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SPECIES DIVERSITY AND SEASONAL ABUNDANCE OF SCARABAEOIDEA AT FOUR LOCATIONS IN SOUTH CAROLINA

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SPECIES DIVERSITY AND SEASONAL ABUNDANCE OF SCARABAEOIDEA AT FOUR LOCATIONS IN SOUTH CAROLINA

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ABSTRACT

Using light, flight-intercept, and pitfall traps, 74, 327 specimens of Scarabaeoidea were captured at four golf courses in South Carolina during 2009-2010. Aphodiinae were identified only to the subfamily level and totaled 57,502 specimens. 16,825 specimens in 47 genera and 104 species in the families Ceratocanthidae, Geotrupidae, Hybosoridae, Lucanidae, Passalidae, Scarabaeidae (excluding Aphodiinae), and Trogidae were identified based on morphological characteristics. Similar to other southeastern studies focusing on phytophagous scarabs, the most abundant species consisted of *Dyscinetus morator* (Fabricius), *Euetheola humilis* (Burmeister), *Cyclocephala lurida* Bland, and *Hybosorus illigeri* Reiche. The most speciose genus captured was *Phyllophaga* Harris, totaling 22 species. A new state record for *Phyllophaga inepta* (Horn) is reported. Light traps captured the highest number of specimens (94% of total specimens captured), followed by pitfall trapping (4%), and flight-intercept traps (2%). Light traps captured the highest number of species (83), followed by flight-intercept traps (52), and pitfall traps (15). Flight-intercept traps captured many Cetoniinae and Scarabaeinae species that were not captured in light traps, suggesting that these species may be non-phototactic. Pitfall traps yielded comparatively fewer species, many of which were already present in high numbers in light traps. The highest species diversity occurred at Camden Country Club. The proximity of this location to the convergence of three physiographical regions may explain the unusually high diversity. Male-biased sex ratios were more prevalent in all trap types.

DEDICATION

I would like to dedicate this work to my mother Teresa, my father Walter, and my brother Mark, for supporting my interest in entomology in every conceivable way from a very young age, and for developing their own sense of enthusiasm for "the little things in life." As only my family could know, my love for entomology all too frequently developed into *an entire home* filled with insects. Beyond simple tolerance, my family's embracement of what many would have considered an ecosystem of unwanted guests is beyond comparison. I would not have developed a love for insects as strongly as I have were it not for my family, and for this I owe them unlimited gratitude. I would also like to dedicate this work to my infant niece, Cameron. I happily anticipate a future of answering, "What's this bug?"

I would also like to dedicate this work to my neighbors, the Doziers. Their gardens presented a paradise for the aspiring naturalist, a paradise where I was always welcome and treated as family. I would especially like to thank Adam for sharing my interest in insects and for so many wonderful summer days spent outdoors. I occasionally recall our tireless search for a particular type of diving beetle among our neighborhood streams. After all these years, I am happy that I can finally call those elusive dytiscids by their proper name: *Acilius*.

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CHAPTER ONE

INTRODUCTION TO SCARABAEOIDEA

Scarabaeoidea in Human History

Scarabaeoidea Latreille is a large and cosmopolitan superfamily consisting of ~31,000 species worldwide (Ratcliffe 2005). The group has played important cultural roles throughout human history. The first cultural record of scarabs is an alabaster case in the shape of a scarab, created ~3,000 BC by the Egyptians during the First Dynasty (Cambefort 1994, Ratcliffe 2006). Species in the genera *Kepher*, *Scarabaeus, Gymnopleurus, Copris,* and *Catharsius* are believed to have played a prominent role in Egyptian religion and hieroglyphs. The genus *Kepher* was named after Kephri, the dung beetle incarnation of the sun god Ra (Ratcliffe 2006). So influential were dung beetles in the development of Egyptian religion that some scholars (e.g., Cambefort 1994) have suggested that the process of mummification was based on an incomplete understanding of the beetles' life cycle. Egyptians believed that Kephri returned to the Land of the Dead in the evening after rolling the sun across the sky like a ball of dung throughout the day. Some modern scholars suggested that mummification was an imitation of the scarab's pupal stage (Cambefort 1994). Adult eclosion from the pupa symbolizes emergence of the mummy into the Land of the Dead, and the replacement of the mummy's heart with scarabs carved from greenstone served as protection against the judgement of Osiris, the god of fertility and the embodiment of death and resurrected kings (Britannica Encyclopedia 2011). Scarabs frequently bore inscriptions containing verses from the *The Book of the Dead*, which prevented the true human heart from bearing witness against its owner on the day of judgement (Klausnitzer 1981, Ratcliffe 2006). The subterranean tombs of the Egyptian pharoahs, along with mummification and burial processes likened to metamorphosis, have led to the idea that the pyramids are large models of dung (Cambefort 1994).

In ancient Greek, Persian, Macedonian, Persian, and Roman societies, Egyptian scarab amulets were adopted as good luck charms, although the beetles might not serve the original mythical purpose for the afterlife (Ratcliffe 2006). Members of the family Geotrupidae were viewed with a mythical perspective by the Europeans. Some European cultures considered geotrupids as evil harbingers of doom. The ancient Greeks believed the Dor beetle [*Geotrupes stercorarius* (L.)] to be the devil's steed, while the Austrians associated the beetle with ghostly manifestations (Ratcliffe 2006). In the east of Germany, geotrupids were associated with witches (Reitter 1961). Stag beetles (Lucanidae) were also objects of malevolent superstition, and were believed to hold smoldering embers between their mandibles and ignite fires on the thatched roofs of homes (Evans and Bellamy 1996).

The same scarabs were also believed to possess benevolent powers. In Finnish culture, geotupids were associated with weather and saving a geotrupid from harm could prevent crops from being destroyed by storms (Reitter 1961). Mandibles of lucanids were worn by the Romans in battle, and the now threatened stag beetle [*Lucanus cervus* (L.)] even came to symobolize Christ in several of Albrecht Durer's classic paintings (Ratcliffe 2006).

Though westernized societies pay little attention to scarabaeoids as objects of religious significance or superstition, many still remain well known to all. The existence of "dung beetles" and "June bugs" is a common knowledge, even among children, and the presence of Japanese beetles is the bane of any North American gardener. South American and African cultures continue to use scarabaeoids in casual and ceremonial attire (Ratcliffe 2006). Larvae are a continuing source of food in cultures throughout Southeast Asia (Ratcliffe 2006), and the collection and rearing of dynastines and lucanids is so popular in Taiwan and Japan that many pet and department stores offer live beetles and beetle rearing supplies (Lai and Hsin-ping 2008). Despite the long history of human interaction with scarabaeoids as objects of religion, aesthetic appreciation, economic significance, and in the case of dung beetles, humor or even mild abhorrence, surprisingly little is known about the biodiversity and life histories of the majority of the world species.

Systematics of Scarabaeoidea

Higher taxonomic relationships concerning the members of Scarabaeoidea is a topic of constant, and sometimes heated, debates. Leading North American authors generally divide the superfamily into 11 families: Belohinidae, Bolboceratidae, Ceratocanthidae, Diphyllostomatidae, Geotrupidae, Glaphyridae, Glaresidae, Hybosoridae, Lucanidae, Ochodaeidae, Passalidae, Pleocomidae, Scarabaeidae, and Trogidae (Ratcliffe 2005). The greatest diversity of scarabaeoid species occurs in the Tropics, with the majority of known species represented by the family Scarabaeidae (Ratcliffe 2005). The family Scarabaeidae has undergone considerable taxonomic revision in the past 30 years, with the greatest disagreements over family placement occurring between the New and Old World workers. Old World workers frequently split the family Scarabaeidae into several smaller families. North American taxonomists traditionally follow the work of Lawrence and Newton (1995), dividing the family into 11 subfamilies: Aclopinae, Aphodiinae, Scarabaeinae, Melolonthinae, Dynastinae, Orphninae, Allidiostomatinae, Rutelinae, Cetoniinae, Trichiinae, and Valginae. Latin American taxonomists refer to much of Scarabaeidae as Melolonthidae, with classification consisting of the subfamilies Melolonthinae, Euchirinae, Phaenomeridinae, Dynastinae, Cetoniinae, Glaphyrinae, and Systellopodinae (Endrödi 1966). According to the Latin American school, subfamilies which do not fall within the classification of Melolonthidae are placed within the Scarabaeidae, with the exception of the scarabaeoid families Trogidae, Lucanidae, and Passalidae (Ratcliffe 2005).

As debate continues over higher level classification, much remains to be done at the genus and species levels. Most of the New World Melolonthinae, Cetoniinae, and Rutelinae cannot be identified to genus accurately even though the majority of scarab taxonomists reside in this region (Ratcliffe 2005). A consensus on valid, universally accepted genera, even among prominent experts, is far from being reached. Jackson and Klein (2006) listed 2,300 genera of Scarabaeidae occurring worldwide, while Ratcliffe (2005) listed 600 genera. Taxonomy of the Dynastinae (Endrödi 1985), Scarabaeinae (Hanski and Cambefort 1991), and Aphodiinae (Dellacasa 1987, 1988a, 1988b, 1991, 1995) is fairly well established. The continuing exploration and assessment of the tropical regions will likely yield new species which will force taxonomists to reorganize systematic placements at all levels of classification. The advent of molecular tools for systematic analyses is likely to reveal a multitude of cryptic species, particularly among groups where morphological traits for species-level determinations are less than reliable. Molecular tools also will contribute to the refinements of our understanding of phylogenetic relationships and, hopefully, consensus for the higher classification of taxa in this superfamily.

Scarabaeoidea of South Carolina

No single key exists for all known scarabaeoid families of South Carolina. Harpootlian (2001) provided a key to the majority of scarabaeoid species of South Carolina, with the exception of the families Passalidae and Lucanidae, and considered the families Bolboceratidae, Ceratocanthidae, Geotrupidae, Glaphyridae, Hybosoridae, Ochodaeidae, and Trogidae as subfamilies within Scarabaeidae. The families which do not occur in South Carolina (Belohinidae, Diphyllostomatidae, Glaresidae, and Pleocomidae) are not discussed in this study.

