I hypothesized that whole animal bait would be the best for attracting *Nicrophorus*, and that artificial bait would not be as successful.

MATERIALS AND METHODS

Oklahoma Trial

Different parts of a chicken were compared to captures using a whole chick to determine if specific parts of the chicken capture more carrion beetles. The effectiveness of using closed bait for multiple days in the field was also examined. Sampling in Oklahoma occurred near Stillwater along a gravel road near the OSU Cross Timbers Range Research Station. Silphidae, particularly *Nicrophorus* spp., were caught using baited pitfall traps (Bedick et al., 2004), following methods recommended by the U.S Fish and Wildlife Service (USFWS 2015). Because *N. americanus* are not present in Payne County, OK, the method of capture was a kill trap. A 4.7 L plastic pail was used to accommodate bait that was housed in a mason jar with a mesh wire lid and was placed in the bottom of the bucket. Plywood was cut to fit on top of the trap as a weather cover, with 2.5 cm wooden sticks holding the board above the trap, allowing room for beetles to crawl into the trap.

A transect was established with 20 traps spaced 0.16 km (0.1 miles) apart. Four replications of each bait type were placed randomly throughout the transect. The rotten chicken baits tested were: chicken drumsticks, thighs, livers, gizzards and hearts, breast meats, and small whole chicks. All chicken parts were purchased at a grocery store, except for whole chicks, which were purchased on Rodentpro.com. Five baits were used at a time with livers, gizzards, and breast meats used during all trials. Whole chicks replaced drumsticks for half of the trial. Traps were checked between August 23 and September 12, 2015 (total of 21 trap nights).

Nebraska Trials

To compare animal and artificial baits trials were conducted using chicken drumstick as the standard bait. Trials were conducted in Nebraska in three counties, Holt, Rock and Garden Counties. Holt and Rock Counties are within the range for *N. americanus*, while Garden County is outside the current range (Jurzenski et al. 2011). In Holt and Rock Counties, artificial baits were used to determine if *N. americanus* could be captured using these baits. Pitfall traps were used in Holt Co., NE near the town of Chambers, NE between June 7 and June 14, 2015. Pitfall traps in Rock Co., NE were used between June 16 and June 27, 2015 on the Barta Brothers Ranch, a research station operated by the University of Nebraska-Lincoln. The ranch is located about 32.18 km south of Long Pine in Rock and Brown Counties (42°14'N, 99°39'W). Pitfall traps in Garden County were placed near Oshkosh, NE and were checked from July 2 to July 23, 2015.

During the Nebraska surveys, baits were changed over the course of the experiment, with rotten mice and Danny King's Catfish Punchbait® always used. If a previously untested bait did not attract many carrion beetles (<10 beetles in 40 trapnights), it was replaced with another bait after 10-14 days, depending on when all baits were scheduled to be changed. The tests included control (no bait), rotten chicken drumstick, rotten tuna fish, Catfish Charlie® Cheese Dip Bait, Strike King® Catfish Dynamite Blood Bait, and Pseudo™ Corpse Scent Formulations I and II obtained from Sigma Aldrich (Table 1).

Because of potential presence of *N. americanus*, live traps were also used in Nebraska. An 18.9 L bucket was buried into the ground, with a wet piece of sponge placed in the bottom. Plywood was cut to fit on top of the trap as a weather cover, with sticks holding the board above the trap, allowing room for beetles to crawl into the trap. Bait was placed into mason jars, and a mesh wire lids were used to allow scent dispersal. Baits (whole mouse, *Mus musculus* (Linnaeus), one chicken drumstick or one can (85 grams) of tuna) were placed inside the jar, while artificial baits (50-60 grams) were placed into a plastic condiment cup that were placed inside the jar. Sigma Aldrich Pseudo™ Corpse Scent Formulations I and II were added to 70% ethyl alcohol and placed into test tubes with a string in the tube acting as a wick. The tubes were placed in mason jars.

A trap array was created and baits were randomly distributed with four replications of each bait. The traps were spaced 0.16 km apart in a transect along a road right of way. All Silphidae were identified to species, recorded and released. For *N. americanus*, pronotum width, sex and age were recorded after which the beetles were branded and released (Jenkins et al. in press).

Statistical Analysis

To analyze the attraction to different parts of a chicken, a one way analysis of variance was used followed by a Tukey test when differences were detected. A one way analysis of variance was also used to compare the capture rates of bait that had been used in the field for 1, 2, and 3 days.

Because the abundance of Silphidae differed among Nebraska counties, data were analyzed separately for Holt, Rock and Garden Counties. The response variable was total Silphidae. A square root transformation was used to normalize the count data which was then analyzed with an ANOVA. When differences were detected, a Fischer's LSD test or Tukey test was also run to determine significance.

RESULTS

The number of Silphidae sampled varied by location and date. Across locations, 18,953 Silphidae were captured (Table 2). These included 15 different species, eight of which were *Nicrophorus* (Table 3). In Nebraska, the most common species captured were *N. marginatus a*nd *N. carolinus* (Table 4). Comparing beetles captured per trap night (one trap open for one night) highlights the difference in abundance across locations sampled. Traps placed in Garden Co., NE caught more Silphidae per trap night, 38.07, compared to all other locations (Table 5).

Oklahoma Trial

When different parts of the chicken were compared, there were significant differences among parts of the chicken, with chicken drumsticks attracting more beetles than livers, gizzards and hearts, or thighs ($F = 5.56$; $df = 5$; $P < 0.05$). Whole chicks, breast meat and drumsticks were equally attractive to Silphidae (Figure 1). Within each bait type, there were no significant difference in capture rates over a three-day period with gizzard showing the most variability in capture rates ($F = 2.37$, $df = 2$, $P = 0.128$) among day 1, 2, and 3 (Figure 2).

Nebraska Trials

In Nebraska studies, whole mouse was used as the standard animal bait to compare capture rates with other bait types. In Holt Co., chicken drumstick caught significantly more ($F = 25.336$ $df = 4$, $P < 0.001$) beetles than all other baits tested (Figure 3). In Rock County, chicken drumstick caught significantly more beetles ($F= 15.336$ $df = 4$ $P <0.001$) than the other baits used at the location (Figure 4). In both Holt and Rock Counties, there were no significant differences ($F = 15.336$ $df = 4$, $P >0.05$) between captures with mice, Danny King's Catfish Punchbait®, Catfish Charlie® Cheese Dip Bait and Strike King® Catfish Dynamite Bait (Figures 3 and 4); however, all of these bait types caught more beetles than unbaited traps.

Chicken drumsticks caught significantly more ($F = 48.62$ $df = 6$, $P <0.001$) beetles than other baits tested at the same time in Garden County. When rotten tuna fish replaced chicken drumsticks, it caught significantly more ($F = 59.644$, $df = 4$, $P <0.001$) beetles than all other baits tested, including the drumsticks (Figure 5). Mice caught more beetles than artificial baits tested, and Danny King's Catfish Punchbait® caught significantly more beetles than Strike King® Catfish Dynamite Bait and both Pseudo™ Corpse Scent formulations (Figure 5). No artificial baits were as attractive to Silphidae as chicken drumsticks or tuna fish, but in Holt and Rock counties, captures with Danny Kings Catfish Punchbait® did not differ significantly from captures with mice (Figures 3 and 4).

In Holt and Rock Counties, 81 *N. americanus* were captured. Sixty-five *N. americanus* were captured using chicken drumsticks, 9 were captured in mouse baited traps and 7 were captured using Danny King's Catfish Punchbait® (Figure 6).

DISCUSSION

With similar types of carrion, different parts of a chicken were found to attract variable numbers of carrion beetles. Chicken drumsticks had the highest mean captures per day and were significantly more attractive than thighs, gizzards and livers (Figure 1). Chicken drumsticks were not significantly different from whole chicks or breast meat. Reasons for these results are unclear. Organ meats tested (gizzards and hearts, and livers) attracted fewer beetles, indicating bone could be an attractive part of the carrion these meats are lacking. However, the thighs tested included bone, and caught the fewest Silphidae. While whole chicks had the second highest mean captures per day, chicken drumsticks are an easier bait to obtain from grocery stores. Whole chicks were obtained frozen from Rodentpro.com and throughout the study, chicken parts were purchased fresh or frozen and then stored frozen until 3 days prior to the trial. Previous freezing did not appear to affect the effectiveness of the bait or the decomposition during rotting.

A potential concern during surveys for *N. americanus* is that researchers generally use bait for 3 days before it is changed. The U.S. Fish and Wildlife Service does not require bait change on a specific day, just when it is dried out or infested with maggots (USFWS 2015). Beetle catch on day 1, 2, and 3 using rotten chicken baits resulted in no significant differences, which is helpful for future studies (Figure 2). Baits were attracting similar amounts of beetles on all three days, which supports the method of changing baits twice a week. Old bait is likely to reduce capture rates through desiccation and lack of odors. My results also indicate that the number of days a trap is in place does not need to be considered in the analysis. However, previous research has shown that a high percentage of burying beetles are not attracted to a baited trap over a period of at least three days (Butler et al. 2013).

When artificial stink baits were tested, none of them attracted as many beetles as rotten animal bait including chicken drumsticks or tuna fish. Danny King's Catfish Punchbait® was the most successful of the artificial baits tested (Figure 5). Strike King® Catfish Dynamite Bait and Catfish Charlie® Cheese Dip Bait also captured burying beetles, although in lesser amounts. These baits were not rotted ahead of time because they were intended to be used without effects from environmental variability. After three days in the trap, artificial baits did not appear to change and odors were not noticeably different. Artificial baits did dry during the experiment and were changed after 3 days. It appears that artificial baits are not as pungent as animal baits and therefore do not attract beetles from as great of distances or do not compete well with animal baits when located within 0.16 km.

Future trapping using only artificial bait may reduce concerns of traps drawing *N. americanus* into an area. In Nebraska, *N. americanus* can travel up to 7.24 km/night (4.5 miles), with one documented movement of 29.19 km (Jurzenski et al. 2011). The capture of *N. americanus* with Danny King's Catfish Punchbait® is the first documentation of success with an artificial bait (Figure 6). If the odor plume of stink bait does not spread as far, the beetles that are captured in the trap may be drawn from closer to the trap, potentially being advantageous for certain application such as determining critical habitat.

Danny King's Catfish Punchbait® attracted more *N. marginatus* than *N. carolinus.* This could indicate a difference in biology between the species or a function of habitat because *N. carolinus* is associated with sandy soils while *N. marginatus* is more of a grassland species.

Volunteer and citizen science efforts to study burying beetles are possible with Danny King's Catfish Punchbait®, lowering pathogen risk, such as salmonella, from handling rotten vertebrate carrion (Meyer et al. 2010). However, the contents of the stink baits used are unknown. Danny King's Catfish Punchbait® contained a hairy substance, most likely from an animal, and could explain why this stink bait was more attractive to burying beetles.

Rotten tuna fish was documented as an attractive bait to Silphidae, capturing more beetles than chicken drumsticks (Figure 5). White albacore tuna fish in spring water was used. The cans were opened and allowed to rot in a sealed bucket for three days, before the tuna was poured into a mason jar.

From these findings, tuna fish should be considered for a standard bait type in burying beetle sampling when closed baits are used in place of whole mice or rats. Having a successful bait that is easy to purchase at a grocery store, versus an online source, could benefit trapping of burying beetles in the future. The use of standardized baits like chicken drumstick or tuna fish eliminates the uncertainty of buying from online retailers, thereby decreasing shipping time and cost, or backorders. Chicken drumsticks and tuna fish are easier to obtain and use than other methods of obtaining carrion that researchers have used in the past, such as road kill (Bedick et al. 2004). It should be taken into consideration, however, that using chicken drumsticks or tuna fish in a closed bait container adds an additional step to the trap checking process when sampling *N. americanus*. When rats are used as open bait, the beetles in the trap feed on the rat. Without access to the closed bait, captured *N. americanus* must be fed prior to their release (USFWS 2011).

Sigma Aldrich Pseudo™ Corpse Scent Formulations I & II did not work for sampling burying beetles. Pseudo™ Corpse Scent is used to train cadaver dogs and comes in 1 mL tubes.

During my experiments, the chemical was then added to a vial of 70% ethyl alcohol, with a string acting as a wick for scent dispersal. While some captures were observed, they were low in comparison to other baits used (Figure 5).

The diversity and abundance of carrion beetle species differ across regions and habitat types. The occurrence of carrion beetle species varies by location in Nebraska (Jurzenski et al. 2011) which was confirmed in the present studies in Holt, Rock, and Garden counties in Nebraska (Tables 2 and 3). Previous literature has shown differences in Silphidae captures among studies across many states: NE, SD, AR, IA, NJ, RI, NJ, MD and MO (Walker and Hoback 2007). While differences in Silphidae abundance among states and habitats occur, comparisons of carrion beetles across surveys could be influenced by the use of different bait types and therefore bait type should be standardized in future studies.

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LITERATURE CITED

Anderson, RS. 1982. Resource partitioning in the carrion beetle (Coleoptera: Silphidae) fauna of southern Ontario: ecological and evolutionary considerations. Canadian Journal of Zoology 60: 1314–1325.

Anderson, R. S. and S.B. Peck. 1985. The insects and arachnids of Canada part 13: The carrion beetles of Canada and Alaska (Coleoptera: Silphidae and Agyrtidae). Agriculture, Canada, Ottawa.

Backlund, D.C., G. M. Marrone, C. K. Williams, and K. Tilmon. 2008. Population Estimate of the Endangered American Burying Beetle, *Nicrophorus americanus* Olivier (Coleopteran: Silphidae) in South Dakota." Coleop. Bull. 62: 9–15.

Bedick, J.C, Ratcliffe, B.C., and Higley, L.G. 2004. A new sampling protocol for the endangered American burying beetle, *Nicrophorus americanus* Olivier (Coleoptera: Silphidae). Coleop. Bull. 58: 57–70.

Bedick, J. C., B.C. Ratcliffe, W.W. Hoback, & L.G. Higley. 1999. Distribution, ecology and population dynamics of the American burying beetle *Nicrophorus americanus* (Coleoptera: Silphidae) in south-central Nebraska, USA. J. Insect Conserv. 3: 171-181.

Butler, S. R., R. Harms, K. Farnsworth-Hoback, K. Koupal, J. Jurzenski, & W.W. Hoback. 2013. Standardized capture rates of the endangered American burying beetle, *Nicrophorus americanus* Olivier (Coleopteran: Silphidae) using different trap protocols. J. of Insect Conserv. 17: 607-613.