Scarabaeidae (Latreille)

The family Scarabaeidae consists of ~27,800 species worldwide, and comprises ~91% of Scarabaeoidea (Ratcliffe 2005). Harpootlian (2001) stated that the species composition of South Carolina is similar to that of Florida. The family Scarabaeidae ranks as one of the most studied and admired groups of the Coleoptera, perhaps owing to the large size and curious armature of many of the scarabaeines and dynastines, and the vibrant color of many Cetoniinae. The family exemplifies diversity in size, form, and feeding habits; *Pleurophorus longulus* Cartwright frequently attains lengths no greater than 1.9 mm, while *Goliathus* sp. can reach 15 cm or more (McNamara 2004). Although the majority of species within Scarabaeidae are of no economic importance, pest species are almost exclusively in the family Scarabaeidae. The economically important scarab species cause considerable damange due to root feeding and defoliation (Arnett et al. 2002) of turfgrasses, ornamentals, and agricultural crops (University of Minnesota Extenstion 2009). Members of the subfamily Scarabaeinae feed primarily on mammalian dung

(Holter et al. 2002), but are also known scavengers of carrion, rotting fruit, fungi, and decaying organic matter (Larsen et al. 2009). Members of the Aphodiinae share similar feeding habits with the Scarabaeinae, but are occasionally minor pests of cultivated plants (Stebnicka 2001). Members of the subfamilies Cetoniinae, Dynastinae, Melolonthinae, and Rutelinae are almost strictly phytophagous (Kazier and Statham 1962). However, predatory habits have been observed in some species of the Dynastinae, and inquilinism is widely reported in the cetoniine tribe Cremastochilini (Kazier and Statham 1962). Some members of the subfamilies Valgiinae and Trichiinae are reported to feed on nectar of flowers (Eaton and Kaufman 2007).

Geotrupidae Latrielle

The family Geotrupidae consists of 68 genera and ~620 species worldwide (Scholtz and Browne 1996). The family is classified in three subfamilies: Geotrupinae, Bolboceratinae, and Lethrinae. Geotrupinae are mainly of Holarctic distribution, Lethrinae are predominately in Eastern Europe and Asia, and Bolboceratinae occur in Africa, Australia, Europe, the United States, and South America (Verdu et al. 2004, Harpootlian 2001). Scholtz and Browne (1996) consider splitting the family into two families (Geotrupidae and Bolboceratidae), while others place Geotrupinae as a subfamily within Scarabaeidae (Ratcliffe 2005). In South Carolina, the 17 geotrupid species are in the genera *Bolboceras, Bolbocerasoma*, *Bradycinetulus*, *Eucanthus*, *Geotrupes*, and *Mycotrupes* (Harpootlian 2001). Adult feeding habits range from saprophagy to coprophagy to mycetophagy, and some adults are not known to feed. No caretaking exists for larval broods, but adults do provision larval burrows with food before eggs hatch (Ratcliffe 2005).

Ochodaeidae Mulsant and Rey

The family Ochodaeidae is a small, cosmopolitan taxon with 13 genera and ~100 species worldwide (Browne and Scholtz 2008). Two species of ochodaeids are known from South Carolina (*Ochodaeus frontalis* LeConte and *Ochodaeus musculus* Say) (Harpootlian 2001). Little has been reported on the biology of the family as a whole. The two species that occur in South Carolina are reportedly attracted to lights and burrow in sandy areas. Woodruff (1973) reported capturing *O. frontalis* using amyl-acetate.

Ceratocanthidae Cartwright and Gordon

Ceratocanthidae includes 40 genera and 328 species worldwide, most from the tropics (Ratcliffe 2005, Browne and Scholtz 2008). Some authors now postion Ceratocanthidae as a subfamily within the Hybosoridae (Ocampo 2006). The family is best represented by tropical species (Browne and Scholtz 2008). All ceratocanthids are capable of rolling into protective balls when threatened, thus earning the common name "the contractile scarabs". Three species of ceratocanthids have been reported from South Carolina: *Germarostes aphodioides* Illiger, *Germarostes globosus* Say, and *Ceratocanthus aeneus* MacLeay (Harpootlian 2001). Little has been reported on the North American fauna, but adults have been collected under bark, in tree holes, or from dead tree limbs by beating (Young 1998). Larvae of *Ceratocanthus* sp. have been collected from termite mounds and raised to adulthood within the cellulose walls of the mound (Morón and Arce 2003).

Hybosoridae Erichson

The family Hybosoridae is a small taxon including 32 genera and ~210 species worldwide (Ocampo 2000). Little has been reported on the life history of this family. Adults have been found associated with dung and carrion, but are believed to be predatory at these sites (Ocampo 2002). *Hybosorus illigeri* Reiche is the only species recorded from South Carolina (Harpootlian 2001). Adults are attracted to lights, yet the larvae are unknown (Ocampo 2002). *Hybosorus illigeri* larvae are thought to be associated with roots and decomposing plant matter (Ocampo 2002, Costa et al. 1988).

Glaphyridae MacLeay

The family Glaphyridae consists of five genera and ~70 species worldwide (Ratcliffe 2005). Adults are active diurnally and are reported to feed on flowers (floriculous). Larvae are free-living in sandy areas, and are known to feed on humus (Browne and Scholtz 2008). The cranberry root grub

[*Lichnanthe vulpina* (Hentz)] is a pest of cranberry bogs of northeastern North America. *Lichnanthe vulpina* is recorded from South Carolina (Harpootlian 2001); concerning its status, Morse et al. (1976) said that it "may be extinct in SE; no known collections since 1930s." Bogs are frequently drained and Morse et al. (1976) listed it as "peripheral, threatened (US)."

Passalidae Leach

Over 500 species of Passalidae are known world wide, and nearly all are tropical (Ratcliffe 2005). Two species are known to occur in eastern North America. *Odontotaenius floridanus* (Schuster) is restricted to Florida (Schuster 1994). Another species, *Odontotaenius disjunctus* (Illiger), is found throughout the East (Arnett et al. 2002) with many collection records for South Carolina located in the Clemson University Arthropod Collection. The species is well known for its subsocial behavior: larvae and adults are reported to communicate using 17 known stridulatory signals (Schuster 1975). Both adults and larvae occupy decaying logs, where adults build tunnel systems to raise the larvae (Wicknick and Miskelly 2009).

Trogidae MacLeay

The family Trogidae is a small, cosmopolitan taxon consisting of ~300 species in three genera (*Omorgus*, *Polynoncus*, and *Trox*) worldwide (Scholtz 1986). *Polynoncus* exist only in South America, while *Trox* and *Omorgus* are the only genera represented in South Carolina (Harpootlian 2001). All known species of trogids are reported to feed on keratin from carrion in the later stages of decay, animal burrows, and bird nests. Larvae of carcass-feeding species live in vertical burrows underneath the carcass (Baker 1968).

Lucanidae (Leach)

The family Lucanidae consists of ~800 species worldwide, with the majority of species being found in Asia (Ratcliffe 2005). Larvae are usually found in rotting wood, often with adults of the same species (Browne and Scholtz 2008). Adults of smaller species may occasionally visit flowers, but those of larger species are found at lights and sap flows from fluxing trees (Ratcliffe 1991). No comprehensive treatment exists for the lucanids of South Carolina, although the author located collection records in the Clemson University Arthropod Collection for species in the genera *Lucanus*, *Dorcus*, *Platycerus*, and *Nicagus*.

Economically important scarabaeids

Of the greatest concern to the human enterprise are those scarabaeid species that are responsible for significant crop losses. Native scarabaeid pests are predominately represented by species in the subfamilies Melolonthinae and Dynastinae. Among the melolonthines, *Phyllophaga* contains more pest species than any other genus of Scarabaeidae. Although *Phyllophaga* spp. are regarded as pests as a whole, one of the more problematic species of *Phyllophaga* to occur in South Carolina is the cranberry white grub *P. anxia* (LeConte), which feeds on a wide range of trees, shrubs, flowers, and agricultural plants (Harpootlian 2001). With the recent addition of *P. inepta* Horn (Chapter 3), 56 species of *Phyllophaga* are currently known from South Carolina. *Phyllophaga* spp. are pests in both adult and larval stages - adults feed on the leaves, flowers and fruits of many ornamental and agricultural plants, and larvae consume the roots of turfgrasses and shrubs.

In South Carolina, two species of dynastines are responsible for damage of turfgrasses in the larval stages - the southern masked chafer, *Cyclocephala lurida* Bland, and the northern masked chafer, *Cyclocephala borealis* Arrow. Adults are not known to feed on ornamentals or turf (Potter 1998). An additional species of Dynastinae, *Euetheola humilis* Burmeister, is gaining considerable attention within the Southeast as a pest of turfgrass (Lockwood and Brandenburg 2011). It has been widely reported throughout the state in large numbers in the spring and fall, when adults emerge and die on golf course lawns, gather at lights, or try to burrow into structures or buildings (Suiter 2010). The exact life cycle is unknown, but current research has suggested that the life cycle is univoltine, with adults of the previous-year generation emerging and reproducing during the spring and the same-year generation completing development and emerging in the fall to feed before overwintering (Lockwood and Brandenburg 2011). Whether adults feed on the rhizomes of turfgrass has not been demonstrated, though adults are confirmed to be sporadic pests of rice, sugarcane, cotton, and corn (Bernadi et al. 2008). Larvae are believed to feed on decaying organic matter within the thatch and soil, but this has not been demonstrated conclusively (Lockwood and Brandenburg 2011).

Pests in the subfamily Cetoniinae are represented only by the species *Cotinis nitida* (L.), commonly known as the green June beetle. Adults are found feeding on thin-skinned or damaged fruits. Larvae of *C. nitida* feed on decaying organic matter within the soil, but are capable of damaging turfgrass roots due to their burrowing habits and mound building (Heller 2007).

Native scarabaeid pests are common, but species of foreign introduction are among some of the most destructive pests. In the United States, one of the most heavily researched and economically important introduced species is the Japanese beetle (*Popillia japonica* Newman) (Baxendale 2006). Adult Japanese beetles are pests of over 300 species of cultivated plants, with a particular preference for roses, apples, stone fruits (cherry, peach and plum), basswood/linden, willow, elm, grape, birch, Japanese and Norway maples, pin oak, horse chestnut, and sycamore (Hodgson 2007). Large feeding assemblages are capable of skeletonizing the leaves of host plants, particularly those which are exposed to direct sunlight (Potter 1998). Larvae are pests on the roots of turfgrasses, creating what may initially begin as localized patches of discolored grass which can later coalesce into larger areas of discolored turf. Heavily damaged sod may feel spongy, and is easily pulled away from the soil (Hodgson and Alston 2006).

Various management approaches have been used to control the Japanese beetle. Trapping adults with commercially available pheromone and floral lures may be useful in monitoring, but are generally ineffective for plant protection and area-wide suppression. Furthermore, Gordan and Potter (1985, 1986) found that plant defoliation was higher in landscapes with single traps or small scale multiple traps. Assessment of Japanese beetle larvae populations requires soil sampling, and threshold damages based on population density vary across grass species, cultivars, soil types, moisture levels, and management regimes

(Crutchfield and Potter 1995a, 1995b, 1995c). In addition, host plant susceptibility to larvae and adults varies by species. Fleming (1976) classified 435 plant species in 95 families into four categories of adult feeding from no records of susceptibility to highly susceptible. Larvae are recorded to feed on the roots of all common cool- and warm-season turfgrasses as well as lawn weeds (Crutchfield and Potter 1995a, 1995b, 1995d, Potter et al. 1992), yet third-instar larvae have repeatedly shown a clear preference for perennial ryegrass over other turgrasses in choice tests (Crutchfield and Potter 1994).

Cultural regimes for controlling the Japanese beetle, which include withholding irrigation during peak beetle flight (due to the female's tendency to seek moist soil for oviposition) and raising cutting heights of grasses to 18 cm, greatly reduced subsequent grub populations in tall fescue (Potter et al. 1996). Crop rotation from corn to soybean produced greater numbers of larvae than nonrotated soybean plots in no-till or reduced till plots where broad leafed weeds provided alternative food, and where a no-till rye-covered crop was planted in the fall (Hammond and Stinner 1987, Smith et al. 1988).

Chemical control for Japanese beetle larvae involves application of an insecticide followed by watering and subsequent leaching of the chemical into the root zone (Potter 1998, Potter and Braman 1991). Short residual carbamates and organophosphates were heavily used in the 1970's and 1980's against white grubs, but many have since been banned (Potter and Held 2002). Imidacloprid and halofenozide were registered in the 1990's and have since become widely used for preventive control of larvae. Other long-residual neonicotinoids (e.g., clothianidin and thiamethoxam) were introduced for management of white grubs shortly after the introduction of imidacloprid. Low vertebrate toxicity and a wide application window have made these pesticides appealing to the turfgrass industry. Effective treatment for Japanese beetle adults involves application of short residual insecticides such as carbaryl to susceptible flowers and foliage (Potter 1998).

The bacterium *Bacillus popilliae* Dutky, commonly sold under the market name "milky spore," was introduced as part of a major campaign in the 1940's-1960's (Fleming 1968) with disappointing results (Frank and Bambara 2009). Efforts to apply *Bacillus thuringiensis* Berliner have also produced ineffective results. It has been suggested that scarab larvae are capable of developing resistance to the Bt Cry toxin. (Bravo and Mario 2008). Moisture has also been determined to play a significant role, showing a positive correlation with increased microbial activity (Lund and Goksoyr 1980). Even under optimal conditions, actual application rate much higher than the recommended rate of microbial products is required to achieve acceptable levels of control. However, *Bacillus thurigniensis* serovar *japonensis* strain “bui bui” has shown high levels of control of Japanese beetle larvae when applied in the spring (Bixby et al. 2007). Other attempts at biological control have included parasitic wasps and flies in the families Tiphiidae and Tachinidae, respectively (Jackson and Klein 2006).

Current research has attempted to use the entomopathogenic nematodes *Steinernema* spp. and *Heterorhabditis* spp. as biological controls against destructive scarab larvae in soil environments. The ambush strategies of certain nematodes, such as *Steinernema carpocapsae* (Weiser), ultimately proved ineffective due to low predator prey interactions that resulted from the similarly sedentary lifestyle of most destructive scarab larvae (Gaugler and Klein 1998). Limited and sporadic success has also been attributed to high host specificity, nematode susceptibility to residual pesticides, soil moisture and temperature, poorly understood pathogenicity of the nematode symbiotic gut fauna, production, and repeated setbacks with product marketing (Stock and Koppenhofer 2003). Moreover, several morphological, behavioral, and physiological adaptations may have evolved in the larvae to ward off pathogenic nematodes (Gaugler et. al 1994).

The Asiatic garden beetle, *Maladera castanea* Arrow (Ruteline), is distributed throughout Korea, Japan, China, and Russia, as well as the eastern coast of the United States, ranging from Maryland and Pennsylvania south to at least South Carolina (Harpootlian 2001, Dawson 1967). Larvae were recently discovered in damaged turf in Alabama (Held and Ray 2009). Adults are known to feed on over 100 species of plants, but are particularly fond of dahlia, aster, roses, and chrysanthemums (Gibb 2008). Larvae are known pests of turfgrass roots, constituting an average 15% (occasionally reaching 100%) of a white grub population found in a survey of New Jersey lawns (Koppenhofer and Fuzy 2003).

One of the more curious notes of pest scarabs within South Carolina concerns the capture of a single specimen of the oriental beetle (*Anomala orientalis* Waterhouse) from Spartanburg (Harpootlian 2001). This record represents the southernmost distribution of the species in eastern North America (Harpootlian 2001). Whether this individual was transported to the location or represented part of a viable population within the state, its presence is worth noting. Adults are known to feed on phlox, petunias, and roses, while larvae consume the roots of turfgrasses and ornamental plants (Pierce 2010).

Another introduced pest, the sweet potato grub (*Plectris aliena* Chapin), is originally from Argentina, Brazil, and Paraguay (Harpootlian, 2001). The species was discovered in Charleston, SC, in 1922 (Woodruff 1968), and is now found throughout much of the Southeast. Adults are not known to feed, but larvae are reported to feed on the roots of turfgrasses and sweet potatoes (Harpootlian 2001). Research investigating the regional distribution of the species in North and South Carolina is currently underway (M. Abney, personal communication).

Members of the Aphodiinae are generally saprophagous, but two species, *Aphodius granarius* (L.) and *Ataenius spretulus* (Haldeman), are turfgrass pests in the larval stages (Simmons 2000). *Ataenius spretulus* occurs throughout the continental United States, with most records coming from east of the Mississippi River. South Carolina records occur throughout the state (Harpootlian 2001). The more cosmopolitan species, *A. granarius*, is found throughout the world due to international commerce, and is well distributed over all of South Carolina (Harpootlian 2001).

The age of international commerce has brought with it the need for continuous awareness of South Carolina's native and introduced insect fauna. Some of the most damaging scarabs posed no significant threat in their native ranges, yet the changes in plant communities and urban and rural landscapes in the introduced ranges produced ideal conditions for the proliferation of once benign species. Japanese beetles were not problematic within their home ranges before the increased cultivation of grassy areas (Potter and Held 2002). The Japanese beetle is now known for local outbreaks in northern Japan and is frequently listed as one of the most damaging insects in the eastern United States.

An additional reason for concern over South Carolina's current scarabaeid fauna is the state's unique geographic position within the United States. South Carolina is a major convergence zone, with a unique position which may represent some of the more southern extremes of northern insect species, and the more northern extreme of southern insect species. Additionally, the state has a dramatically different geography from east to west, with the easternmost portion of the state being Coastal Plain, with a flat topography, loamy soil, and an agricultural industry of sweet potato, cotton, and soybean. South Carolina's coast is lined by the Tidewater region, which is composed mainly of salt marshes and wetlands and may serve as a major port of entry for destructive scarabs. The westernmost portion of the state contains the Blue Ridge, with mountainous terrain and an entirely different array of agriculture. Between the mountainous west and the Coastal Plain lies a large area of largely clayish soil, called the Piedmont, and a small sliver of largely sandy area, called the Sandhills. Each soil type and physiographical region may support a unique assemblage of scarab beetles. No study is known to document such difference in species diversity among the four physiographical regions.

Scarabaeinae as indicators of ecosystem health

With the ever accelerating rate of deforestation and the consequent loss of species on a global scale, there as an increasing need to assess ecosystem health and develop a comprehensive understanding of the world's biodiversity. Unfortunately, the majority of decisions regarding conservation have been made based on knowledge collected from a small portion of the world's fauna, most notably birds, mammals, and plants (Myers 2003). To date, few invertebrate taxa have been the target of conservation efforts (Black et al. 2001, Stein et al. 2002). Dung beetles in the scarabaeid subfamily Scarabaeinae have been repeatedly proposed as a group for biodiversity inventory and monitoring. The majority of dung-feeding scarabaeoids fall within this subfamily of Scarabaeidae. Scarabaeinae fit all of the major criteria for use as an assessment for ecosystem health, and Spector (2006) has summarized the following benefits of examining Scarabaeinae as a focal taxon for conservation and biodiversity studies:

1) *Scarabaeinae are amenable to standardized sampling*. Effective methods for trapping dung beetles are being refined and standardized, as reflected by recent publications on proper trap spacing for the most accurate assessment of species and numbers.

2) *Scarabaeinae are taxonomically accessible*. Species-level identification is possible because dung beetles are a favorite taxon among coleopterists, and a community of ~60 taxonomists are describing new Scarabaeinae taxa and developing tools for identification (Ratcliffe 2006)**.**

3) *Scarabaeinae have a broad geographic distribution.* Scarabaeinae are represented by ~5,700 species (with ~35 new species described per year) occurring on every continent except Antarctica (ScarabNet 2006). Species richness can range from ~10 species in a given location in the higher temperate latitudes, to ~75 species or more in tropical forests or savannahs (Hanski 1989, Price 2004).

4) *Scarabaeinae display a range of responses to environmental change and disturbances.* A meta-analysis of 26 studies involving dung beetle responses to habitat modification and fragmentation showed that species richness, abundance, and biomass declined in a clear, stepwise fashion across the modification gradient ranging from intact tropical forests to clear-cut areas (Nichols et. al in press). Scarabaeinae are also ecologically and economically important. Dung beetles play a critical role in nutrient recycling in both agricultural and natural habitiats.