Creighton J.C., C.C. Vaughn and B.R. Chapman. 1993. Habitat preference of the endangered American burying beetle (*Nicrophorus americanus*) in Oklahoma. The Southwestern Naturalist. 38: 275–306.

Hoback W.W., A.A. Bishop, J. Kroemer, J. Scalziti and J.J. Shaffer. 2003. Differences among antimicrobial properties of carrion beetle secretions reflect phylogeny and ecology. J. of Chem. Ecol. 30: 719-729.

Jenkins, T.M., Hoback, W.W., and Mulder, P.G. In press. Elytron-branding as a permanent marking technique for *Nicrophorus* beetles (Coleoptera: Silphidae). Coleop. Bull.

Jurzenski, J., D. G. Snethen, M.L. Brust, and W.W. Hoback. 2011. New records of carrion beetles in Nebraska reveal increased presence of the American burying beetle, *Nicrophorus americanu*s Oliver (Coleoptera: Silphidae). Great Plains Research, 21: 131-43.

Leasure, D. R., D.M. Rupe, E.A. Phillips, D.R. Opine, and G. R. Huxel. 2012. Efficient new above-ground bucket traps produce comparable data to that of standard transects for the endangered American burying beetle, *Nicrophorus americanus* Olivier (Coleoptera: Silphidae). Coleop. Bull. 66: 209-18.

Meyer, C., S. Thiel, U. Ullrich, and A. Stolle. 2010. Salmonella in raw meat and by-products from pork and beef. J. Food Protection. 73: 1780-4.

Scott, M. P. 1998. The ecology and behavior of burying beetles. Ann. Rev. of Entomol. 43: 595-618.

USFWS (U.S. Fish and Wildlife Service) 2008. American Burying Beetle Nebraska Trapping Protocol.

USFWS (U.S. Fish and Wildlife Service) 2011. American burying beetle *Nicrophorus americanus* survey guidance for Oklahoma. Tulsa, Oklahoma.

USFWS (U.S. Fish and Wildlife Service). 2015. American Burying Beetle *Nicrophorus americanus* Oklahoma Presence/Absence Live-trapping Survey Guidance.

Walker T.L. and W.W. Hoback. 2007. Effects of invasive eastern redcedar on capture rates of *Nicrophorus americanus* and other Silphidae. Environ. Entomol. 36: 297-307.

TABLES AND FIGURES

Table 1. Location and dates of baits tested, both animal and artificial, in three Nebraska counties in 2015. There were twenty pitfall traps with four replications of each bait type at a time, with bait replacements in baits that did not perform well. No bait/control traps were no longer used in Garden Co. after capturing no beetles in previous locations.

Holt*	Rock*	Garden
June 7-14	June 16-27	July 2-23
No bait/control Mouse Chicken drumstick Punchbait Cheese bait	No bait/control Mouse Chicken drumstick Punchbait Cheese bait Dynamite bait	 Mouse Chicken drumstick Punchbait Dynamite bait Corpse I Corpse II Tuna fish

**N. americanus* present in Holt and Rock counties.

Table 2. Total Silphidae captures in pitfall traps in all locations tested across the two U.S. states.

Date	State	County	Nicrophorinae	Silphinae	Total Silphidae

9/3/15- 9/12/15	Oklahoma	Payne	584	296	880
6/7/15- 6/14/15	Nebraska	Holt	93	97	190
6/15/15- 6/27/15		Rock	652	483	1,135
7/02/15- 7/23/15		Garden	15,695	1,053	16,748
		TOTAL	17,024	1,929	18,953

Table 3. All Silphidae species captured during pitfall trapping across four locations sampled in the two U.S. States. Species presence indicated by X.

Species	**Payne Co., OK**	**Holt Co., NE**	**Rock Co., NE**	**Garden Co., NE**
Nicrophorus americanus		X	X	
Nicrophorus carolinus	X	X	X	X
Nicrophorus guttula				X
Nicrophorus marginatus	X	X	X	X
Nicrophorus obscurus				X
Nicriophorus orbicollis	X		X	X
Nicrophorus pustulatus	X		X	X
Nicrophorus tomentosus	X	X	X	X
Necrophila americana	X	X	X	
Necrodes surinamensis	X	X	X	X
Heterosilpha ramosa		X	X	
Oieceoptoma inaequale		X	X	
Oieceoptoma novaboracense			X	
Thanatophilus lapponicus		X	X	X
Thanatophilus truncatus	X		X	X

Table 4. Total number of *Nicrophorus* beetles by species captured in Holt, Rock and Garden County, NE, June 1-July 23, 2015.

County	***N. americanus***	***N. carolinus***	***N. guttula***	***N. marginatus***	***N. obscurus***	***N. orbicollis***	***N. pustulatus***	***N. tomentosus***	**Total**
Holt	13	12	0	57	0	0	0	11	93
Rock	68	226	0	303	0	5	1	48	652
Garden	0	1,251	37	13,974	10	415	4	4	15,695
Total	81	1,489	37	14,334	10	420	5	63	16,440

Table 5. Total Silphidae captures/ trap night in all locations tested across the two U.S. states (Trap night equals one trap open for one night, in order to compare across studies).

Trap Nights	**State**	**County**	**Nicrophinae**	**Silphinae**	**Silphidae**
21	Oklahoma	Payne	1.39	0.70	2.09
8	Nebraska	Holt	0.58	0.61	1.19
13		Rock	2.72	12.08	4.73
22		Garden	35.67	2.39	38.07

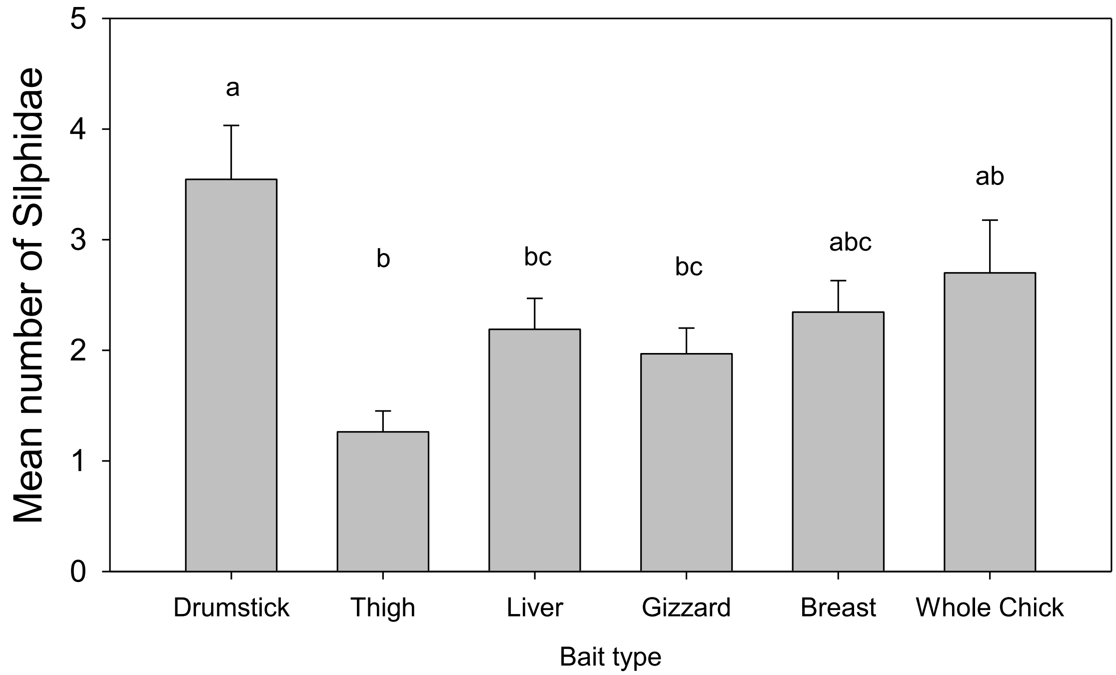

Figure 1. The mean number of daily Silphidae captures using chicken bait types in Payne Co., OK, September 3 to September 12, 2015. Data were transformed by square root and analyzed with an Analysis of Variance followed by a Tukey test. Different letters indicate significance ($P < 0.05$).

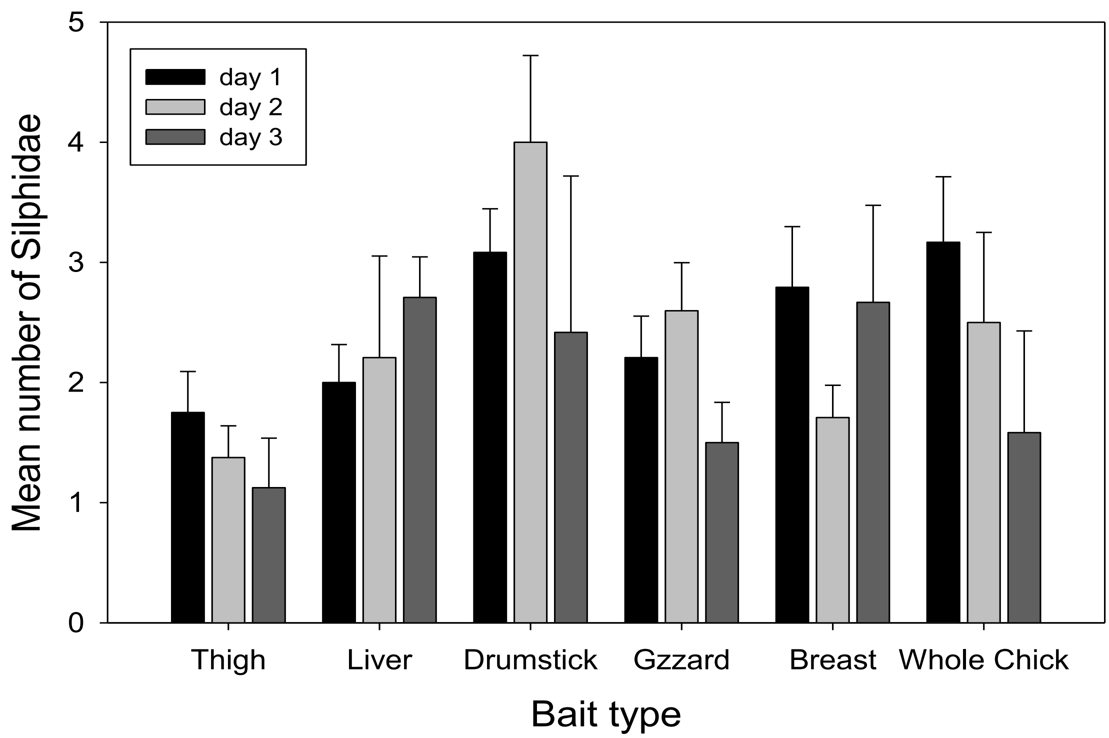

Figure 2. The mean number of daily Silphidae captures using chicken bait type in Payne Co., OK, September 3 to September 12, 2015 on day 1, 2, and 3. Data were transformed by square root and analyzed with an Analysis of Variance followed by a Tukey test. Means within each bait type are not significantly different ($P < 0.05$).

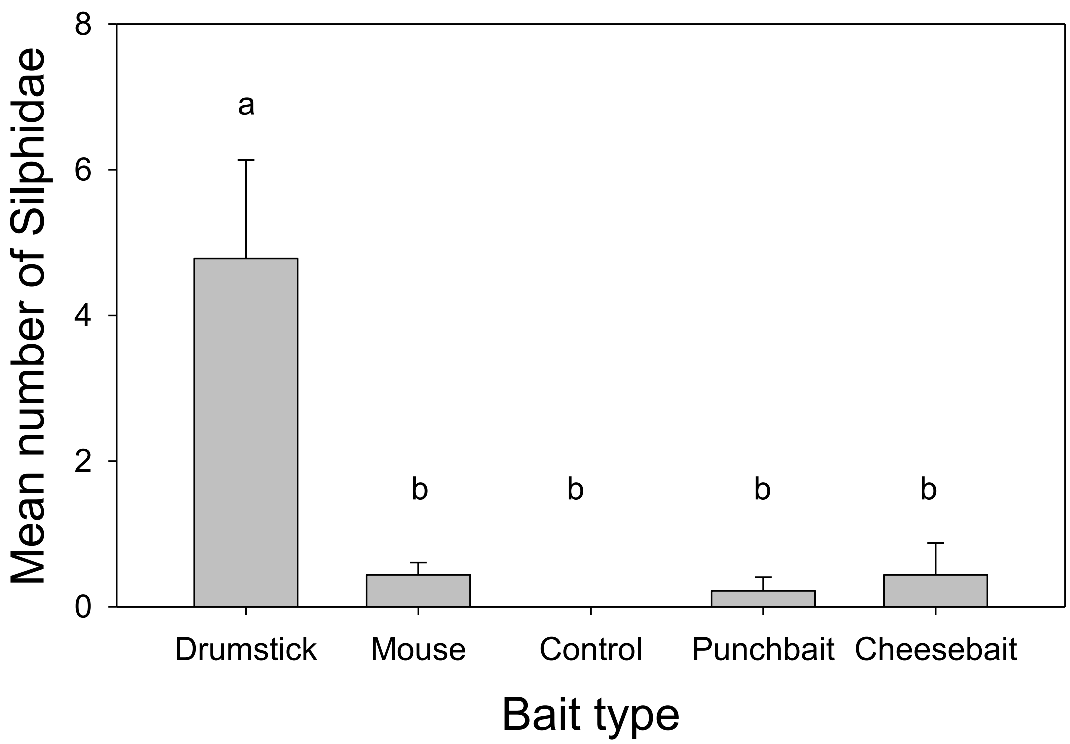

Figure 3. The mean number of daily Silphidae captures using various animal and artificial stinkbaits in Holt Co., NE, June 7 to June 14, 2015. The bait types include rotten chicken drumstick, rotten mouse, Danny King's Catfish Punchbait®, Catfish Charlie® Cheese Dip Bait, and control (no bait). Data were transformed by square root and analyzed with an Analysis of Variance followed by a Tukey test. Means followed by the same letter are not significantly different ($P < 0.05$).