Scarabaeinae have been intentionally introduced into many regions of the world to accelerate rates of mammalian waste removal, and through waste movement and burial, are known to play key roles in seed dispersal. Additionally, Scarabaeinae have been used to control populations of pestiferous flies which feed upon dung, particularly in Australia, where native dung feeders have not evolved to eliminate the waste of introduced cattle. Scarabaeinae also serve as modes of transportation for nematodes, fungi, flies, and mites. The dependency of these taxa on dung beetles is not only reflective of a cascading effect that may result from a decline in dung beetle populations, but is also an indication of potential agricultural and health concerns posed by nematodes and arthropods which rely upon dung beetles for transportation or serve as intermediate hosts. Scarabaeinae also bear strong correlations to other taxa. In association with vascular plants, Scarabaeinae may be optimal indicators of total biodiversity and areas of concern for conservation. As the majority of Scarabaeinae are dependent upon mammalian dung for food sources, Scarabaeinae community biomass is believed to be indicative of mammalian biomass (Spector 2006).

CHAPTER TWO

EXAMINATION OF SPECIES DIVERSITY AND SEASONAL ABUNDANCE OF SCARABAEOIDEA AT FOUR LOCATIONS IN SOUTH CAROLINA

The family Scarbaeidae is the fifth largest family of the largest order of all known life. To date, even the most basic life history information is lacking for many scarabaeoid species. Information on scarabaeoids is often limited to collection records which are sporadic in reference to date and location of collection. Despite the lack of comparative studies examining scarabaeoid species presence and abundance in specific physiographic regions within South Carolina, two noted Coleoptera authors (Harpootlian 2001 and Ciegler 2007) state that many species of Coleoptera are confined to specific physiographic regions of the state. Some genera of scarabs (*Osmoderma, Dichelonyx, Dialytes*) reach their southern limits in the Blue Ridge. The Piedmont and Coastal Plain regions are major farming areas, and an awareness of phytophagous species within these regions would provide more informed management of crops. Furthermore, the unique condition of the Sandhills as an ancient coastline may harbor species still unknown to science. The flightless *Mycotrupes retusus* (LeConte) is found only within this region of the state (Harpootlian 2001). The Tidewater also hosts unusual species found nowhere else within the state. *Geopsammodius hydropicus* (Horn), *Odontopsammodius bidens* (Horn), and *Aphodius phaleroides* are restricted specifically to dunes and beaches (Harpootlian 2001). Harpootlian (2001) noted that only 1% of our scarab fauna is endemic to the state. The state may exhibit a broad overlap in ranges of North American species, and the wide array of climates and physiographic regions within the state may continue to yield new state distribution records or even new species.

The purpose of this study was to examine species diversity and seasonal abundance of Scarabaeoidea at locations in four regions of South Carolina. Scarabaeoidea, and particularly several species of Scarabaeidae, pose significant economic problems due to feeding behavior on a wide variety of plants. By documenting population sizes and species trends throughout the state, more informed, regionally specific pest management decisions may be made. Furthermore, the few North American studies which have analyzed seasonal abundance and species diversity of scarabs have concentrated exclusively on phytophagous scarabs using light traps only. No North American treatment exists for Scarabaeoidea as a whole, and no study has employed multiple trapping methods. By employing multiple traps, a greater variety of species may be captured to obtain a more realistic estimate of species and seasonal activity by location. The use of multiple traps, and the taxa captured which are specific to each trap type, will enable future researchers to use the most effective trapping methods based on the scarabaeoid taxa targeted for collection.

Materials and Methods

Sampling locations

Assessments of species diversity and seasonal abundance of Scarabaeoidea were conducted from March 2009 to December 2010 using one light, one pitfall, and one flight-intercept trap at each of four locations in South Carolina. Research sites were located at the Country Club of South Carolina, Florence (34°14'59.81" N, 079°40'34.96" W), Camden Country Club, Camden (34°16'10.44"N, 080°36'42.76"W), the Cliffs Center for Environmental Golf Research , Marietta (referred to as Cliffs CEGR) (35°05'38.62" N, 082°27'59.95" W), and the Walker Golf Course, Clemson (34°40'14.19"N, 082°50'16.12"W). Sites were chosen for their unique physiographical positions in the state (Fig 2.01). Bennett and Patton (2008) detailed the physiographic regions of North and South Carolina by compiling data for locations in each region, and soil types were determined at each location using the USDA web soil survey.

The Country Club of South Carolina was opened in 1969 and is located in the Middle Atlantic Coastal Plain, an area ranging along the eastern coast from Delaware to Florida. Bennett and Patton (2008) examined Bertie County, North Carolina to characterize this region, and reported an average temperature of ~25 °C in the summer and ~5°C in the winter, with an average annual precipitation of 1,143-1,270 mm. This region is dominated by pine forests and sandy, nutrient-limited soil. Agricultural lands occupy the best soil, consisting of a well-drained, loamy surface layer with a moderate amount of organic material. Soil type at the Country Club of South Carolina consisted of a mosaic of Pantego series loam, Barth series loamy sand, and Wagram series sand. Turfgrass species and cultivars at the Country Club of South Carolina include '419' hybrid bermudagrass, common bermudagrass, 'Tifeagle' hybrid bermudagrass, 'Meyer' zoysiagrass, and 'Emerald' zoysiagrass.

Opened in 1903, Camden Country Club is located in the Sandhills, in close proximity to the narrowest distance among the Middle Atlantic Coastal Plain, the Sandhills, and the Southern Piedmont. Bennett and Patton (2008) examined Cheraw in Chesterfield County, South Carolina to characterize the Sandhills. This site averages ~1,025 mm of rainfall per year, with a mean January temperature of ~3.8 °C and a mean July temperature of ~25.5°C. Much of the Sandhills is forested with xerophytic plants (longleaf pines, turkey oaks, succulents) adapted for sandy, nutrient-poor soil. Water ranges from permanent to intermittent (Ciegler 2007). Soil type at Camden Country Club consisted of Alpin series sand and Wagram series sand. Grass species and cultivars at Camden Country Club included zoysiagrass (cultivar unknown) and common bermudagrass.

The Walker Golf Course was opened in 1995, and is located in the Southern Piedmont region. The Southern Piedmont ranges in altitude from ~182-457 m above sea level. Bennett and Patton (2008) examined Greensboro in Guilford County, North Carolina to characterize this region. This site averages ~1,117 mm of annual precipitation, and averages ~4.4°C in the winter and ~24.4°C in the summer. The Southern Piedmont is characterized by rolling hills, river bottoms, farmland, monadnocks, and orchards (Ciegler 2007). Soil type at the Walker Golf Course consisted of Cecil series sandy loam. Grass species and cultivars included 'Tifway' bermudagrass, 'Crenshaw' creeping bentgrass, and 'Meyer' zoysiagrass.

The Cliffs CEGR is located in the northwestern-most region of the state in the Blue Ridge Mountains. The Blue Ridge Mountains range from ~426-2,011 m in altitude. This zone is characterized by forested hills, rocky outcrops, and ravines (Ciegler 2007). Bennett and Patton (2008) report varying levels of precipitation based on altitude, with an average annual precipitation exceeding 2,159 mm near the highest peaks at the southern end of the range. The Cliffs CEGR is a recently established research facility (within four years) and an updated USDA web soil survey has not been performed for this location at the time of this publication. However, soil types provided by staff at the Cliffs CEGR included sandy loam with pockets of clay, and grass species consisted of 'Palisades' zoysiagrass, 'Celebration' bermudagrass, 'Diamond' zoysiagrass, 'Champion' bermudagrass,' Miniverde' bermudagrass, and 'Tifeagle' bermudagrass.

<u>Sampling with flight-intercept traps</u>

In 2009, Townes-style Malaise traps were used to collect scarabs from each of the four golf courses. These traps proved generally ineffective at capturing scarabs, as the tendency for scarabs in flight to drop to the ground after encountering an object prevented specimens from being captured in the containers housed at the top of the traps (Hinson, personal observation). In June of 2009, a different flight-intercept trap was employed (Fig. 2.02). The trap was originally designed to assess distribution and abundance of the sweet potato grub *Plectris aliena* Chapin in golf courses and sweet potato fields (M. Abney, NCSU, personal communication). This trap consisted of two vertical PVC pipes and a horizontal PVC pipe spanning the distance between the vertical pipes at their apices. These pipes connected at 90° angles with "elbow" PVC connectors. The trap was anchored to the ground by driving two rebar rods partway into the ground and inserting the vertical pipes over the protruding portions of the rebar. Mesh fabric, which had been sewn into sleeves at the edges for insertion of the PVC pipes, spanned the area framed by the pipes, creating an effective in-flight barrier for scarabs. Plastic troughs were placed at the bottom of the trap on either side of the net and half filled with soapy water (prepared by dissolving about 1 teaspoon of dish detergent in 3.8 L of water) for the disruption of water tension, rapid drowning, and partial preservation of specimens. Traps were sampled weekly by examining the contents of the trough, removing specimens with forceps, and placing specimens in glass vials filled with 70% ethyl alcohol. Sampling date and collection locations were recorded. After sampling, troughs were refilled with a mixture of soapy water for sampling the subsequent week.

Sampling with light traps

Each light trap (Fig. 2.03) consisted of a 22-watt (120V, alternating current) circline black light tube supported within a transparent, three-paned, flight-intercept vane (BioQuip 2815L Universal Light Trap, Rancho Domingo, CA). This unit was placed over an aluminum funnel that was housed in a large bucket. Beneath this funnel, and within the larger, outer bucket, sat a small bucket with 355 ml of antifreeze (ethylene glycol). To prevent rain from entering the inner bucket and diluting the antifreeze, the lid of the outer bucket was placed over the top of the entire unit, and secured to the bucket on four sides using malleable wires. Light ballasts were hung on the outside of the trap and were shielded from rain using plastic sandwich bags. This entire unit was then supported with wire or string from a branch or elevated post at ~1-1.5m above ground level. Each light trap was connected to a photosensitive switch that received power from a nearby electrical outlet. The photosensitive switch was set to a dusk/dawn setting, activating the light trap at night and turning the lights off at dawn. Once per week, contents from the inner bucket were emptied into temporary storage containers. Collection dates and locations were recorded on paper and placed in these containers until sorting.

The light trap at Camden Country Club was located ~50 meters from the nearest light source (tennis court), but was placed in the shadow of a utility building. This trap was hung from a rod projecting from a telephone pole. The light trap at the Cliffs CEGR was adjacent to a small facility with no major light sources at night. This trap was supported with a standing PVC structure. The light traps at the Country Club of SC and the Walker Golf Course were roughly ~100 meters from the nearest light sources. The light trap at the Country Club of South Carolina was hung on the side of a golf course pump house, and the light trap at the Walker Golf Course was hung from the branch of a crape myrtle tree.

Sampling with pitfall traps

Pitfall traps within this study represented a relatively novel approach to pitfall sampling. Each pitfall trap consisted of PVC pipes (1.3 cm diameter), with the upper 1/3 of each pipe removed, creating open channels into which ground-active scarabs could wander (2.04). These pipes were laid horizontally in the soil and the openings sat flush with ground level to allow scarabs to drop within the channels. Pipes were laid in a crosswise fashion, with all pipes emptying into a central bucket. The inner end of each pipe was covered with a larger, ~3 cm length piece of pipe (2.5 cm in diameter), which could be removed to aid in the removal of the smaller, central bucket. This central bucket housed ethylene glycol, and sat in a larger, outer bucket that was burried in the ground. Once per week, the contents of this inner bucket were removed and stored in a temporary container until sorting. Labels recording date and collection location were placed in each container until sorting. The grass around pitfall traps was trimmed with a weadeater or removed by hand twice per month during the growing season (spring-fall) or once per month during winter months.

Sorting and Identification

Contents from pitfall and light traps were strained through a copper-wire strainer and rinsed thoroughly with tap water to remove excess ethylene glycol before sorting. All insects from the traps were then placed into an insect sorting tray. Scarabs removed from flight-intercept traps were placed in 70% ethanol upon collection, and did not require straining. Scarabaeids were placed under dissecting microscopes for identification. The primary source for identification of species was *Scarab Beetles of South Carolina* (Harpootlian 2001). Additional references included *Scarab Beetles of Florida* (Woodruff 1973) and *Phyllophaga of the United States and Canada* (Luginbill and Painter 1953). Methods of identification varied by taxonomic group and publication, with dichotomous keys, species descriptions, and genitalia illustrations comprising the majority of identification aids. The minute size and overall similarity of subfamily Aphodiinae as distinct from all other scarabaeoids allowed for on-sight identification. Members of Aphodiinae were not identified to species because of a lack of reliable identification keys.

Total numbers of Aphodiinae were recorded per trap type, per date, per location. Along with species identification, specimens were sexed throughout 2009 to examine male/female ratios. The number of each species at each sampling date and trap type was recorded and plotted against time to determine patterns in seasonal activities.

Voucher specimens were deposited in the Clemson University Arthropod Collection, the Pee Dee Research and Education Center Insect Museum, and in the private collection of the author.

Results

A total of 74,326 specimens in 7 families, 47 genera, and 104 species were captured among all locations and all trap types during 2009-2010 (Table 2.1). Camden Country Club produced the greatest diversity in species (63) followed by the Country Club of South Carolina (56), the Cliffs CEGR (52), and the Walker Golf Course (32). A new state record for *Phyllophaga inepta* Horn is reported (Chapter 3). The majority of captured specimens (57,502) belonged to the scarabaeid subfamily Aphodiinae. The remaining specimens (16,825) were primarily composed of scarabaeids in the subfamilies Dynastinae, Melolonthinae, Rutelinae, and Scarabaeinae. A more detailed treatment of abundance and seasonality is given for species captured in light traps meeting or exceeding 200 specimens captured. Species are recorded as being captured in very low numbers (0-49 total captures), low numbers (50-99 total captures), moderate numbers (100-199 total captures), high numbers (200-999), and very high numbers (1,000 or more).

Among the Dynastinae, nine genera and 11 species were captured. Three of the four most-frequently captured species of scarabaeoids were dynastines [*Cyclocephala lurida* Bland, *Dyscinetus morator* (Fabricius), *Euetheola humilis* (Burmeister)] captured in very high numbers (Table 2.1). Captures of *C. lurida* among all trap types and all locations in 2009-2010 totaled 1,373 specimens. A total of 1,316 specimens of *C. lurida* were captured in light traps, 56 specimens were captured in flight-intercept traps, and a single male was captured in pitfall traps. *Cyclocephala lurida* were overwhelmingly male, with sex ratios of 98% males among 2009 light trap and flight-intercept trap captures. Captures of *D. morator* among all trap types and all locations in 2009-2010 totaled 4,655, of which 4,413 specimens were captured in light traps, 212 in pitfall traps, and 30 in flight-intercept traps. *Dyscinetus morator* were more female-biased when represented by higher total numbers in light traps (43% male) and pitfall traps (49% male), with a slight male bias (53%) in flight-intercept traps. A total of 4,234 specimens of *E. humilis* were captured among all trap types at all locations in 2009-2010. A total of 3,265 specimens of *E. humilis* were captured in light traps. Pitfall traps captured 795 specimens of *E. humilis*, and flight-intercept traps captured 174 specimens. *Euetheola humilis* were more female biased in light traps (48% male) as opposed to flight-intercept (70% male) and pitfall traps (62% male).

Two dynastine species captured in high numbers included *Cyclocephala borealis* Arrow and *Tomarus gibbosus gibbosus* (De Geer). *Cyclocephala borealis* consisted of 326 total captures, with 296 captures occurring in light traps (97% male), 27 captures occurring in flight-intercept traps (93% male), and three captures occurring in pitfall traps (3% male). *Tomarus gibbosus gibbosus* consisted of 416 total specimens, with 386 specimens captured in light traps (56% male), 28 specimens captured in flight-intercept traps (46% male), and 2 specimens captured in pitfall traps (2% male).

Melolonthinae included eight genera and the highest total number of species (37) at the subfamily level (Table 2.1). Within Melolonthinae, the genus *Phyllophaga* contained the greatest number of species (22) among all genera collected within the study (Table 2.1). *Phyllophaga* spp. totaled 709 specimens, but individual species were generally captured in very low to low numbers. Very low specimen totals were collected for *Phyllophaga aemula* (Horn), *Phyllophaga anxia* (LeConte), *Phyllophaga diffinis* (Blanchard), *Phyllophaga drakii* (Kirby), *Phllophaga ephilida* (Say), *Phyllophaga fervida* (Fabricius), *Phyllophaga forsteri* (Burmeister), *Phyllophaga hirsuta* (Knoch), *Phyllophaga hirticula* (Knoch), *Phyllophaga ilicis* (Knoch), *P. inepta*, *Phyllophaga knochii* (Schonherr and Gyllenhal), *Phyllophaga mariana* Fall, *Phyllophaga omani* Sanderson, *Phyllophaga parvidens* (LeConte), *Phyllophaga quercus* (Knoch), and *Phyllophaga ulkei* (Smith). Several species captured in low numbers included *Phyllophaga* *crenulata* (Froelich), *Phyllophaga latifrons* (LeConte), *Phyllophaga prununculina* (Burmeister), and *Phyllophaga uniformis* (Blanchard). Only *Phyllophaga impar* Davis was captured in high numbers (302 total specimens), with 289 specimens captured in light traps (100% male) and 13 specimens captured in flight-intercept traps (100% male).

Maladera castanea Arrow was captured in high numbers, consisting of 732 total specimens among all trap types and all locations in 2009-2010. Light traps captured 706 *M. castanea*, and flight-intercept traps captured 26 specimens. Specimens of *M. castanea* were overwhelmingly male in both trap types (95% male captured in light traps and 100% male captured in flight-intercept traps). *Serica* spp. totaled 244 specimens and were represented primarily by *Serica georgiana georgiana* Leng. *Serica goergiana georgiana* was captured in high numbers, totaling 218 specimens among all trap types at all locations in 2009-2010. *Serica georgiana georgiana* was represented by 213 specimens in light traps (98% male) and five specimens in pitfall traps (100% males).

The subfamily Rutelinae included four genera and 10 species, and was represented primarily by the genus *Anomala* (Table 2.1). *Anomala* spp. totaled 1,282 specimes, with several species [*Anomala flavipennis flavipennis* Burmeister, *Anomala marginata* (Fabricius), *Anomala parvula* Burmeister] captured in high numbers. A total of 378 specimens of *A. flavipennis flavipennis* were captured among all trap types at all locations in 2009-2010. Light traps captured 372 specimens of *A. flavipennis flavipennis* and pitfall traps captured six specimens. *Anomala flavipennis flavipennis* were predominately male in all trap types, including 80% males among specimens captured in light traps, and 100% males among specimens captured in flight-intercept traps. *Anomala marginata* totaled 391 specimens among all trap types at all locations in 2009-2010. *Anomala marginata* totaled 386 specimens in light traps, three specimens in flight-intercept traps, and two specimens in pitfall traps. *Anomala marginata* was predominately female in light traps (40% male), and 100% male among flight-intercept trap captures. *Anomala parvula* totaled 237 specimens among all trap types and all locations in 2009-2010. *Anomala parvula* was represented by 233 specimens in light traps and four specimens in flight-intercept traps. *Anomala parvula* consisted of 97% males in light traps with100% males among flight-intercept trap captures. *Pelidnota punctata* was captured in high numbers, totaling 344 specimens among all trap types and all locations in 2009-2010. *Pelidnota punctata* totaled 336 specimens in light traps and eight specimens in flight-intercept traps. Captures consisted of 21% males in light traps, with all flight-intercept trap captures occurring in 2010.

Among the Scarabaeinae (eight genera and 20 species captured), the genus *Onthophagus* included the greatest diversity, consisting of nine species and 535 specimens (Table 2.1). *Onthophagus hecate hecate* (Panzer) was captured in high numbers, totaling 341 specimens among all trap types at all locations in 2009-2010, and ranked as the highest in total numbers captured for a single scarabaeine species. *Onthophagus hecate hecate* totaled 288 specimens in flight-intercept traps, and 53 specimens in pitfall traps. Captures consisted of 44% males in flight-intercept traps and 49% males in pitfall traps.