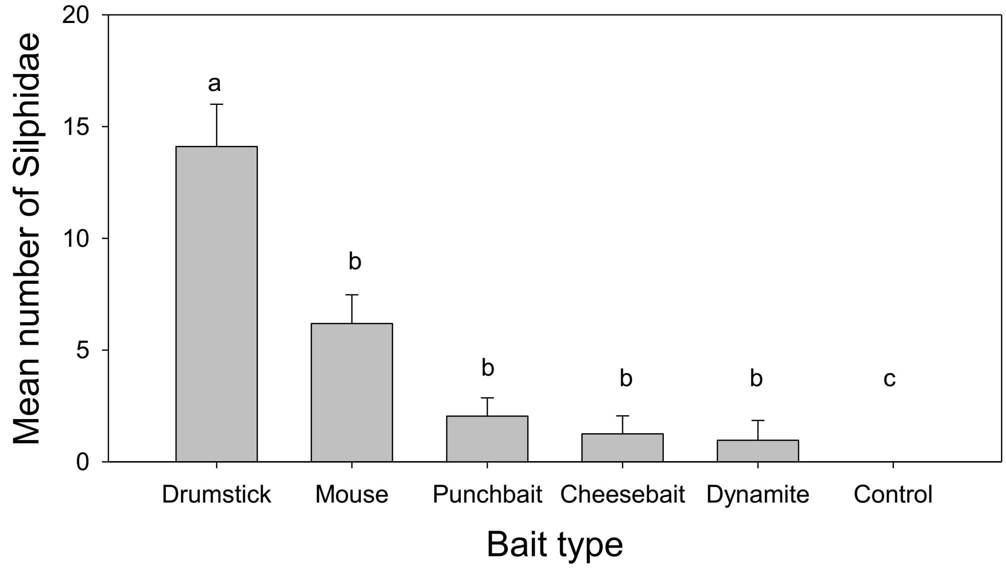

Figure 4. The mean number of daily Silphidae captures using various animal and artificial stink baits in Rock Co., NE, June 16 to June 27, 2015. The bait types include rotten chicken drumstick, rotten mouse, Danny King's Catfish Punchbait®, Catfish Charlie® Cheese Dip Bait Strike King® Catfish Dynamite Blood Bait, and control (no bait). Data were transformed by square root and analyzed with an Analysis of Variance followed by a Tukey test. Means followed by the same letter are not significantly different ($P < 0.05$).

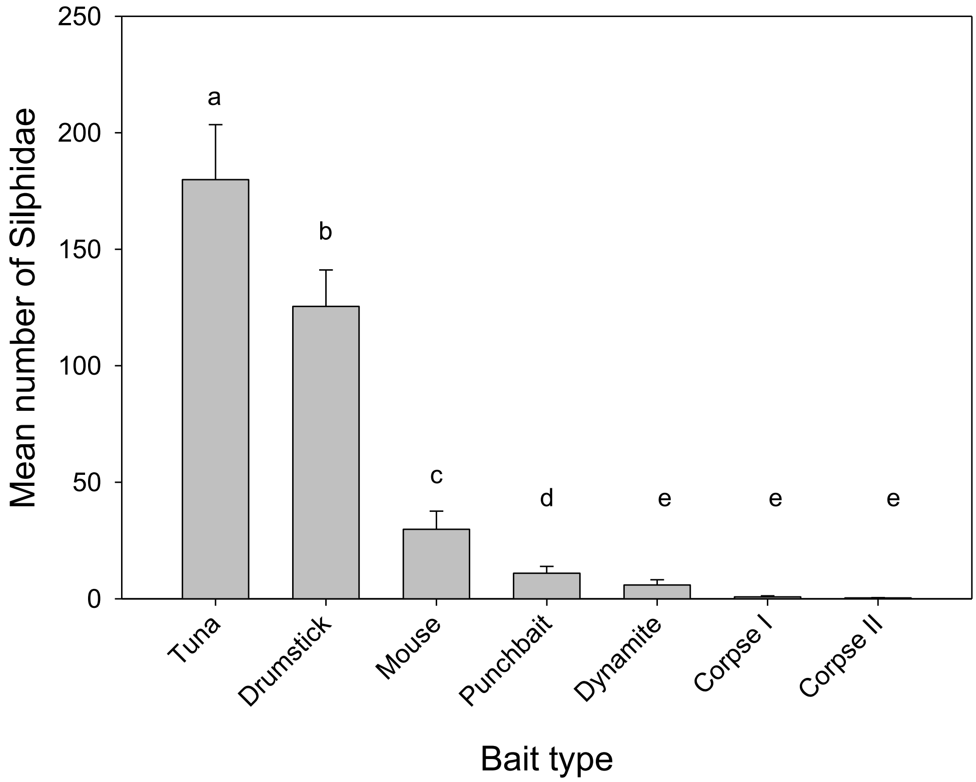

Figure 5. The mean number of Silphidae captured by bait type in Garden Co., NE, July 2 to July 23, 2015. The bait types include rotten tuna fish, rotten chicken drumstick, rotten mouse, Danny King's Catfish Punchbait®, Strike King® Catfish Dynamite Blood Bait, and Pseudo™ Corpse Scent Formulations I and II obtained from Sigma Aldrich. Data were transformed by square root and analyzed with an Analysis of Variance followed by a Fishers LSD test. Means followed by the same letter are not significantly different ($P < 0.05$).

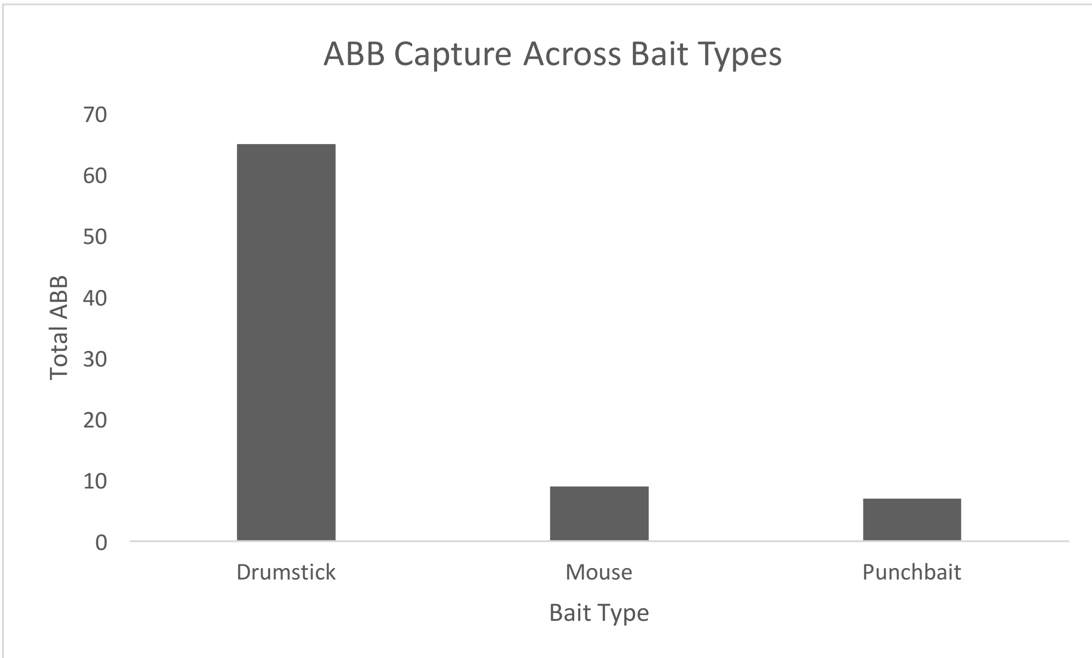

Figure 6. All *Nicrophorus americanus* (Olivier) (81 total) captured in Holt and Rock counties in Nebraska, June 7 to June 27, 2015. *N. americanus* captured in Chicken drumstick, mouse, and Danny King's Catfish Punchbait® baited traps.

CHAPTER IV

CITIZEN SCIENCE IN ENTOMOLOGY AND THE BANISHED BEETLE PROJECT

ABSTRACT

Citizen science is the collaboration between researchers and members of the public to answer scientific questions. It is a technique used by scientists to outsource large-scale data collection to the public while also inspiring the community to learn about environmental and conservation issues. Citizen science projects can be used as teaching tools in the classroom, exposing primary and secondary students to science and experimentation. The Banished Beetle Project was developed including teaching materials and a pitfall trapping project to encourage citizens to trap for burying beetles. The project was designed to highlight burying beetle biology and introduce conservation efforts of the American burying beetle, *Nicrophorus americanus* (Olivier). In Oklahoma, four classrooms were involved in the project; however, no burying beetle activity was detected. Online marketing should be increased to promote interest in the Banished Beetle Project. Participants from across the U.S. could contribute to data and burying beetle assemblages could be characterized.

INTRODUCTION

Citizen science is public contribution to scientific research and data collection. The public may include students, other professionals, or lay persons (Trautmann et al. 2013). Citizen science has also been labelled as crowdsourced science, participatory science, or networked science (Clarke 2013). Citizen science allows professional scientists and volunteers to collaborate to study environmental and biological trends over regions and large time spans (Trautmann et al. 2013). Many citizen science programs also include educational components and most projects are a mix of research, education, community development, and conservation (Oberhauser and Prysby 2008). Projects using citizen scientists vary from searching for a rare species and surveying amphibian communities to classifying the shapes of galaxies and gathering data on climate change (Trautmann et al. 2013). Children's involvement in citizen science projects can be an advantage due to their novel outlook and unique perspectives (Burns 2012).

For centuries, citizen scientists have been collecting weather data and field notes on butterfly distribution and behavior. Created in 1900, The National Audobon Society's annual Christmas Bird Count may be considered one of the first citizen science projects. The Christmas Bird Count is still active today, solicits public data collection on distribution and abundance. Citizen science projects are beneficial in collecting bird data and could be very useful in many areas of entomological research (Oberhauser and Prysby 2008).

The first citizen science project to answer a research question involved the Monarch butterfly, *Danaus plexippus* (Linnaeus) (Oberhauser and Prysby 2008, Trautmann et al. 2013). The act of tagging Monarchs to study their migration began in 1952 at Zoology University in Toronto, Canada. By 1971, 600 citizens were involved with the tagging project. The program was popular and the cover of the 1976 edition of National Geographic featured this work. University of Kansas has taken over this project, which is now known as Monarch Watch, and has over 100,000 participants in annual tagging programs, many of them from classrooms and local nature centers (Burns 2012). Monarch Watch is an education-based project providing information to the public about the biology of Monarch butterflies and their migration. Besides asking participants to tag butterflies, Monarch Watch provides educational tips and methods for classroom involvement, including assistance raising Monarchs and growing milkweed plants (Monarch Watch 2016).

Another entomological citizen science project is The Lost Ladybug Project. This project began in 2000 when researchers from Cornell and 4H Cooperative Extension Master Gardeners surveyed ladybird beetles in New York. While being used by elementary classes, in 2006 the Lost Ladybug Project detected a rare nine-spotted lady beetle, *Coccinella novemnotata* (Herbst), a species thought extinct. Since then, 35,247 ladybird beetles have been contributed to the Lost Ladybug database (The Lost Ladybug Project 2016). The Lost Ladybug project was developed to incorporate both educational and scientific study in a citizen science project (Sickler et al. 2014). Participants take pictures of ladybird beetles they find and submit them on the website (The Lost Ladybug Project 2016). Multiple field guides, posters, kids coloring books, bookmarks and other activities are available on the website. An interactive map is also included and locations of rare ladybird beetles found are highlighted. This project also uses a Facebook page and mobile app (Burns 2012, The Lost Ladybug Project 2016).

Backyard Bark Beetles is a citizen science project "for the protection of our forests" (Backyard Bark Beetles 2015). This project, launched in 2013 at the University of Florida, focuses on bark and ambrosia beetles, which include a lot of invasive species that attack trees. The project gives volunteers instructions to capture bark beetles using a soda bottle and hand sanitizer, and then mail the beetles to the project scientists for identification. The website includes resources intended for teachers, Master Gardeners, Florida Naturalists, 4H extension agents and a general audience. A brochure highlights the purpose of the project and tips to get started, while an instruction manual provides step by step instructions on crafting a beetle bottle trap. The trap consists of a two-liter soda bottle and an attractant, such as Purell® hand sanitizer. The trap design allows the pubic to use cheap, common items instead of requiring a professional trap, costing in excess of $50 (Backyard Bark Beetles 2015, Korzekwa 2015). Project organizers use public submissions to continuously update a beetle distribution map (Backyard Bark Beetles 2015).

The American burying beetle, *Nicrophorus americanus* (Olivier), were listed as federally endangered in 1989. The historical range of *N. americanus* has decreased 90%, and currently are only found in two large populations in eastern Oklahoma and Nebraska, spreading into Kansas, Arkansas, and South Dakota, as well a maintained island population in Rhode Island (Bedick et al. 2004). In 1991, the U.S. Fish and Wildlife Service created a recovery plan for *N. americanus*, which recommended: 1) protect and manage extant populations, 2) maintain captive populations, 3) continue Penikese Island reintroduction effort, 4) conduct studies, 5) conduct searches for additional populations, 6) characterize habitat and conduct vertebrate inventories, 7) conduct additional reintroductions, 8) continue to conduct research into the species decline, and 9) conduct informational and educational programs (Panella 2013). While the other components of ther recovery plan have been addressed, no coordinated effort has been made to increase education and promote outreach of *N. americanus*.

In 2015, the Banished Beetle Project was created to provide educational curricula and generate additional searches for *N. americanus*, following methods of Monarch Watch and The Lost Ladybug Project's methods of involving citizens in conservation efforts of a beneficial insect species, and Backyard Bark Beetle's use of cheap and simple trapping protocol. The Banished Beetle Project promotes educational awareness of *N. americanus*, targeting the general public and K-12 classrooms, and providing age-appropriate background information about burying beetle, *Nicrophorus spp*. biology and their role as natural recyclers/detritivores. An educational emphasis is placed on the burial process of burying beetles, highlighting their beneficial role in the environment and that they help reduce fly populations.

Citizens are encouraged to aid scientists in *N. americanus* conservation efforts by pitfall trapping for burying beetles, using cheap trap materials and an attractive bait. Instructions for building a pitfall trap and purchasing bait are described in an educational module. To aid in identification, *Nicrophorus* species are pictured and additional identification tools are provided to help recognition of *N. americanus*. Volunteers are asked to monitor pitfall traps and record burying beetle captures on provided data sheets. Data on all burying beetle species obtains additional abundance and distribution records.

MATERIALS AND METHODS

Educational Materials

An educational module for the Banished Beetle Project was developed for educators highlighting facts about *N. americanus,* with a focus on pitfall trapping for burying beetles. The purpose of this module was to give teachers background information on *N. americanus* and instructions for both the teacher and students on building and using pitfall traps. Objectives for this module include learning about the U.S. Fish and Wildlife Service's Endangered Species Act, burying beetle biology, the use of a pitfall trap, and identification of *N. americanus*. If teachers choose to implement the advanced pitfall trapping activity for burying beetles, the pitfall trap is baited with a safe, commercially available stink bait is recommended rather than rotten animal bait to attract burying beetles. A map of current location records of *N. americanus* in Oklahoma is included and detailed procedures are outlined in case of an *N. americanus* capture. Identification tips are included to distinguish common species of carrion and burying beetles. Data sheets are provided for both the general insect and burying beetle trapping activities. This educational module was provided to all participants in the Banished Beetle Project, and can be found in Appendix II.