Cetoniinae were collected in very low to low numbers and consisted of five species in three genera, including *Cotinis nitida* (L.), *Euphoria herbacea* (Olivier), *Euphoria inda* (L.), *Euphoria sepulcralis* (Fabricius), and *Stephanucha areata* (Fabricius) (Table 2.1). *Euphoria* spp. totaled 111 specimens. Trichiinae consisted of two species [*Trichiotinus bibens* (Fabricius), *Trigonopeltastes delta* (Forster)] captured in very low numbers, and Valgiinae consisted of a single captured specimen of *Valgus canaliculatus* (Fabricius).

Among other scarabaeoid families, Ceratocanthidae was represented in very low numbers by three species in two genera (*Germarostes aphodiodes* (Illiger), *Germarostes globosus* (Say), and *Ceratocanthus aeneus* (MacLeay)] (Table 2.1). *Germarostes* spp. totaled only 6 specimens. Geotrupidae was represented in very low numbers by five species in four genera [*Bolboceras thoracicornis* Wallis, *Bolbocerasoma farctum* (Fabricius), *Eucanthus lazarus* (Fabricius), *Geotrupes blackburnii blackburnii* (Fabricius) and *Geotrupes egeriei* Germar]. *Geotrupes* spp. totaled nine specimens. Hybosoridae was represented in very high numbers by a single species (*Hybosorus illigeri* Reiche). *Hybosorus illigeri* totaled 1,171 specimens captured among all trap types and all locations in 2009-2010. *Hybosorus illigeri* consisted of 1,091 specimens captured in light traps, eight specimens captured in flight-intercept traps, and 72 specimens captured in pitfall traps. Captures consisted of 34% males in light traps, 75% males in flight-intercept traps, and 52 % males in pitfall traps. Passalidae consisted of one captured specimen of *Odontotaenius disjunctus* Illiger, and Lucanidae consisted of one captured specimen of *Dorcus brevis* (Say). Trogidae was represented in very low to low numbers by six species in two genera [*Omorgus suberosus* (Fabricius), *Trox affinis* Robinson, *Trox foveicollis* Harold, *Trox hamatus* Robinson, *Trox unistriatus* Beauvois, *Trox variolatus* Melsheimer]. *Trox* spp. totaled 11 specimens.

Light trap diversity and seasonal abundance

The majority of total numbers and species captured within this study were taken with light traps (seven families, 84 species and 70,081 specimens including Aphodiinae). Aphodiinae were captured predominately in light traps, and exhibited peaks in seasonal abundance (Figs. 2.05-2.08). Among the Scarabaeidae, the subfamilies Dynastinae, Melolonthinae, and Rutelinae were among the highest in total numbers of specimens captured and total species diversity.

Dynastinae consisted of 11 species captured in light traps (Table 2.1). Among the Dynastinae, *C. borealis*, *C. lurida*, *E. humilis*, *D. morator*, and *T. gibbosus gibbosus* were captured in high to very high numbers and exhibited distinct patterns of abundance and seasonal activity (Figs. 2.09-2.13). *Cyclocephala borealis* peaked in early to mid June (Fig. 2.09). *Cyclocephala lurida* peaked in late June to early July (Fig. 2.10). *Dyscinetus morator* peaked in early June (Fig. 2.11). *Euetheola humilis* peaked initially in late April to early May, followed by an additional peak in August to early October (Fig. 2.12). *Tomarus gibbosus gibbosus* peaked in late May (Fig. 2.13). Six species of dynastines were captured exclusively in light traps (0-14 total specimens per species), including *Aphonus castaneus* (Melsheimer), *Dynastes tityus* (L.), *Tomarus neglectus* (LeConte), *Phileurus valgus valgus* (L.), *Strategus splendens* (Beauvois), and *Xyloryctes jamaicensis* (Drury) (Table 2.1).

Among the 37 melolonthine species captured in light traps, 29 were captured exclusively in light traps (Table 2.1). All four *Diplotaxis* spp. (totaling 71 specimens) were captured exclusively in light traps, peaking in late June (Table 2.1). All species of *Phyllophaga* captured in this study were taken in light traps. *Phyllophaga* spp. captured in light traps totaled 713 specimens, and peaked in late June (Fig. 2.14).

Non-*Phyllophaga* melolonthines collected in very low numbers included *Dichelonyx linearis* (Gyllenhal), *Diplotaxis harperi* Blanchard, *Diplotaxis punctatarugosa* Blanchard, *Macrodactylus angustatus* (Beauvois), *Macrodactylus subspinosus* Fabricius, *P. aliena*, *Polyphylla comes* Casey, *Polyphylla occidentalis* (L.), *Serica aspera* Dawson, *Serica carolina* Dawson, *Serica sericea* (Illiger), and *Serica vespertina* Gyllenhal. *Maladera castanea*, *P. impar,* and *S. georgiana georgiana* represented the most abundantly collected melolonthines. *Phyllophaga impar* peaked in mid to late April (Fig. 2.15). *Maladera castanea* peaked in early to mid-July (Fig. 2.16). *Serica georgiana georgiana* peaked in late April to early May (Fig. 2.17).

Ten species of Rutelinae were captured in light traps (Table 2.1). Species included *A. flavipennis flavipennis*, *Anomala innuba* (Fabricius), *A. marginata*, *Anomala oblivia* Horn, *A. parvula*, *Anomala umbra* Casey, *Anomala undulata* Melsheimer, *Parastasia brevipes* LeConte, *P. punctata*, and *Popillia japonica* Newman. *Anomala* consisted of 1,239 specimens in light traps. *Anomala flavipennis flavipennis* peaked in late May to early June (Fig. 2.18). *Anomala marginata* peaked in mid-June (Fig. 2.19). *Anomala parvula* peaked in early to mid-June (Fig. 2.20). *Pelidnota punctata* peaked in mid- to late July (Fig. 2.21). *Parastasia brevipes* was the only species of Rutelinae captured exclusively in light traps.

Seven species of Scarabaeinae were captured in light traps (Table 2.1). Species captured in very low numbers included *Ateuchus histeroides* Weber, *Canthon depressipennis* LeConte, *Canthon vigilans* LeConte, *Copris minutus* Drury, *Dichotomius carolinus* (L.), and *Onthophagus depressus* Harold. *Onthophagus* spp. (consisting only of *O. gazella* and *O. depressus*) totaled 95 specimens in light traps. *Onthophagus gazella* was collected in low numbers but represented the highest total number (81) of any scarabaeine species captured in light traps. *Onthophagus gazella* activity exhibited a wide range of low abundance during May through October. Among the seven species of Scarabaeinae captured in light traps, four species were captured exclusively in light traps, including *A. histeroides*, *C. minutus*, *O. depressus*, and *O. gazella.* One specimen of Valgiinae [*Valgus canaliculatus* (Fabricius)] was captured in this study, and was captured in light traps (Table 2.1).

Among additional scarabaeoid families, all Ceratocanthidae (*C. aeneus*, *G. aphodioides*, and *G. globosus*) were captured exclusively in light traps in very low numbers during May through June. Geotrupidae were represented in light traps in very low numbers, and consisted of *B. farctum*, *B. thoracicornis*, *E. lazarus*, *G. blackburnii blackburnii*, and *G. egeriei* (Table 2.1). Geotrupidae exhibited a wide range of activity from April to November. All geotrupid species captured within this study were captured in light traps, with two species (*E. lazarus* and *G. egeriei*) captured exclusively in light traps. Hybosoridae was represented in light traps by a single species (*H. illigeri*) in very high numbers (1,091), peaking around mid-June (Fig. 2.22). One specimen of Lucanidae (*D. brevis*) and one specimen of Passalidae (*O. disjunctus*) were captured in light traps (Table 2.1). The most abundant trogid captured in light traps consisted of 55 captures of *O. suberosus* (Table 2.1), active in low numbers May through August. The remaining light traps captures of Trogidae consisted of four species (*T. affinis*, *T. hamatus*, *T. unistriatus,* and *T. variolatus*) being captured exclusively in light traps in very low numbers in May to July.

<u>Flight-intercept trap diversity and seasonal abundance</u>

Flight-intercept traps produced fewer specimens and species than light traps (four families, 51 species and 1,274 specimens) (Table 2.2). A total of 48 specimens of Aphodiinae were captured in flight-intercept traps. Accurate seasonal abundance for species was difficult to obtain due to low numbers and trapping challenges discussed below. However, seasonal ranges for captures generally fell within the range of seasonal activity recorded from light traps (Table 2.1).

Five species of Dynastinae (*C. borealis, C. lurida*, *D. morator*, *E. humilis,* and *T. gibbosus gibbosus*) were captured in very low to moderate numbers in flight-intercept traps, with no species captured excusively in flight-intercept traps (Table 2.2).

Ten species of Rutelinae were captured in flight-intercept traps (Table 2.2). 40 *Anomala* specimens and 26 *Popillia* specimens were captured in flight-intercept traps, including *A. innuba*, *A. oblivia*, *A. umbra*, *A. undulata*, and *P. japonica*. *Strigoderma pygmaea* (Fabricius) (one specimen) was captured exclusively in flight-intercept traps.

Eight species of Melolonthinae were captured in flight-intercept traps in very low to low numbers, including *M. castanea, P. aemula*, *P. ephilida*, *P. impar, P. latifrons*, *P. prununculina*, *P. uniformis*, and *P. aliena* (Table 2.2). *Phyllophaga* spp. captured in flight-intercept traps totaled 57 specimens. Melolonthinae species captured in flight-intercept traps were also captured with other trap types.

Sixteen species of Scarabaeinae were collected in flight-intercept traps (Table 2.2). Flight-intercept traps captured the highest total numbers of Scarabaeinae of any trapping method (Table 2). Species collected in very low to low numbers included *Canthon pilularius* (L.), *Canthon vigilans* LeConte, *Deltochilum gibbosum gibbosum* (Fabricius), *Dichotomius carolinus* (L.), *Melanocanthon bispinatus* (Robinson), *Onthophagus orpheus orpheus* (Panzer), *Onthophagus striatulus* (Say), *Onthophagus subaeneus* (Beauvois), *Onthophagus taurus* (Schreber), *Onthophagus tuberculifrons* Harold, *Phanaeus triangularis triangularis* (Say), and *Phanaeus vindex* MacLeay. *Onthophagus* spp. captured in flight-intercept traps totaled 387 specimens. The more abundant scarabaeine species captured in flight-intercept traps consisted of *O. hecate hecate*, *Onthophagus concinnus* Laporte, *Phanaeus igneus* MacLeay, and *Canthon depressipennis* Leconte. Among all scarabaeine species, only *C. depressipennis, C. vigilans*, *D. carolinus,* and *O. hecate hecate* were captured in other trap types.

Cetoniinae captured in flight-intercept traps included five species (Table 2.2). Three species collected in very low numbers consisted of *S. areata*, *E. herbacea*, and *E. inda*, while the two species collected in low numbers included *C. nitida* and *E. sepulcralis*. *Euphoria* spp. consisted of 110 specimens. Among all Cetoniinae species, only *E. herbacea* and *C. nitida* were captured (in low numbers) with light and pitfall traps, respectively. Trichiinae were captured exclusively in flight-intercept traps in very low numbers, and consisted of *T. bibens* and *T. delta*.

Three species of Geotrupidae (*B. thoracicornis*, *B. farctum*, and *G. blackburnii blackburnii*) were captured in flight-intercept traps, with no species being exclusively captured in flight-intercept traps

(Table 2.2). One species of Hybosoridae (*H. illigeri*) was captured in flight-intercept traps (Table 2.2). One specimen of Trogidae (*T. affinis*) was captured using flight-intercept traps.

Pitfall trap diversity and seasonal abundance

Accurate seasonal abundance for species was difficult to obtain due to low numbers and trapping challenges. However, seasonal ranges for pitfall trap captures (Table 2.3) generally fell within the range of seasonal activity recorded from light traps (Table 2.1). A total of 1,764 specimens of Aphodiinae were captured in pitfall traps.

Pitfall traps captured the lowest total number of of families (3) and species (15) among the three trapping methods. Five species of Dynastinae (*C. borealis*, *C. lurida*, *D. morator*, *E. humilis*, and *T. gibbosus gibbosus*) were captured in pitfall traps, with no species exclusively captured in pitfall traps.

Three species of Rutelinae (*A. marginata*, *A. undulata*, and *P. japonica*) were captured in pitfall traps in low numbers, with no species being captured exclusively in pitfall traps. Pitfall trap captures for *A. undulata* consisted of a single specimen. Pitfall trap captures for *P. japonica* consisted of six specimens.

Two species of Melolonthinae (one specimen of *P. uniformis* and five specimens of *S. georgiana georgiana*) were captured in pitfall traps, with neither species being captured exclusively in pitfall traps.

Two species of Scarabaeinae (*O. hecate hecate* and *P. igneus*) were captured in pitfall traps in very low to low numbers. Neither species was captured exlusively in pitfall traps. One species of Cetoniinae (*C. nitida*) was captured in very low numbers in pitfall traps. One specimen of Geotrupidae (*G. blackburnii blackburnii*) was captured using pitfall traps. One species of Hybosoridae was captured in low numbers using pitfall traps.

The use of multiple trap types

Taxa captured in multiple trap types differed substantially in the percentages of specimens captured per taxon (Table 2.1). 97% of Aphodiinae were captured in light traps, <1% in flight-intercept traps, and >2% in pitfall traps. *Anomala* spp. totaled 97% in light traps, 3% in flight-intercept traps, and <1% in pitfall traps. *Bolboceras thoracicornis* totaled 80% in flight-intercept traps and 20% in light traps. *Bolobocerasoma farctum* totaled 50% in light traps and 50% in flight-intercept traps. *Canthon* spp. totaled 77% in flight-intercept traps and 23% in light traps. *Cotinis nitida* totaled 97% in flight-intercept traps and 3% in pitfall traps. *Cyclocephala borealis* totaled 91% in light traps, 8% in flight-intercept traps, and 1% in pitfall traps. *Cyclocephala lurida* was represented by >99% of captures in light traps, followed by <1% for pitfall and flight-intercept captures. Ninety-five percent of *D. morator* were captured in light traps, followed 5% in pitfall traps and 1% in flight-intercept traps. Seventy-five percent of *E. humilis* were captured in light traps, followed by 25% in pitfall traps, and 5% in flight-intercept traps. *Geotrupes* spp. totaled 66% in light traps, 22% in flight-intercept traps, and 11% in pitfall traps. *Hybosorus illigeri* comprised 93% in light traps, 6% in pitfall traps, and 1% in flight-intercept traps. *Tomarus gibbosus gibbosus* comprised 93% in light traps, followed by <7% in flight-intercept traps and >1% in pitfall traps. *Onthophagus hecate hecate* totaled 84% in flight-intercept traps, and 16% in pitfall traps. *Pelidnota punctata* totaled 74% in light traps and 26% in flight-intercept traps. *Phyllophaga* spp. totaled 92% in light traps, following by 7% in flight-intercept traps, and <1% in pitfall traps. *Popillia japonica* totaled 69% in flight-intercept traps, 14% in light traps, and 17% in pitfall traps. *Plectris aliena* totaled 59% in light traps and 41% in flight-intercept traps. *Pelidnota punctata* totaled 74% in light traps and 26% in flight-intercept traps. *Phanaeus* spp. totaled 96% in flight-intercept traps and 4% in pitfall traps.

Species diversity and seasonal abundance by location

Camden Country Club produced the greatest diversity of scarabaeoid species (63) among all sites with the highest total of unique species (20). Dynastine species unique to Camden included *A. castaneus*, *L. neglectus, P. valgus valgus*, and *S. splendens*. Unique melolonthine species consisted of *D.*

harperi, *P. diffinis*, *P. hirticula, P. impar*, *P. knochii*, *P. mariana*, *P. parvidens*, and *P. ulkei*. Unique scarabaeine species included *O. orpheus orpheus*, *O. subaeneus*, and *O. tuberculifrons*. Two species of Trichiinae (*T. bibens* and *T. delta*) were captured exclusively at Camden. Unique geotrupids included *B. thoracicornis* and *G. egeriei*. One specimen of Passalidae (*O. disjunctus*) was captured in this study at Camden.

Light traps at Camden Country Club produced the highest totals for four species captured in high abundance in this study during 2009-2010, including *C. borealis*, *A. parvula*, *P. impar*, and *S. georgiana georgiana*. Camden Country Club frequently ranked second among all sites for total abundance of several species collected in high abundance in light traps, including 736 specimens of *D. morator*, 1,387 specimens of *E. humilis*, 117 specimens of *A. flavipennis flavipennis*, and 80 specimens of *A. marginata*. *Anomala flavipennis flavipennis* activity ranged from late May to mid-July, with peak abundance at 26 specimens on 12 June 2009. *Anomala marginata* activity ranged from late May to mid-August, with peak abundance at 22 specimens on 26 June 2009. *Anomala parvula* activity ranged from early to late June, with peak abundance occurring on 19 June 2009 at 28 specimens. *Cyclocephala borealis* activity ranged from early June to late July, with peak abundance at 93 specimens on 19 June 2009. *Cyclocephala lurida* activity ranged from late June to late September, with peak abundance occuring on 10 July 2009 at 52 specimens. *Dyscinetus morator* activity ranged from early April to mid-October, with peak abundance at 99 specimens on 15 May 2008. *Euetheola humilis* activity ranged from early April to early November, with peak spring abundance on 7 May 2010 at 252 specimens, and peak fall abundance at 71 specimens on 27 August 2010. *Hybosorus illigeri* activity ranged from late May to late August, with peak abundance occurring on 11 June 2010 at 38 specimens. *Tomarus gibbosus gibbosus* activity ranged from late April to early October, peaking in abundance at five specimens on 15 May 2009. *Maladera castanea* activity ranged from early June to early August, with peak abundance on 4 June 2010 at five specimens. *Pelidnota punctacta* activity ranged from mid-June to early August, with peak abundance on 26 June 2009 at 14 specimens. *Phyllophaga* spp. activity ranged from late April to late August, with peak abundance occurring on 19 June 2009 at 22 specimens. *Phyllophaga impar* was captured exclusively at Camden Country Club, ranging in activity from early April to early May, with a peak abundance occurring on 24 April 2009 at 64 specimens. *Serica georgiana georgiana* was captured almost exlusively at Camden Country Club, with 189 total specimens collected in light traps at Camden Country Club compared to 20 total specimens collected in light traps at all other locations combined. *Serica georgiana georgiana* activity ranged from early April to late May, with peak activity occurring on 30 April 2010 at 59 specimens. No species that were collected in high abundance were absent from Camden Country Club.

The Country Club of South Carolina produced the second highest total (56) scarabaeoid species, with nine species being unique to the site. Unique melolonthine species included *P. aliena* and *P. uniformis*. Unique ruteline species included *S. pygmeae*. Unique Scarabaeinae consisted of *C. pilularius*, *D. gibbosum gibbosum*, *P. igneus igneus, P. triangulari*s *triangularis*, and *P. vindex*. Unique trogids included *T. foveicollis.*

Light traps at the Country Club of South Carolina produced the highest totals for several species captured in high abundance in this study, including 245 specimens of *A. flavipennis flavipennis*, 275 specimens of *A. marginata*, 3,487 specimens of *D. morator*, 563 specimens of *H. illigeri*, and 130 specimens of *P. punctata*. No species that were collected in high abundance were absent from the Country Club of South Carolina. *Anomala flavipennis flavipennis* activity ranged from late May to mid-June, with peak abundance occurring on 28 May 2010 at 88 specimens. *Anomala parvula* activity ranged from late May to early July, with peak abundance occurring on 18 June 2010 at 78 specimens. *Anomala marginata* activity ranged from mid-June to early August, with a peak abundance of 80 specimens on 18 June 2010. *Cyclocephala borealis* activity ranged from early to late June, with peak abundance occurring on 11 June 2010 at 12 specimens. *Cyclocephala lurida* activity ranged from early June to early July, with a peak abundance of 21 specimens on 11 June 2010. *Dyscinetus morator* activity ranged from early April to mid-September, with a peak abundance of 454 specimens on 26 June 2009. *Euetheola humilis* activity ranged from early April to early November, with a peak spring abundance at 15 specimens on 15 May 2010. No fall peak was recorded. *Hybosorus illigeri* activity ranged from mid-May to mid-September, with peak abundance on 11 June 2010 at 174 specimens. *Tomarus gibbosus gibbosus* ranged from mid-May to mid-

August, with peak abundance occurring on 15 May 2009 at five specimens. *Maladera castanea* ranged from mid-June to mid-July, with peak abundance of 4 specimens on 11 June 2010. *Pelidnota punctata* ranged from late May to mid-August, with peak abundance of 25 specimens on 25 June 2010. *Phyllophaga* spp. activity ranged from early May to early September, with peak abundance occurring on 26 June 2009 at 27 specimens.