A tri-fold poster display was developed to illustrate the burial process and to emphasize the benefits of burying beetles and the endangered status of ABB. A diorama was also created to display the underground view of a burying beetle adults and larvae with a carcass. A box of pinned Silphidae specimens was also displayed to classrooms, with ABB among other burying and carrion beetles. A bookmark (Figure 1), was designed with an illustration of an ABB, and facts about it, along with and contact information. The bookmark was provided to classrooms and at other events. To reinforce the image of ABB, a poster was displayed with an artistic rendering of the American burying beetle.

Additional interactive educational materials were developed for use both in a classroom setting and at large outreach events where children move rapidly through multiple educational stations. The first of these was an interactive burial box with toy mice and toy beetles in fake soil to allow children to help the beetles bury a dead mouse.

Another was a coloring exercise developed to help students learn how to identify ABB in comparison with other burying beetle species. Students were given an uncolored beetle (Figure 1) in conjunction with a laminated picture of a specific burying beetle species and asked to color their blank beetle like the laminated picture. A poster was designed to illustrate the difference between burying beetles and carrion beetles in the family Silphidae and to show different burying beetle species side by side. The coloring exercise and guide to Silphidae were used to highlight species markings on the beetles which facilitate species identification.

All educational materials were used during the 2015 and 2016 Southwestern Branch ESA Insect Expo and in four Tulsa, Oklahoma, classrooms. A quiz was developed to assess student understanding of burying beetle educational materials. The quiz consisted of four questions attempting to quantify *N. americanus* knowledge assimilated. The quiz was given to a classroom of 21 third grade students before and after the burying beetle coloring exercise.

Participation in the Banished Beetle Project

In order to recruit participants for The Banished Beetle Project, various outlets were utilized. 1) A presentation was made at a curriculum development workshop at Oklahoma State University's Insect Adventure. Attendees were seeking entomology-related projects to use in their classrooms. 2) The project was listed on Scistarter.com, a website with a growing list of citizen science projects. 3) A Facebook page was also created for the project. Both the SciStarter page and Facebook page provided a contact for those willing to participate in the project. Additional emails were sent and forwarded to teachers in the Tulsa, Oklahoma, area to promote the project.

Pitfall trapping materials were given to 20 educators at the curriculum development workshop and to participating Oklahoma teachers. Materials included: one quart-sized container, one flower pot, a bait cup, bait, and wire to secure the trap. Participants were asked to dig the pitfall trap into the ground, use the provided bait, Danny King's Catfish Punchbait, and observe the trap over a few days, noting and identifying all burying and carrion beetles. Data sheets and relevant information were provided to participants who planned on setting out traps. Other participants who were not recruited at the teacher workshop were provided with the educational module on how to build a pitfall trap, using their own materials.

RESULTS

Educational Materials

Teaching was successful in the ESA Insect Expo and classroom setting, generating enthusiasm among participants. Teachers and students were very interested in learning about burying beetle biology. Approximately 900 students visited the ABB table at the 2015 Southwestern Branch ESA Insect Expo, and approximately 1,000 students at the 2016 Southwestern Branch ESA Insect Expo. The four classrooms were visited by an ABB researcher between September-October, 2015. A total of 31 middle school students were visited and 40 elementary school students.

There was evidence of an increase in knowledge after participation in the classroom exercise. Initially, in the pre-quiz when the class was asked to circle the correct picture of ABB, four students answered correctly; however, in the post-quiz 16 answered correctly (Figure 4). In response to the pre-quiz question about the name of the endangered burying beetle, two students answered the name American burying beetle and in the post quiz 17 students answered correctly. During the pre-quiz, when asked if the pictured beetles were different and why, 17 students answered yes because of different colors/patterns, and 18 students in the post quiz answered similarly. In the question, “How many different species are pictured?” 7 students answered correctly in the pre quiz and 10 in the post quiz (Figure 5).

Participation in the Banished Beetle Project

From the SciStarter website, 3 individuals requested instructions to become involved in the project, but did not trap during the 2015 season. An additional participant became involved from word of mouth, and conducted the pitfall trap activity in Texas. Of about 20 teachers who were instructed and given trapping materials at the curriculum development workshop, 3 teachers responded through email confirming they attempted trapping for burying beetles. One of those teachers spread the word to Global Gardens and Rosa Parks elementary school teachers, resulting in 2 additional teachers participating.

The Facebook page generated 80 likes, and continues to be viewed by the public. The bookmark was handed out in classrooms and distributed to a research station through the University of Nebraska-Lincoln. One graduate student researcher located a burying beetle and emailed the contact on the bookmark with pictures to alert the finding of what was thought to be an ABB, but was identified as *Nicrophorus carolinus* (Linnaeus).

Four classrooms used burying beetle pitfall traps as a class activity, with a total of 71 students involved. Both Global Gardens and Rosa Parks Elementary School classrooms dug in multiple pitfall traps in school gardens, with a total of 7 traps, and checked them during class periods for a few weeks. All participants conducted their pitfall trapping between September and October, 2015. No burying beetles were found in any of the pitfall traps. However, the classrooms that participated still used the pitfall traps as a class activity and observed the insects that were collected in the traps. No data sheets were turned in, even from general insect pitfall trap exercises.

DISCUSSION

The Banished Beetle Project is an appropriate citizen science project topic. It is both important from a research perspective, and interesting to nonscientists (Oberhauser and Prysby 2008). Teaching kids how burying beetles bury and eat dead animals piqued their interest – whether they were grossed out or amazed, they responded enthusiastically. Students paid attention because of the "ick" factor. Students were eager to help and wanted to participate in a hands-on way, digging and preparing the pitfall trap. They expressed excitement to check the traps with their class throughout the week, and said they hoped they would get a chance to see the endangered American burying beetle. Citizen science is a form of education that can set in motion life-long environmental learning (Roth and Lee, 2004).

All educational materials created reinforced the need to conserve *N. americanus*. The coloring exercise and pre- and post-quiz results were a good indication that students learned that *N. americanus* is the only endangered burying beetle, and could understand that the different colors and patterns of burying beetles could be used to identify different species. In the future, the quiz could be modified for use with different age groups. The third grade classroom that completed the quiz had some issues spelling words such as "American." It would be beneficial to limit the quiz for younger students to only multiple choice questions. The quiz could also be expanded upon and solicit more detail with older audiences. The quiz works well in a classroom setting but is not fit for a large outreach event. The coloring exercise was popular during the 2015 and 2016 Insect Expo event, with many kids participating in coloring a beetle. However, because of the fast-pace environment, many kids moved to a different station half-way through coloring and may not have gained what was intended from the coloring exercise.

Successfully recruiting participants was difficult, and any project being developed should be evaluated to reduce the barriers of participation (Phillips et al. 2014). More workshops and methods of contacting teachers should be utilized. With additional funding, a website could be constructed where all relevant information could be included and a wider audience could be reached. Successful citizen science projects like The Lost Ladybug Project, Monarch Watch and Backyard Bark Beetles, have their own website in addition to a Facebook page and SciStarter page (The Lost Ladybug Project 2016, Monarch Watch 2015, Backyard Bark Beetles 2015.) A website would also create an easy way for participants to upload data sheets, and to make all data available to the public. In order for the Banished Beetle Project to continue, it should be evaluated to determine strengths and weaknesses, to gather evidence of success, and sustain or obtain additional funding (Phillips et al. 2014). Participants also need to be encouraged to increase engagement beyond a minimal level (Sickler et al. 2014). More effort should be made to follow up with participants to keep them engaged and responsive. Emails should be sent once a week to receive an update on the class activity and collect data sheets. An online version of the data sheet should also be created to make the process easier for participants.

Similar to the Backyard Bark Beetles, trapping protocol was appropriate for a citizen science project because it was both simple and inexpensive (Oberhauser and Prysby 2008, Backyard Bark Beetles 2015). While pitfall trapping resulted in no captures of burying beetles, students were excited to get outside and examine pitfall traps. Teachers, as well, were invested in this process and expressed enthusiasm to use this activity in future classes. Future work on this project should encourage participation during summer months of peak burying beetle activity. Since pitfall trapping was done during October and September, there was a low chance of burying beetles being captured. Other reasons for the poor results include locations of the classrooms in Tulsa, OK, which were within the city limits, and the use of artificial bait. Participants could be encouraged to use cans of tuna fish if they are willing to work with rotten meat. However, completed pitfall trapping with a result of no burying beetles is still important to note. Citizen scientists should report how intensely they attempted to collect data, even if they found nothing. Whether successful or not, this information improves the overall picture of what species are in the environment or where they are absent (Burns 2012).

All outreach materials used in the Banished Beetle Project are housed at Oklahoma State University's Insect Adventure. The educational module is available for download on The Banished Beetle Project tab on the Insect Adventure homepage, http://insectadventure.okstate.edu. Future graduate students are encouraged to continue spreading awareness of *N. americanus* in classrooms and at outreach events.

The American burying beetle is an important organism for the public to learn about beyond initial conservation issues. This beetle, listed the endangered species list, has caused some controversy in the areas it resides. The oil and gas industry in Oklahoma is provided with a streamlined Endangered Species Act (ESA) permitting process for activities that may impact *N. americanus.* This has resulted in high cost of mitigation for the oil and gas industry through compliance with this program (Thomas 2015). It is vital that the public is able to find a balance, and be aware that *N. americanus* needs protection, and oil can still be produced safely. Due to backlash from oil companies, *N. americanus* has a bad name. The Monarch butterfly is an endangered insect that people view fondly; however, it has not interfered with oil projects. Increasing education and spreading awareness of *N. americanus* with the Banished Beetle Project will hopefully generate more appreciation and understanding of this beetle.

LITERATURE CITED

Backyard Bark Beetles. 2015. Retrieved from http://www.backyardbarkbeetles.org.

Burns, L.G. 2012. Citizen scientists: be a part of scientific discovery from your own backyard. Published in the United States by Henry Holt and Company.

Clarke, Chandra. 2013. Be the change: saving the world with citizen science.

Monarch Watch. 2016. Retrieved from http://www.monarchwatch.org.

Oberhauser, K.S., and M.D. Prysby. 2008. Citizen Science: Creating a Research Army for Conservation. Amer. Entomol. 54 (2):103-105.

Phillips, T. B., M. Ferguson, M. Minarchek, N. Porticella, and R. Bonney. 2014. User's Guide for Evaluating Learning Outcomes in Citizen Science. Ithaca, NY: Cornell Lab of Ornithology.

Roth, W.M., and S. Lee. 2004. Science education as/for participation in the community. Sci. Educ. 88: 263–291.

Sickler, J., T.M. Cherry, L. Allee, R.R. Smyth, and J. Losey. 2014. Scientific Value and Educational Goals: Balancing Priorities and Increasing Adult Engagement in a Citizen Science Project. App. Environ. Educ. & Comm. 13: 109-119.

The Lost Ladybug Project. 2016. Retrieved from http://lostladybug.org.

Thomas, B. 2015. Bugging the oil and gas industry: the American burying beetle in Oklahoma. Oil and Gas, and Natural Resources Energy Journal. 1: 221-240.

Trautmann, N, J. Fee, and T.M. Tomasek. 2013, Citizen Science: 15 Lessons That Bring Biology to Life, 6-12, National Science Teachers Association, Arlington, VA, USA.

FIGURES

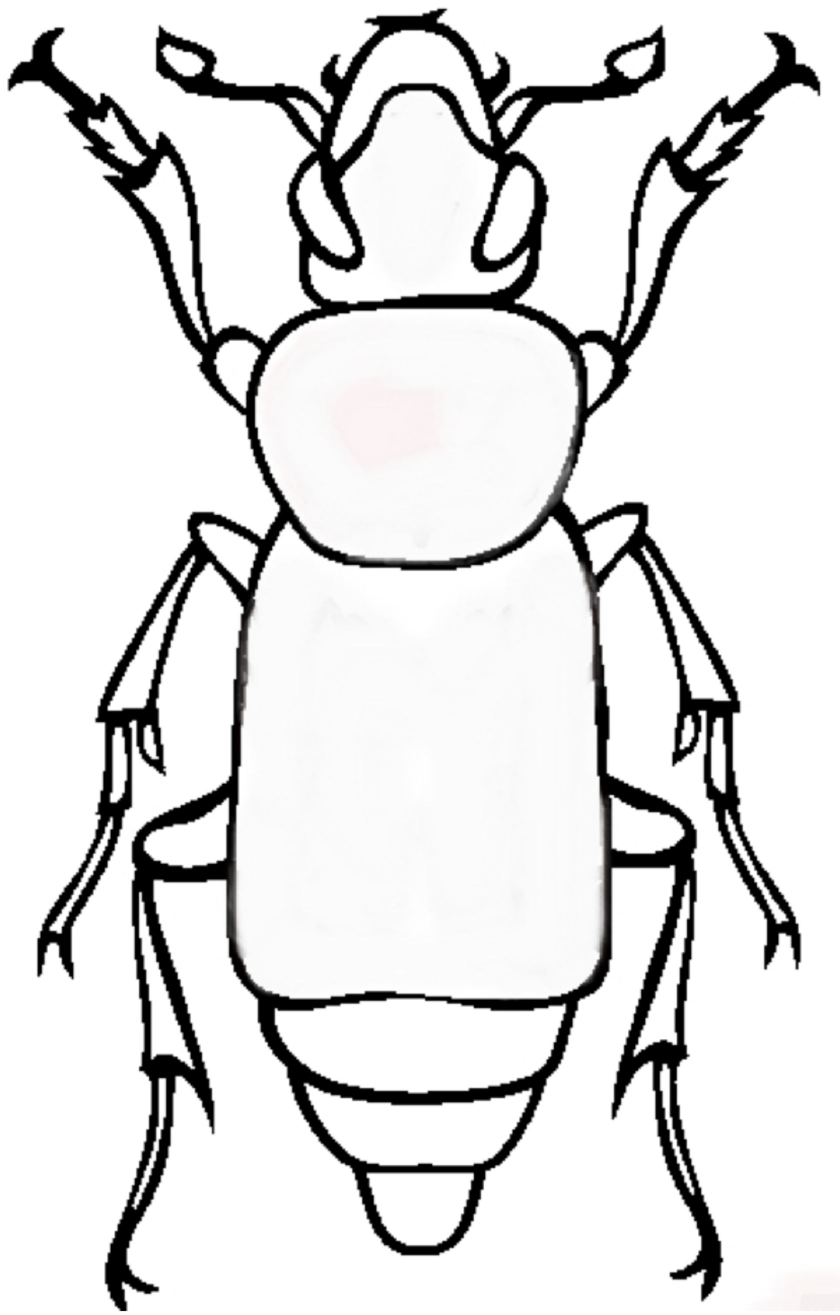

Figure 1. A blank burying beetle given to students to color in to learn about different species of burying beetles.

Name: ______________________

1. Circle the **endangered** burying beetle below

   - What is its name? ________________________________

2. Are these beetles different from each other? Why do you think so?

3. How many different species are pictured?

   A. 1 (they are all the same)
   B. 2
   C. 4
   D. 6

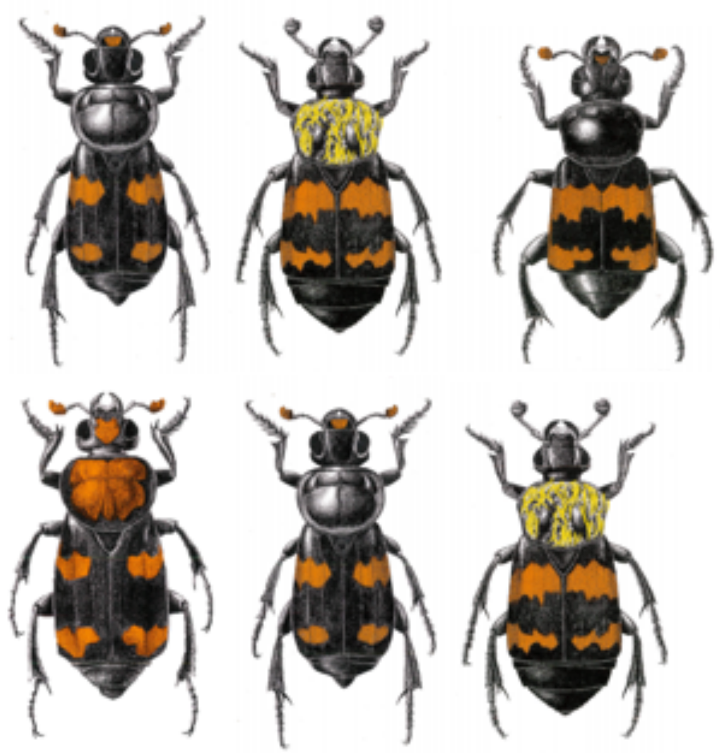

Figure 2. A quiz was given to an elementary class before and after the coloring exercise to determine what students learned.

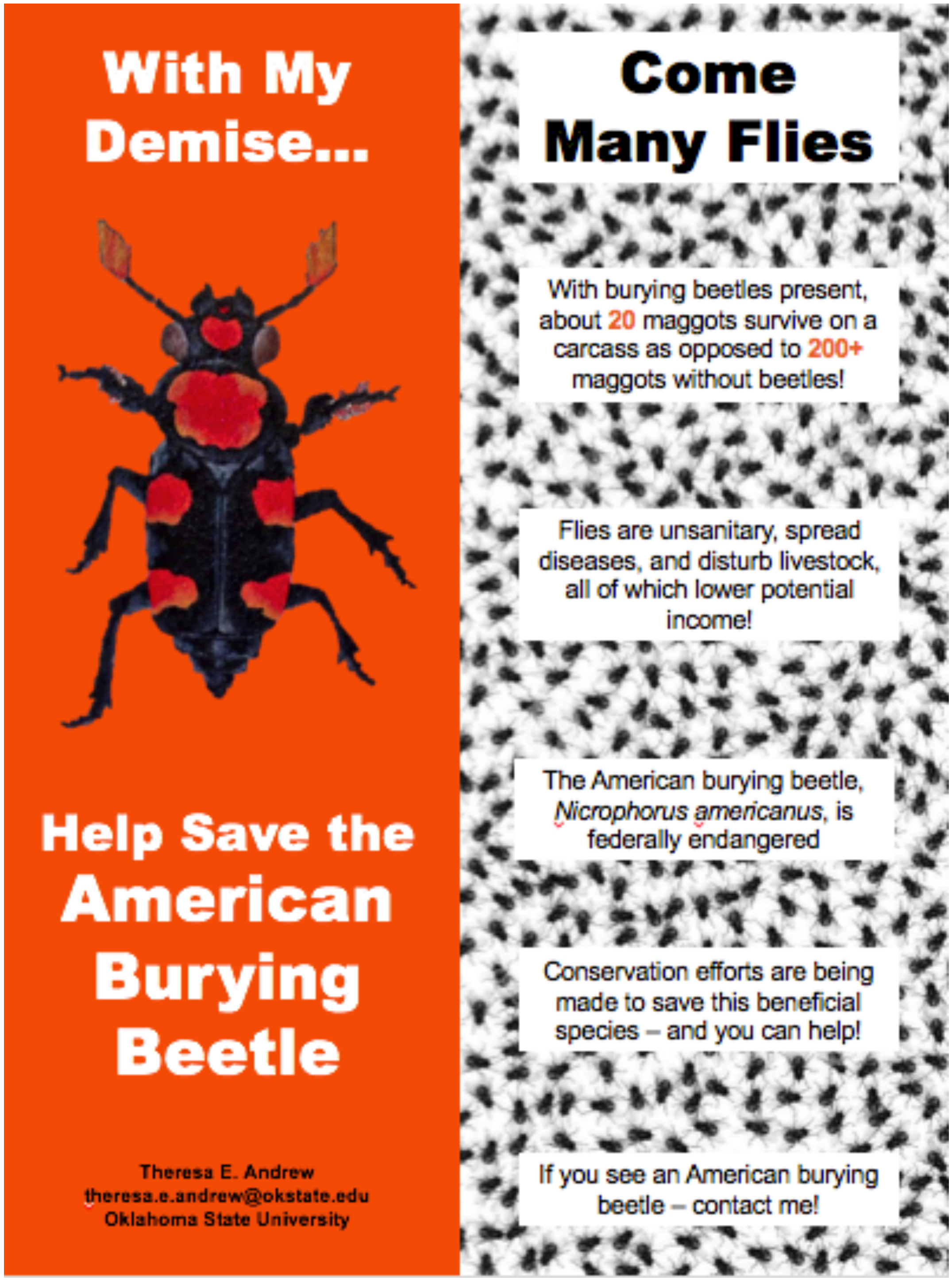

Figure 3. A bookmark with American burying beetle information was handed out to classrooms.

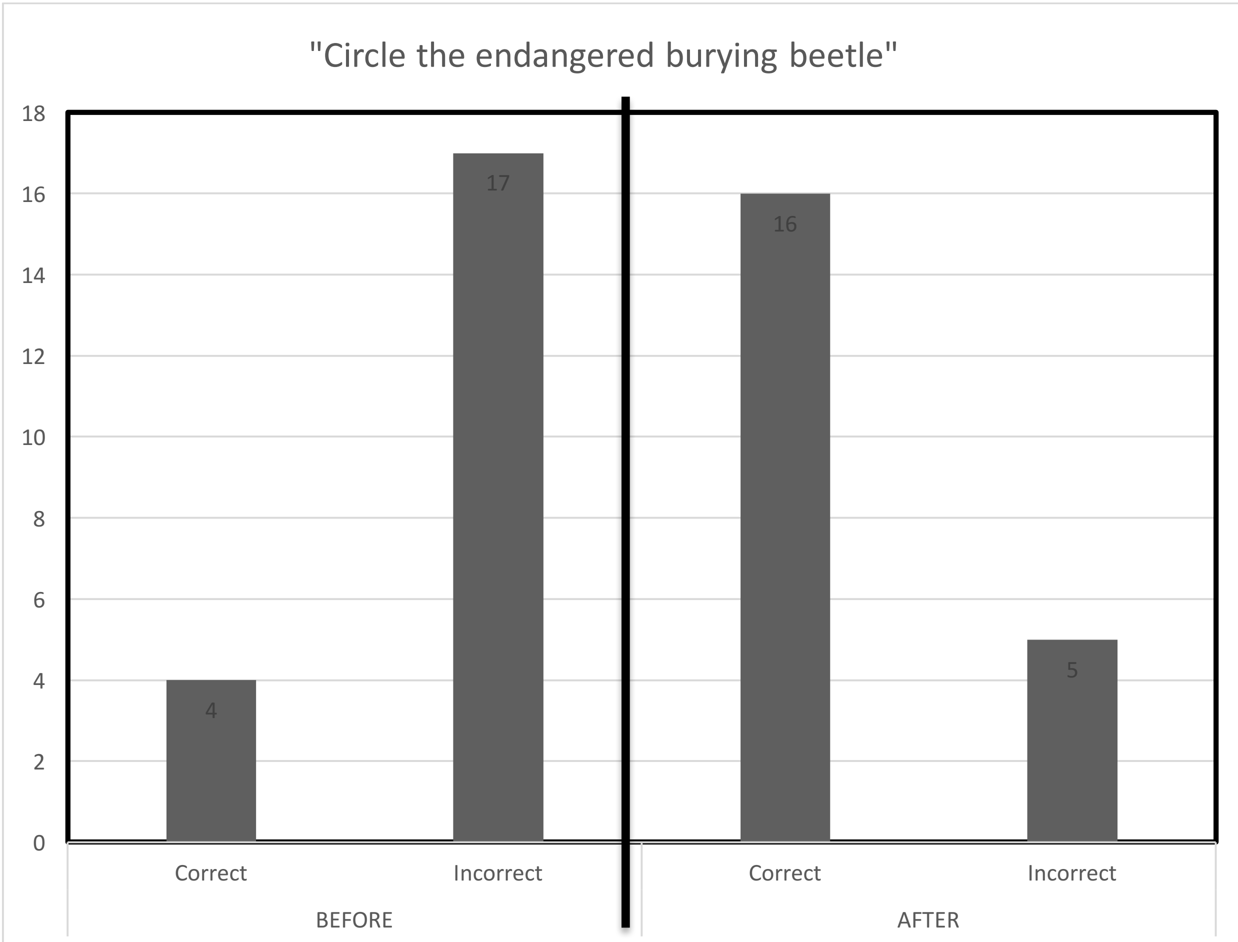

Figure 4. Quiz results from a third grade Rosa Parks elementary school quiz asking students to circle the endangered burying beetle out of a few pictures, with results before and after coloring exercise.

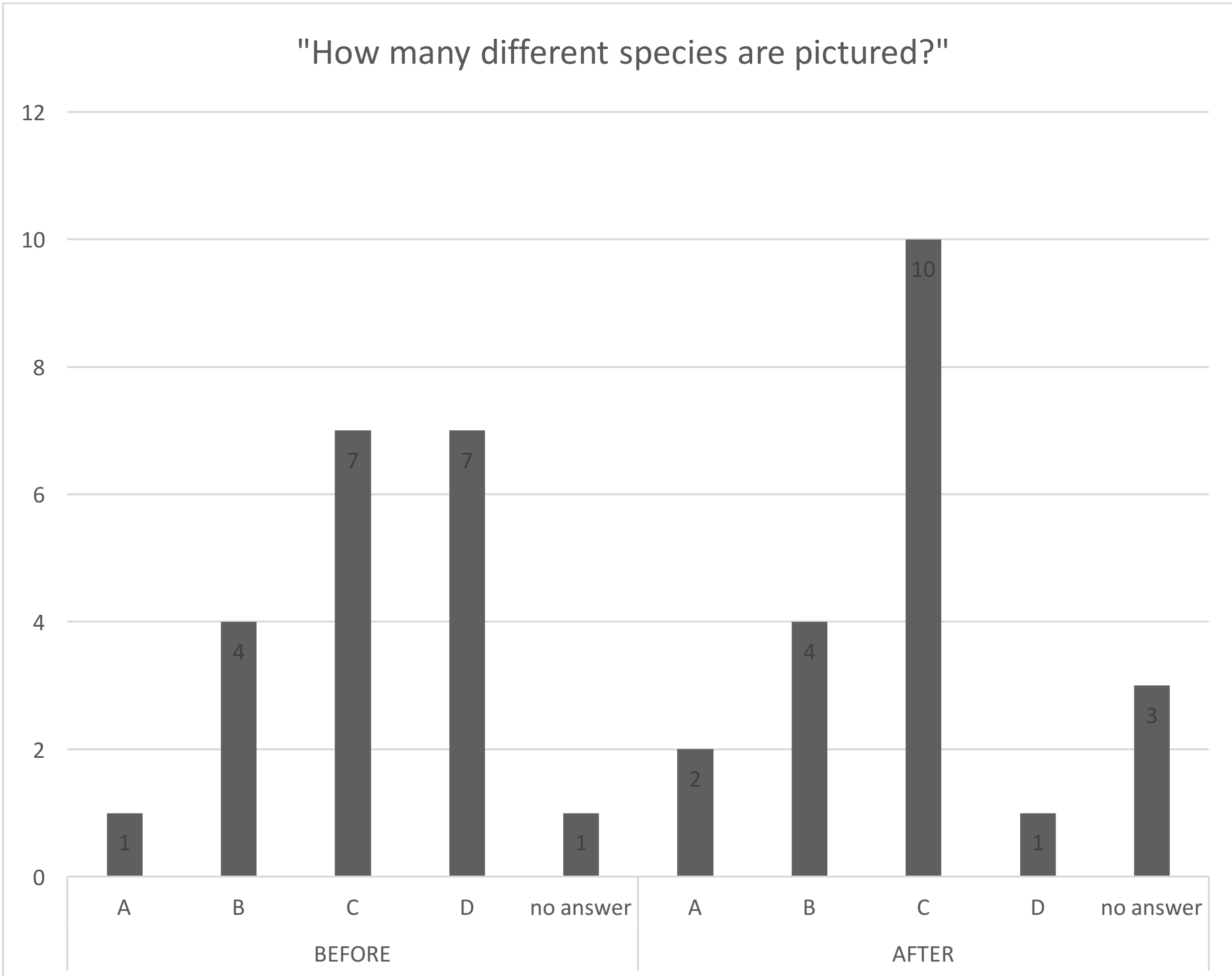

Figure 5. Quiz results from a third grade Rosa Parks elementary school quiz asking students how many different species are pictured in a few illustrations (correct answer C), with results before and after coloring exercise.

CHAPTER IV

MANAGEMENT IMPLICATIONS

The objectives of this project were to examine the effects of bait type for trapping of Silphidae, and to create a citizen science project to educate the public about burying beetles, with the goal of collecting crowdsourced data of burying beetle distribution. All Silphidae beetle species were recorded, with a focus on burying beetles, *Nicrophorus* spp.

As part of the USFWS recovery plan for the American burying beetle, *N. americanus* (Olivier), pitfall trapping is used to locate undocumented populations (Bedick et al.2004). Survey protocols for *N. americanus* have become standardized in order to make data comparable. While past trapping efforts used different methods and baits, recent studies use five trap night method, with a 5-gal or 18.9-L bucket as a pitfall trap. This allows reduced contact among beetles, improved ventilation, and more room for bait (Bedick et al. 2004, Leasure et al. 2012).

While the number of survey nights and the appropriate size for pitfall trap have been examined through research, bait type has not been standardized. Both open bait and placing bait in a closed container to eliminate beetle contact are currently used, and carrion type varies among studies. In Nebraska, previously frozen lab rats, that are thawed and aged in direct sun for 3 day are the current bait (Bedick et al. 2004, USFWS 2015). However, road kill and other rotten animal parts are still used in surveys (Backlund et al 2008, Butler et al. 2013). This study examined bait preference of Silphidae. Whole animal bait was tested with laboratory mice and immature chickens. Mice were used instead of rats in order to use similar bait amounts and have traps in close proximity. Animal parts included tuna fish, beef liver, chicken drumstick, chicken thigh, chicken liver, chicken gizzards and hearts and chicken breast. Potential artificial baits tested included catfish stink baits and a Sigma Aldrich cadaver-scented chemical, Pseudo Corpse ™ Scent. Stink baits tested were Danny King's Catfish Punchbait®, Strike King® Catfish Dynamite bait and Catfish Charlie® Cheese Dip bait. Stink baits were obtained from Walmart or Amazon.com.

During these surveys, all animal bait was rotted in buckets placed outside in direct sun for three days, while artificial bait was kept at room temperature. Whole mice acted as the control. From these results, tuna fish and chicken drumsticks caught significantly more Silphidae than other baits tested. When chicken parts were tested at the same time, chicken drumsticks caught more beetles, but not significantly more than breast meat and whole chicks.

This study shows tuna fish and chicken drumsticks are successful alternatives to whole animals when used as bait for burying beetles. Purchasing cans of tuna fish in spring water or packs of chicken drumsticks at a grocery store eliminates ordering laboratory animals online. These baits may be too messy and difficult to use as open bait; however, using tuna fish or chicken drumsticks could be recommended as the new protocol in trapping *N. americanus* when using a closed bait method. Along with closed bait protocol, captured *N. americanus* need to be fed cat food before being released (USFWS 2015).

The second part of this study examined entomology citizen science projects and launch one for burying beetles. Citizen science is a way for scientists to include volunteers to solve environmental problems over a large area or time range (Trautmann et al. 2013). The Banished Beetle Project was created to be used in primary and secondary education as a class project, but could easily be done individually. Instructions were given for basic pitfall trapping and observation of insects, as well as instruction for baiting. The artificial stink baits tested previously were projected to be used in this project. Danny King's Catfish Punchbait® worked better than other artificial baits tested, and was recommended for use in this project.

While the catfish stink baits did not draw in the same number of beetles as animal baits tested, it can be used without exposing citizen scientists to dead animal bodies. However, potential pathogen exposure may still be an issue, as contents of the stink baits are unknown and may contain animal hair. The Banished Beetle Project originally instructed teachers and citizens to use Solo cups to form a pitfall trap, and larger sand pails were given to classrooms. Results of initial trapping revealed no burying beetles were captured. In future studies, 5-gal buckets may need to be used, similar to the standardized approach in *N. americanus* surveys. When smaller buckets are used as a live trap, it is possible that beetles could escape. Danny King's Catfish Punchbait® can be used as the best artificial bait; however, if the volunteer is willing, a can of tuna fish is recommended as a commercially and easily available bait.

Participants for the project were targeted through Scistarter.com, the Banished Beetle Project's Facebook page, and a Master Gardeners teacher workshop. While all necessary trapping materials and instructions were given to 22 teachers, only 4 fully participated. In addition, two elementary school classrooms and two middle school classrooms participated in the project and used pitfall traps in their school's gardens. Two individual volunteers also participated. While the classrooms were enthusiastic about the project, no burying beetles were captured. Recruiting large numbers of volunteers was difficult, and more efforts should be made to increase participation. Additional funding would help promote the project, and following successful citizen science projects, a website should be constructed. Continuing the Banished Beetle Project further will enhance education about burying beetles and could generate undocumented burying beetle species distribution, possibly even *N. americanus*.

LITERATURE CITED

Bedick, J. C., B.C. Ratcliffe, W.W. Hoback, and L.G. Higley. 1999. Distribution, ecology and population dynamics of the american burying beetle *Nicrophorus americanus* Olivier (Coleoptera, Silphidae)] in south-central nebraska, USA. J. Insect Conserv. 3(3): 171-181.

Backlund, D.C., G. M. Marrone, C. K. Williams, and K. Tilmon. 2008. Population Estimate of the Endangered American Burying Beetle, *Nicrophorus americanus* Olivier (Coleoptera: Silphidae) in South Dakota". Coleop. Bull. 62: 9–15.

Bedick, J.C, Ratcliffe, B.C., and Higley, L.G. 2004. A New Sampling Protocol for the Endangered American Burying Beetle, *Nicrophorus americanus* Olivier (Coleoptera: Silphidae). The Coleop. Bull. 58: 57–70.

Butler, S. R., Harms, R., Farnsworth-hoback, K., Koupal, K., Jurzenski, J., & Hoback, W. W. 2013. Standardized capture rates of the endangered American burying beetle, *Nicrophorus americanus* Olivier (Coleoptera: Silphidae) using different trap protocols. J. Insect Conserv. 17(3): 607-613.

Leasure, D. R., D. M. Rupe, E. A. Phillips, D. R. Opine, and G. R. Huxel. 2012. Efficient new above-ground bucket traps produce comparable data to that of standard transects for the endangered American burying beetle, *Nicrophorus americanus* Olivier (Coleoptera: Silphidae). Coleop. Bull. 66:209–218.

Trautmann, N, J. Fee, and T.M. Tomasek. 2013, Citizen Science: 15 Lessons That Bring Biology to Life, 6-12, National Science Teachers Association, Arlington, VA, USA.

USFWS (U.S. Fish and Wildlife Service). 2015. American burying beetle *Nicrophorus americanus* Oklahoma Presence/Absence Live-trapping Survey Guide.

APPENDIX I

Table 1. The mean number of Silphidae captured per day by bait type in Garden Co., NE, July 2 to July 23, 2015. The bait types include rotten tuna fish, rotten chicken drumstick, rotten mouse, Danny King's Catfish Punchbait®, Strike King® Catfish Dynamite Blood Bait, and Pseudo™ Corpse Scent Formulations I and II obtained from Sigma Aldrich. Data were transformed by square root and analyzed with an Analysis of Variance followed by a Fishers LSD test. Means followed by the same letter are not significantly different ($P < 0.05$).

DATE	TRT	MNTOTSILPHS	SETOTSILPHS	PVALUE
1	CHEESEBA	0.00 a	0.00000	0.0758
1	CHICKEN	9.75 a	8.12788	
1	CONTROL	0.00 a	0.00000	
1	MOUSE	0.50 a	0.50000	
1	PUNCHBAI	0.00 a	0.00000	
2	CHEESEBA	0.00 a	0.00000	0.1141
2	CHICKEN	2.75 a	1.88746	
2	CONTROL	0.00 a	0.00000	
2	MOUSE	0.25 a	0.25000	
2	PUNCHBAI	0.00 a	0.00000	
3	CHEESEBA	3.50 a	3.50000	0.1559
3	CHICKEN	3.00 a	1.35401	
3	CONTROL	0.00 a	0.00000	
3	MOUSE	1.25 a	0.75000	
3	PUNCHBAI	0.00 a	0.00000	
4	CHEESEBA	0.00 a	0.00000	0.0747
4	CHICKEN	2.00 a	0.70711	
4	CONTROL	0.00 a	0.00000	
4	MOUSE	1.00 a	1.00000	
4	PUNCHBAI	0.25 a	0.25000	
5	CHEESEBA	0.00 b	0.00000	<.0001
5	CHICKEN	8.75 a	3.19831	
5	CONTROL	0.00 b	0.00000	
5	MOUSE	0.50 b	0.28868	
5	PUNCHBAI	0.00 b	0.00000	
6	CHEESEBA	0.00	0.00000	
6	CHICKEN	0.00	0.00000	
6	CONTROL	0.00	0.00000	
6	MOUSE	0.00	0.00000	
6	PUNCHBAI	0.00	0.00000	
7	CHEESEBA	0.00 b	0.00000	<.0001
7	CHICKEN	2.75 a	1.18145	
7	CONTROL	0.00 b	0.00000	

7	MOUSE	0.00 b	0.00000	
7	PUNCHBAI	0.00 b	0.00000	
8	CHEESEBA	0.00 a	0.00000	0.0524
8	CHICKEN	9.25 a	6.01907	
8	CONTROL	0.00 a	0.00000	
8	MOUSE	0.00 a	0.00000	
8	PUNCHBAI	1.50 a	1.50000	
9	CHEESEBA	2.75 b	2.75000	0.0022
9	CHICKEN	10.50 a	1.32288	
9	CONTROL	0.00 b	0.00000	
9	MOUSE	2.00 b	1.08012	
9	PUNCHBAI	0.75 b	0.47871	
10	CHEESEBA	1.00 b	1.00000	0.0009
10	CHICKEN	5.50 a	1.19024	
10	CONTROL	0.00 b	0.00000	
10	MOUSE	1.25 b	0.75000	
10	PUNCHBAI	0.00 b	0.00000	
11	CHEESEBA	0.00 c	0.00000	<.0001
11	CHICKEN	13.00 a	3.62859	
11	CONTROL	0.00 c	0.00000	
11	MOUSE	2.00 b	0.91287	
11	PUNCHBAI	0.25 bc	0.25000	
12	CHICKEN	7.00 a	2.44949	<.0001
12	CONTROL	0.00 b	0.00000	
12	DYNAMITE	0.00 b	0.00000	
12	MOUSE	0.75 b	0.47871	
12	PUNCHBAI	0.00 b	0.00000	
13	CHICKEN	20.25 a	4.26956	0.0010
13	CONTROL	0.00 c	0.00000	
13	DYNAMITE	6.25 bc	5.60320	
13	MOUSE	6.75 b	2.59406	
13	PUNCHBAI	0.50 c	0.28868	
14	CHICKEN	22.75 a	4.64354	<.0001
14	CONTROL	0.00 c	0.00000	
14	DYNAMITE	0.25 c	0.25000	
14	MOUSE	9.50 b	2.72336	
14	PUNCHBAI	1.75 c	0.85391	
15	CHICKEN	8.00 a	3.3166	<.0001
15	CONTROL	0.00 b	0.0000	
15	DYNAMITE	0.00 b	0.0000	
15	MOUSE	5.50 a	1.8484	
15	PUNCHBAI	0.00 b	0.0000	
16	CHICKEN	8.25 b	0.7500	<.0001
16	CONTROL	0.00 c	0.0000	
16	DYNAMITE	0.00 c	0.0000	
16	MOUSE	11.50 a	3.1225	
16	PUNCHBAI	2.50 bc	1.8484	
17	CHICKEN	22.50 a	4.3684	<.0001
17	CONTROL	0.00 c	0.0000	
17	DYNAMITE	0.00 c	0.0000	
17	MOUSE	2.25 b	0.6292	
17	PUNCHBAI	1.00 bc	0.5774	

18	CHICKEN	19.50 a	1.8484	<.0001
18	CONTROL	0.00 c	0.0000	
18	DYNAMITE	0.00 c	0.0000	
18	MOUSE	9.75 b	4.1908	
18	PUNCHBAI	8.75 b	4.1708	
19	CHICKEN	20.75 a	3.6142	<.0001
19	CONTROL	0.00 b	0.0000	
19	DYNAMITE	0.00 b	0.0000	
19	MOUSE	12.75 a	3.7053	
19	PUNCHBAI	2.25 b	1.4361	
20	CHICKEN	11.25 a	2.4958	0.0047
20	CONTROL	0.00 c	0.0000	
20	DYNAMITE	0.50 c	0.5000	
20	MOUSE	10.25 ab	1.6520	
20	PUNCHBAI	6.75 bc	6.7500	
21	CHICKEN	53.00 a	3.5824	<.0001
21	CONTROL	0.00 c	0.0000	
21	DYNAMITE	4.25 b	3.9238	
21	MOUSE	3.50 bc	2.8431	
21	PUNCHBAI	3.50 bc	0.8660	
22	CHICKEN	130.75 a	35.4950	<.0001
22	CONTROL	0.00 c	0.0000	
22	DYNAMITE	7.25 c	6.9207	
22	MOUSE	30.50 b	12.2780	
22	PUNCHBAI	5.00 c	2.0817	
23	CHICKEN	135.50 a	57.0636	0.0021
23	CONTROL	0.00 c	0.0000	
23	DYNAMITE	18.75 bc	18.7500	
23	MOUSE	31.00 b	7.0475	
23	PUNCHBAI	1.50 bc	0.2887	
24	CHICKEN	173.50 a	39.9427	<.0001
24	DYNAMITE	0.25 b	0.2500	
24	MOUSE	8.25 b	5.9214	
24	PUNCHBAI	0.50 b	0.2887	
24	TWOMALES	0.75 b	0.7500	
25	CHICKEN	127.25 a	54.0330	0.0007
25	DYNAMITE	7.25 bc	5.7064	
25	MOUSE	42.75 ab	15.3372	
25	PUNCHBAI	4.50 c	1.8484	
25	TWOMALES	0.00 c	0.0000	
26	CHICKEN	105.00 a	28.9165	<.0001
26	DYNAMITE	2.50 b	1.8930	
26	MOUSE	3.75 b	2.4281	
26	PUNCHBAI	1.00 b	0.4082	
26	TWOMALES	0.00 b	0.0000	
27	CHICKEN	111.00 a	15.2480	<.0001
27	DYNAMITE	5.00 b	4.6726	
27	MOUSE	4.25 b	2.0156	
27	PUNCHBAI	1.25 b	1.2500	
27	TWOMALES	0.00 b	0.0000	

28	CHICKEN	80.75 a	10.5465	<.0001
28	DYNAMITE	3.25 b	3.2500	
28	MOUSE	2.50 b	1.8484	
28	PUNCHBAI	0.75 b	0.7500	
28	TWOMALES	0.00 b	0.0000	
29	CHICKEN	53.25 a	19.6781	0.0531
29	CORPSE1	0.00 a	0.0000	
29	CORPSE2	0.50 a	0.5000	
29	MOUSE	32.75 a	31.1057	
29	PUNCHBAI	2.25 a	1.0308	
29	TWOMALES	2.50 a	2.5000	
30	CHICKEN	141.75 a	41.1185	<.0001
30	CORPSE1	0.00 c	0.0000	
30	CORPSE2	0.00 c	0.0000	
30	MOUSE	52.25 b	17.7781	
30	PUNCHBAI	40.00 b	13.1212	
30	TWOMALES	0.25 c	0.2500	
31	CHICKEN	213.00 a	59.2157	<.0001
31	CORPSE1	0.00 c	0.0000	
31	CORPSE2	0.50 c	0.2887	
31	MOUSE	70.75 b	13.6282	
31	PUNCHBAI	38.50 b	24.8948	
31	TWOMALES	0.00 c	0.0000	
32	CHICKEN	183.00 a	21.4515	<.0001
32	CORPSE1	0.25 c	0.2500	
32	CORPSE2	0.25 c	0.2500	
32	MOUSE	62.50 b	22.6661	
32	PUNCHBAI	8.25 c	2.8100	
32	TWOMALES	0.25 c	0.2500	
33	CORPSE1	0.00 c	0.0000	<.0001
33	CORPSE2	0.25 bc	0.2500	
33	MOUSE	18.75 b	14.4648	
33	PUNCHBAI	8.00 bc	3.0277	
33	TUNA	209.00 a	51.5089	
33	TWOMALES	0.00 c	0.0000	
34	CORPSE1	0.50 c	0.5000	<.0001
34	CORPSE2	0.00 c	0.0000	
34	MOUSE	25.25 b	7.8249	
34	PUNCHBAI	24.75 b	7.2385	
34	TUNA	45.75 a	5.9774	
34	TWOMALES	0.25 c	0.2500	
35	CORPSE1	0.00 c	0.0000	<.0001
35	CORPSE2	0.00 c	0.0000	
35	MOUSE	8.25 b	1.8875	
35	PUNCHBAI	28.50 b	16.0442	
35	TUNA	155.75 a	25.4538	
35	TWOMALES	0.00 c	0.0000	
36	CORPSE1	0.00 c	0.0000	<.0001
36	CORPSE2	0.00 c	0.0000	
36	MOUSE	11.00 b	5.4467	
36	PUNCHBAI	4.50 bc	2.8723	
36	TUNA	243.50 a	55.0704	

36	TWOMALES	0.00 c	0.0000	
37	CORPSE1	0.00 c	0.0000	<.0001
37	CORPSE2	1.00 c	0.7071	
37	MOUSE	2.50 bc	1.5546	
37	PUNCHBAI	7.00 b	2.2730	
37	TUNA	130.25 a	16.8542	
37	TWOMALES	0.00 c	0.0000	
38	CORPSE1	1.75 b	1.0308	<.0001
38	CORPSE2	0.00 b	0.0000	
38	MOUSE	0.75 b	0.4787	
38	PUNCHBAI	4.25 b	2.0156	
38	TUNA	117.00 a	34.3390	
38	TWOMALES	0.25 b	0.2500	
39	CORPSE1	0.25 c	0.2500	<.0001
39	CORPSE2	0.25 c	0.2500	
39	MOUSE	146.75 a	36.6410	
39	PUNCHBAI	27.00 b	6.4161	
39	TUNA	222.00 a	43.1412	
39	TWOMALES	0.25 c	0.2500	
40	CORPSE1	0.25 c	0.2500	<.0001
40	CORPSE2	1.00 c	0.0000	
40	MOUSE	50.00 b	20.8846	
40	PUNCHBAI	26.50 b	8.1904	
40	TUNA	282.75 a	63.4316	
40	TWOMALES	0.75 c	0.4787	
41	CORPSE1	6.25 cd	3.8810	<.0001
41	CORPSE2	0.50 d	0.2887	
41	MOUSE	24.50 b	11.5938	
41	PUNCHBAI	9.50 bc	2.7839	
41	TUNA	183.00 a	24.4097	
41	TWOMALES	0.00 d	0.0000	
42	CORPSE1	1.00 c	1.0000	<.0001
42	CORPSE2	1.00 c	0.7071	
42	MOUSE	9.25 b	5.0724	
42	PUNCHBAI	8.50 b	2.2174	
42	TUNA	160.00 a	5.6716	
42	TWOMALES	2.75 c	2.7500	

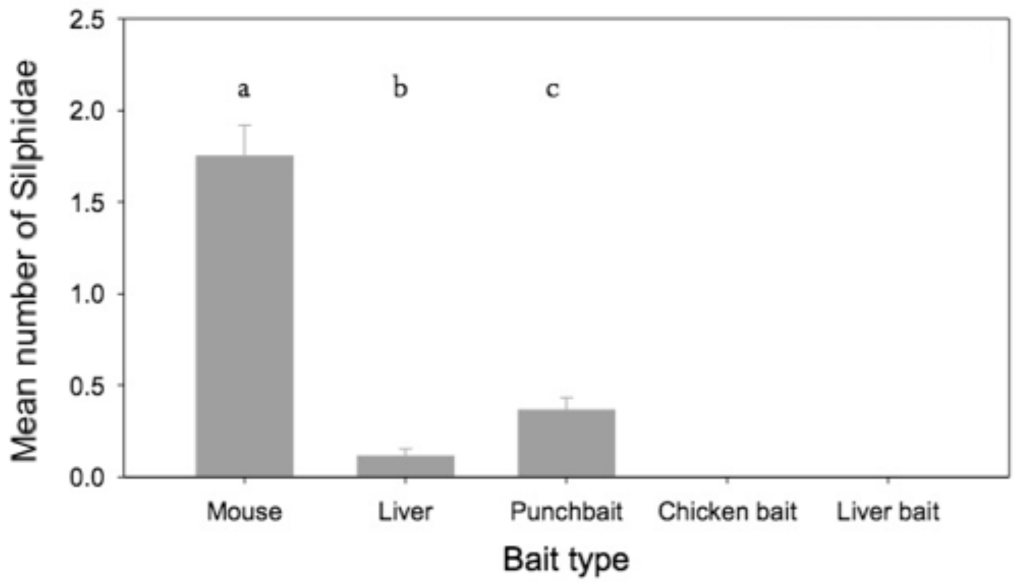

Figure 1. Mean (±1 S.E.) of carrion beetles captured near Stillwater, OK, September 8–November 11, 2014, using different types of bait*.

*The bait types include rotten mouse, rotten beef liver, Danny King's Catfish Punchbait®, Little Stinker® Chicken Liver Bait, Little Stinker® Liver and Blood Bait. Data were transformed by square root and analyzed with an Analysis of Variance followed by a Fisher's LSD test. Means followed by the same letter are not significantly different ($P < 0.05$).

APPENDIX II

The Banished Beetle Project

- **My goal is to involve citizen scientists in the pursuit of saving the endangered American burying beetle – I need your help!**
- In this packet you will find background information on the American burying beetle and classroom experiments.
- I introduce pitfall trapping for the amateur entomologist, as well as an advanced activity to trap burying beetles.
- I encourage your students to get outside, get their hands dirty and marvel at the many insects they will find.

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The American Burying Beetle (ABB)

The American burying beetle, *Nicrophorus americanus* (Oliver), belongs to the order Coleoptera, and is in the family Silphidae, which groups together all the carrion and burying beetles. ABB are easy to recognize, as they are large, about 25-35 mm in length and have distinctive markings. They are shiny black with two orange-red spots on each elytron, a star shaped red marking on the protonum, as well as an orange facial marking and orange-tipped clubbed antennae. Males and females can be told apart by the facial marking; males have a square and females have a triangle. Adults are fully nocturnal and are most active from May through September, and breed during June and July. They are habitat generalists and have a broad vegetational landscape tolerance and have been found in grasslands, scrublands and forest edges. They require an area with an abundance of bird and mammal carrion, and proper soil to bury the carrion.

They are unique among non-social insects because they display parental care. The male ABB will locate a carcass, and then attract a female with his pheromones. Together they will bury the carcass, clean it of its feathers or fur and excrete oral and anal secretions to delay decomposition. Along with all other beetles, burying beetles are holometabolous with a life cycle consisting of egg, larvae, pupae and adult. Eggs are laid in a tunnel near the carrion, and can range from 3 to 30. At least one adult, but usually both, will provide care for the young until at least the third instar. Even though the larvae have the ability to eat with chewing mouthparts just like the adults, the adults will feed them predigested carrion. They also provide care by protecting their young from predators. Larvae grow rapidly, and in about 10-14 days crawl off and pupate in the nearby soil and emerge as adults in 5-6 weeks.

The American burying beetle has been listed as endangered by the United States Fish and Wild- life Service since July 13, 1981. It is one of only about 30 insects protected under the Endangered Species Act of 1973. Formerly, ABB were found throughout temperate eastern North America, as well as Minnesota, South Dakota, Nebraska, Oklahoma and Texas. There has been a 90% decrease in their original range, and are currently present in Rhode Island, South Dakota, Kansas, Arkansas, Nebraska and eastern Oklahoma. There are many hypotheses for their decline including habitat alteration, competition with vertebrates, lack of appropriately sized carrion, use of pesticides, light pollution and more. The extinction of two appropriately sized carrion, the passenger pigeon and the greater prairie chicken, may also explain a decline in ABB populations. Under section 4 of the Endangered Species Act, it is required that the Fish and Wildlife Service develop recovery plans. The recovery plan for ABB was completed in 1991 and includes monitoring existing wild populations, maintaining captive populations, conducting surveys for additional populations and conducting additional reintroductions. Progress has been made through these efforts, and ABB have even been found in 13 counties of eastern Oklahoma.

This banished beetle plays a vital role in the environment as a re- cycler and undertaker. They significantly reduce fly populations, saving humans from the filth, diseases and agricultural dilemmas that flies cause. Research is also being done to investigate the oral and anal secretions the beetles produce as a possible antibiotic for humans. The first step to saving this species is knowledge, which is where you come in!

Insect Conservation

A look at the American Burying Beetle

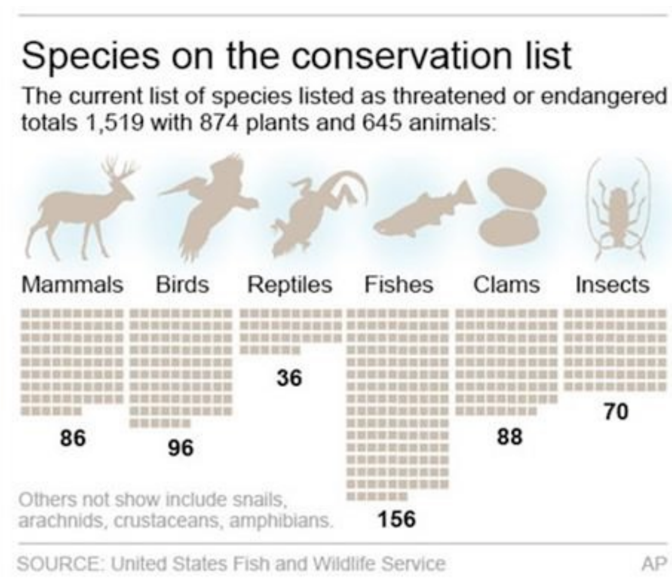
Introduction: Most people understand that wildlife conservation is important, that our own survival may depend on other species that we share the planet with. Some people are even fascinated with wildlife and don't want to see their favorite animals go extinct. But what about insects? Insects make up about four fifths of animal biodiversity of earth, and play a large part in enabling other types of wildlife to survive.

Objectives: Upon completion of this module you shall:

- Learn about the U.S. Fish & Wildlife Service's Endangered Species Act
- Be able to use a pitfall trap
- Be able to identify the American burying beetle

Endangered Species Act

The U.S. Fish and Wildlife Service created the Endangered Species Act after realizing that many native plants and animals are at risk of going extinct. The Endangered Species Acts serves to protect and recover imperiled species. When an organism is placed under ESA, it is defined as threatened or endangered. If it is threatened, that means it is likely to become endangered in the forseeable future. If it is endangered, it means the species is in danger of extinction throughout all or most of its range. There are currently 2,054 species listed under the Endangered Species Act. The ESA protects its listed species by prohibiting the "take" of these animals, deeming it unlawful to collect or harm one.



"The biodiversity crisis is undeniably an insect biodiversity crisis. Yet insect conservation remains the awkward "kid sister" to vertebrate conservation." (Dunn 2005)

DIY Pitfall Trap

What can you do to help conserve insect biodiversity?

- Observation is key
- Go in your backyard or playground and see what insects and arthropods you find!

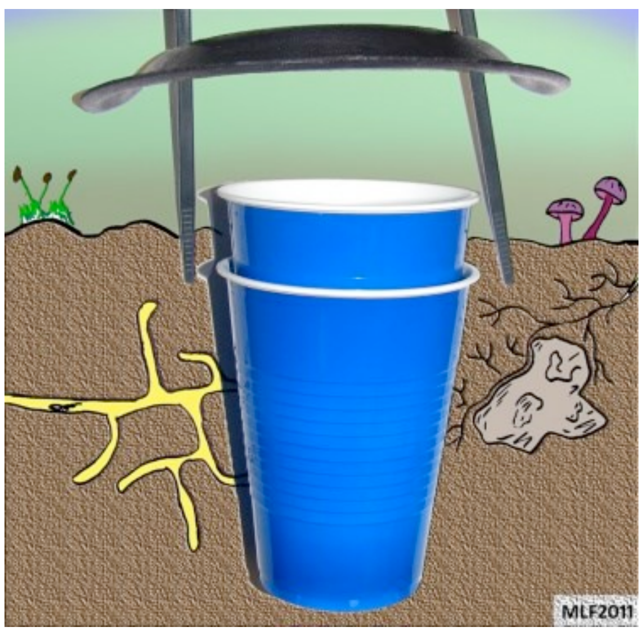
What you need:

- Two solo cups or similar sized cups (yogurt cup, etc)
- A shovel
- Styrofoam plate
- Chopsticks

Activity TIME!!!!

Pick a spot outside to dig your pitfall trap, preferably away from a lot of activity. Choose an open pasture or a spot in a forest. Dig a hole in the ground with your shovel that's big enough to fit your solo cup (or your cup of choice). Once you have your hole, place both cups securely in the ground so that the top of the cups are flush with the ground. Fill your cup with about an inch of soapy water. Using your styrofoam plate and chopsticks (or similar materials), poke the chopsticks through the plate and secure the chopsticks into the ground so that the plate hovers above your trap. This will stop rain from flooding your trap.

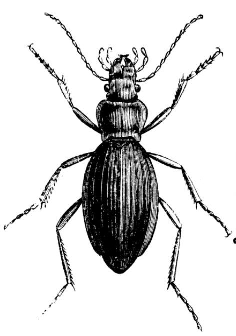
Step 1: Dig a hole
Step 2: Place cups in hole
Step 3: Place soapy water in cup
Step 4: Position rain shield
Step 5: Collect some insects!!!



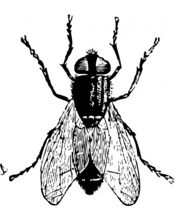
Time to Collect Data!

Now that you have your pitfall trap set up and ready to go, you can start observing what insects you catch in your trap and start collecting data. Check the trap every Monday, Wednesday and Friday for two weeks, fill out this data sheet and look at your results!

DATE:	Coleoptera (Beetles)	Diptera (Flies)	Hemiptera (True bugs)	Hymenoptera (Ants, bees, wasps)	Orthoptera (Grasshopers, katydids)	Others

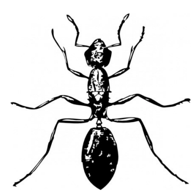


Coleoptera

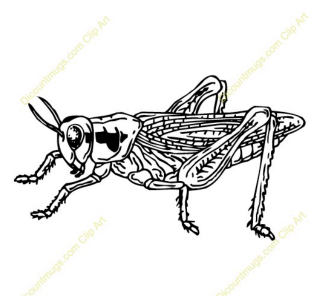


Diptera

Hemiptera



Hymenoptera



Orthoptera

Burying Beetle Baited Trap

Advanced Activity!!!

Use the same pitfall trap, but add a bait to trap for burying and carrion beetles.

- The American burying beetle, like all burying and carrion beetles, use dead animals for their reproduction and food source.
- Using a bait that imitates the smell of dead animal can attract them to your trap!
- Be sure to **NOT** add soapy water to your cups this time, in case of collecting American burying beetles (remember, they are protected under the Endangered Species Act!)

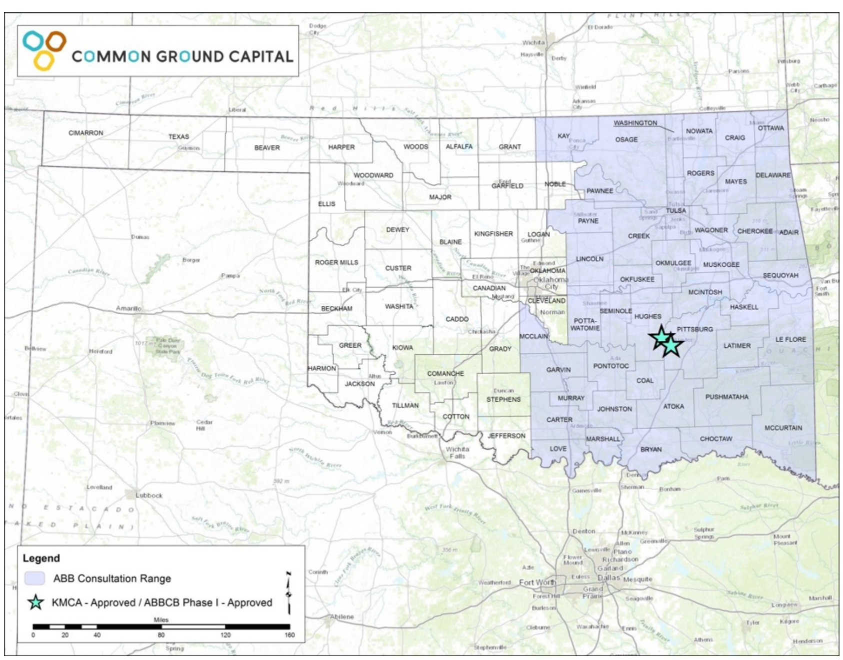
What you need:

- Two solo cups or similar sized cups (yogurt cup, etc)
- A shovel
- Styrofoam plate
- Chopsticks
- Danny King's Catfish Punch Bait (available at Walmart)

This can be added in a smaller cup or a baggie with holes in it, and placed inside your pitfall cups

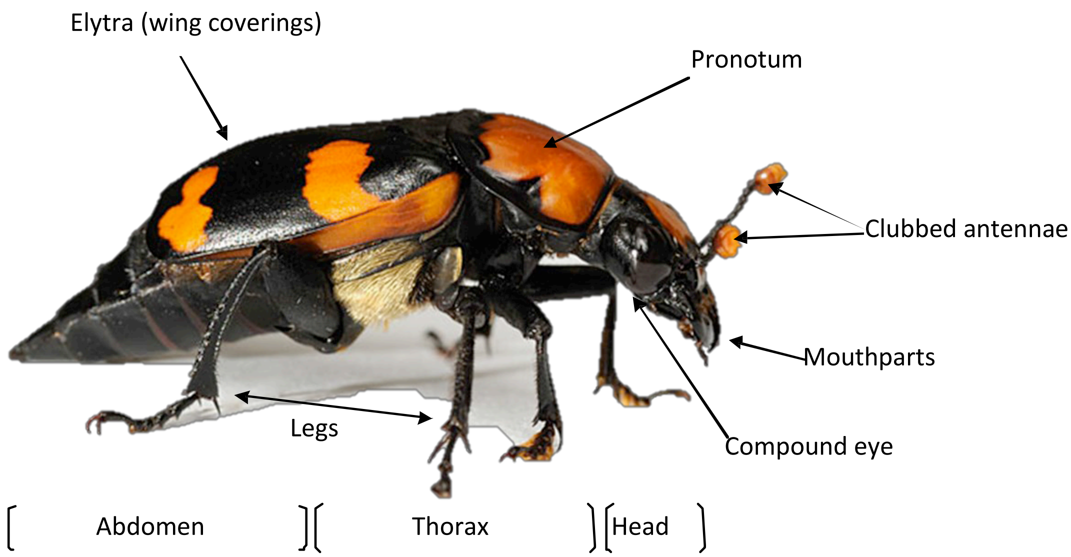
ABB are in OK!

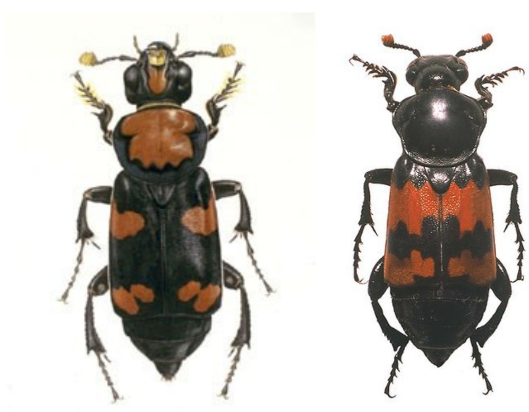
Please be aware of your location and the possibly of catching American burying beetles. If you are in any of the eastern, blue counties of Oklahoma shown below, please use your pitfall trap with caution! Check them frequently, so as not to let the beetles trapped for too long.



Oklahoma's Brightest Orange!

ABB Anatomy

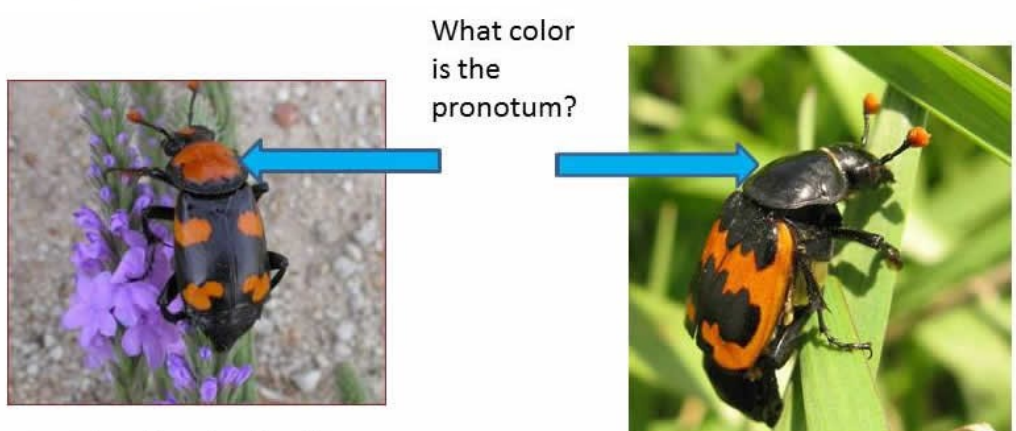




Look Closely

The **American burying beetle** has distinctive orange markings on its head, pronotum and elytra. But, don't be fooled! Other species have similar markings.

- Can you tell the difference between these two?
- Which one is the American burying beetle?



American Burying Beetle

Nicrophorus marginatus

Common Burying & Carrion Beetle Identification:

Nicrophorus marginatus

"Marg" have bright orange bands that connect on their sides.

Nicrophorus carolinus

"Carols" have small orange markings, the bottom two in a "C" shape. There is no notch on the pronotum.

Nicrophorus tomentosus

"Toms" also have bright orange bands, but they do not connect. The prontum is yellow and fuzzy.

Necrodes surinamensis

They have a flatter, wider appearance, with tiny orange dots at the bottom of the elytra.

Nicrophorus orbicollis

"Orbies" have smaller orange markings that are more circular. The is a notich in the middle of the pronotum.

Necrophila americana

They are flattened and round, no orange markings but they have a distinctly yellow pronotum.

Coleoptera: Silphidae

The Burying and Carrion Beetles

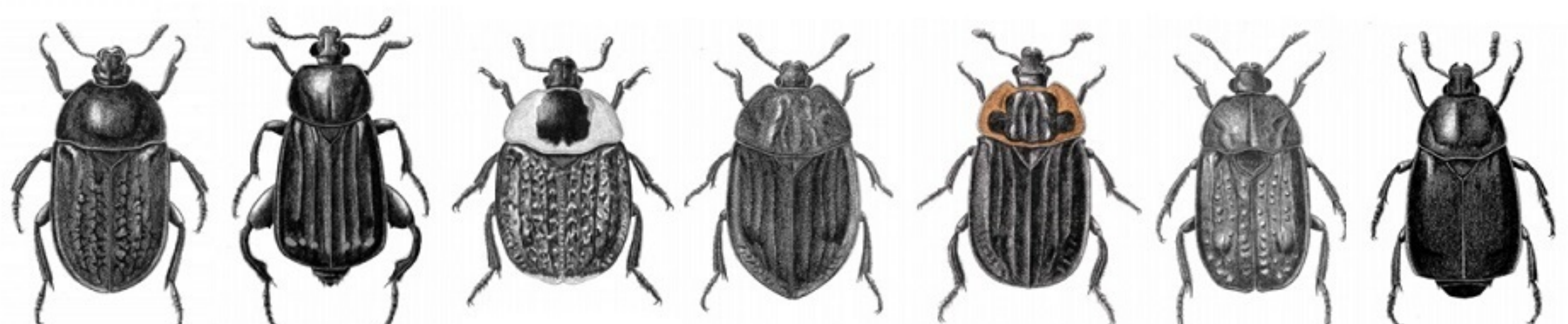
Nicrophorus americanus

The American Burying Beetle

Burying Beetles

Nicrophorus carolinus · *Nicrophorus guttula* · *Nicrophorus marginatus* · *Nicrophorus obscurus* · *Nicrophorus orbicollis* · *Nicrophorus pustulatus* · *Nicrophorus tomentosus*

Carrion Beetles



Heterosilpha ramosa · *Necrodes surinamensis* · *Necrophila americana* · *Oiceoptoma inaequale* · *Oiceoptoma novaboracense* · *Thanatophilus lapponicus* · *Thanatophilus truncatus*

Time to Collect Data!

Now, repeat the previous trapping exercise, this time adding stink bait. With your new knowledge on burying and carrion beetles, record what beetles you find. Please do not use water or any substance in the bottom of your traps, keep your beetles alive! Also, keep in mind that the American burying beetle is rare and won't always be found. Any information on burying beetles is a useful contribution to my research—thank you!

What to do if you catch an American burying beetle:

- Take a picture!
- **Carefully release the beetle back into the environment**
- Contact the U.S. Fish & Wildlife Service

  Anita Barstow, anita_barstow@fws.gov
- Contact me with pictures and any data

DATE:	*Nicrophorus americanus*	*Nicrophorus marginatus*	*Nicrophorus tomentosus*	*Necrodes su-rinemensis*	*Necrophila americana*	Other

VITA

Theresa Elizabeth Andrew

Candidate for the Degree of

Master of Science

Thesis: ANIMAL AND ARTIFICIAL BAIT PREFERENCE OF SILPHIDAE AND A CITIAZEN SCIENCE PROJECT ON THE AMERICAN BURYING BEETLE, *NICROPHORUS AMERICANUS*

Major Field: Entomology and Plant Pathology

Biographical:
Theresa E. Andrew grew up in Haddonfield, NJ, a suburb of Philadelphia, PA. As a young girl she was fascinated by insects, particularly caterpillars. After high school graduation in 2008, Theresa attended Bryn Mawr College, moved and transferred to Delaware Technical and Community College and then University of Delaware. While working towards a degree in Wildlife Conservation, she picked up Entomology as a second major. While working toward her degree requirements, she was also entomology club secretary and agricultural college council secretary, as well as an employee in the Department of Entomology and Wildlife Ecology. Following her undergraduate studies she joined the Department of Entomology and Plant Pathology at Oklahoma State University in 2014. During her Master's program, she gave multiple presentations all over the nation including Entomological Society of America (ESA) 2015 national meeting in Minneapolis, MN, where she also organized a symposium, "Citizen Scientists Contribute to Conservation." She also presented at Southwestern Branch ESA meetings in 2015 and 2016, as well as the joint Kansas-Arkansas Entomological Society meeting, 2015, and the first OSU Soil Biology Symposium, 2015. After obtaining her Master's Degree, Theresa intends to continue her education by pursuing a PhD in Entomology at Purdue University.

Education:

Completed the requirements for the Master of Science in Entomology at Oklahoma State University, Stillwater, Oklahoma in May, 2016.

Completed the requirements for the Bachelor of Science in Entomology and Wildlife Ecology at University of Delaware, Newark, Delaware in 2014.

Experience:

Entomology and Plant Pathology Grad. Student Assoc. Vice President, 2015-16

Graduate Teaching Assistant, Oklahoma State University, 2014-2015

Assistant, Insect Reference Collection, University of Delaware, 2014

Professional Memberships:

Entomological Society of America
Southwestern Entomological Society