The Cliffs CEGR captured 52 species of scarabaeoids, including 15 species which were not present among other sampling sites. Unique species of Dynastinae consisted of *Xyloryctes jamaicensis* (Drury). Unique melolonthine species included *D. linearis*, *M. angustatus*, *M. subspinosus*, *P. aemula*, *P. hirsuta*, *P. drakii*, *P. comes*, and *S. sericea*. Unique Scarabaeinae consisted of *O. taurus*. Unique ceratocanthids included *G. aphodioides.* Unique geotrupids included *E. lazarus*, and uique trogids consisted of *T. hamatus*, *T. unistriatus*, and *T. variolatus*.

Light traps at the Cliffs CEGR produced the highest totals for several species captured in high abundance in this study, including 297 specimens of *T. gibbosus gibbosus* and 363 specimens of *M. castanea*. Species collected in high abundance in light traps which were absent from the Cliffs CEGR included *C. borealis*, *A. flavipennis flavipennis*, and *A. parvula*. *Anomala marginata* activity ranged from late May to early August, with a peak abundance of 10 specimens on 3 July 2009. *Cyclocephala lurida* ranged from late May to late July, with a peak abundance of 92 specimens on 2 July 2010. *Dyscinetus morator* activity ranged from early May to early July, with a peak abundance of five specimens on 22 May 2009. *Euetheola humilis* activity ranged from late April to late September, with a peak spring abundance of 25 specimens on 2 July 2010, and a peak fall abundance of 7 specimens on 27 August 2010. *Hybosorus illigeri* activity ranged from late June to early July, with a peak abundance of 27 specimens on 2 July 2010. *Tomarus gibbosus gibbosus* ranged from late April to late September, with peak abundance of 63 specimens on 28 May 2010. *Maladera castanea* ranged from mid-June to late September, with a peak abundance of 49 specimens on 3 July 2010. *Phyllophaga* spp. activity ranged from late April to mid-August, with peak abundance at 13 specimens on 22 May 2009. *Pelidnota punctata* activity ranged from mid-June to late September, with peak abundance of 10 specimens on 3 July 2009 and 2 July 2010.

The Walker Golf Course produced the lowest number of scarabaeoid species (32) among all sites with only five species unique to the site. Species unique to this location included the scarabaeine *A. histeroides*, the valgiine *V. canaliculatus*, the ceretocanthid *C. aeneus*, the lucanid *D. brevis*, and the trogid *T. affinis*.

Among species captures in high abundance in light traps, the Walker Golf Course produced the highest totals for *C. lurida* and *E. humilis*. Absent species captured in high abundance at other locations included *C. borealis* and *A. parvula*. *Anomala flavipennis flavipennis* activity ranged from mid- to late June, with peak abundance occurring on 12 June 2009 at three specimens. *Amomala marginata* consisted of two total specimens, captured 19 June 2009, 11 June 2010. *Cyclocephala lurida* activity ranged from mid-June to mid-October, with peak abundance at 145 specimens on 31 July 2009. *Dyscinetus morator* activity ranged from early April to late August, with peak abundance at 19 specimens on 7 May 2010. *Euetheola humilis* activity ranged from early April to late October, with a peak spring abundance of 344 specimens on 7 May 2010, and a peak fall abundance of 244 specimens on 3 September 2010. *Hybosorus illigeri* activity ranged from mid-May to early October, with a peak abundance of 76 specimens on 12 June 2009. *Maladera castanea* ranged from early June to mid-September, with peak activity June through July. *Pelidnota punctata* ranged from mid-June to mid-August, with a peak abundance of 14 specimens on 26 June 2009. *Phyllophaga* spp. activity ranged from late April to mid-September, with the highest peak abundance of three specimens on 12 June and 31 July 2009.

Discussion

Species diversity and seasonal abundance in light traps

Light traps produced the greatest species diversity and abundance of specimens captured within this study (Table 2.1). Light traps are "active" traps, attracting insects from a distance, as compared to "passive" flight-intercept and pitfall traps, which require specimens to encounter the trap while navigating through the environment. As many species of scarabaeoids are recorded to be phototactic (Harpootlian 2001), higher total numbers and greater diversity is not unexpected in light trap captures. Predominately male-biased sex ratios are the norm among many insects captured in light traps. Bowden (1982) analyzed published data on a wide variety of insects captured in light traps, and recorded a 10:1 male to female ratio. Several factors may explain the higher percentage of males in light traps, including higher levels of phototaxis and flight behavior among males or, inherent male-biased sex ratios among many insect populations.

Although light trapping is a common means of gauging population size for many insect species, light trap captures may not necessarily reflect total population numbers or species diversity. Insect species attracted to light traps are predominately nocturnal or crepuscular. A species must be phototactic to be captured in light traps and possess adequate flight capabilities to accurately encounter the trap in flight. In addition, abundance in traps may reflect periods of heightened levels of phototaxis which correspond with a particular period in the adult stage of an insect.

The majority of species and total numbers of Ceratocanthidae, Geotrupidae, Hybosoridae, Lucanidae, Passalidae, Trogidae, and the scarab subfamilies Dynastinae, Melolonthinae, and Rutelinae captured in this study were attracted to light traps as compared to other trapping methods, suggesting that light traps may be the single most effective method for sampling these taxa. Several species of Scarabaeinae captured in this study (most notably *D. carolinus*, *O. depressus, O. gazella*, *C. vigilans*, and *C. minutus*) were represented predominately or exclusively in light traps, while the majority of scarabaeinae species were not captured with this trapping method. An overall consensus on the effectiveness of trapping Scarabaeinae with lights is difficult to reach, and may be a species-specific issue. Although several species of *Onthophagus* were captured predominately or exclusively in light traps, several of the more abundant species (most notably *O. hecate hecate*) were captured exclusively in flight-intercept traps in close proximity (within 30 meters) to light traps. Furthemore, two sister species of *Canthon* (*C. vigilans* and *C. pilularius*) differ in phototaxis to the extent that, along with minor morphological characters, *C. vigilans* is distinguished from *C. pilularius* in being “attracted to lights” (Harpootlian 2001).

Similar to many of the Scarabaeinae, the lack of Cetoniinae in light traps adjacent to flight-intercep traps which captured Cetoniinae suggests that the subfamily may be largely nonphototactic. I regularly noted several species captured in this study engaging in diurnal flight and feeding behaviors in the field. A diurnal life history may be non-conducive to phototaxis and light trap captures. Trichiinae captured in this study were captured exclusively in flight-intercept traps, and are known to be diurnal flower feeders.

Aphodiinae totaled 55,690 specimens in light traps representing 97% of captures among all trap types, and 1,764 specimens in pitfall traps representing >2% of captures among all trap types. Although Apodiinae were identified to subfamily only, Harpootlian (2001) listed records for four genera and 20 species attracted to lights, including *Aidophus parcus* (Horn), *Aphodius campestris* Blatchley, *Aphodius granarius* (L.), *Aphodius nigrita* Fabricius, *Aphodius pseudolividus* Balthasar, *Aphodius rubeolus* Beauvois, *Aphodius stupidus* Horn, *Aphodius troglodytes* Hubbard, *Ataenius alternatus* (Melsheimer), *Ataenius cylindrus* Horn, *Ataenius erratus* Fall, *Ataenius figurator* Harold, *Ataenius gracilis* (Melsheimer), *Ataenius imbricatus* (Melsheimer), *Ataenius picinus* Harold, *Ataenius platensis* (Blanchard), *Ataenius simulator* Harold, *Ataenius spretulus* (Haldeman), *Ataenius strigatus* (Say), and *Platytomus longulus* (Cartwright). Given the broad overlap of light trap and pitfall trap captures within this study, the overwhelming majority of species collected in this study were likely represented by phototactic species in the genera *Aphodius* and *Ataenius*. *Aphodius granarius* and *A. spretulus* are known pests, and future studies wishing to examine diversity of Aphodiinae and economically important species may wish to employ light traps.

Despite providing the majority of information on population sizes and seasonal abundance in this study, occasional light trap ballast failures resulted from high humidity or rain. Future studies may wish to seal the ballast more effectively to protect it from moisture, particularly if sampling during warmer and wetter months in the Southeast.

Flight-intercept trap diversity and seasonal abundance

Flight-intercept traps captured many scarabaeine and cetoniine species not collected with other trapping methods, as well as several species of Trichiinae. Species captured in both light traps and flight-intercept traps, particularly among the subfamilies Dynastinae (*E. humilis*, *D. morator*, *T. gibbosus gibbosus*), Melolonthinae (*Phyllophaga* spp.), and Rutelinae (*Anomala* spp.), were generally captured in low numbers in flight-intercept traps during normal seasonal activity observed from light traps, suggesting that flight-intercept traps are a comparatively ineffective means of sampling for the majority of Dynastinae, Melolonthinae, and Rutelinae. Despite being captured in low total numbers among all trapping sites, trapping methods, and locations, 35% of total geotrupid captures occurred in flight-intercept traps, suggesting that this may be an alternative method to light trapping for sampling geotrupid species. Species captured almost exlusively in flight-intercept traps among the Scarbaeinae and Cetoniinae were primarily active during May through August. Though captured Cetoniinae (*Cotinis nitida* and *Euphoria* spp.) were widely distributed throughout the state, the overwhelming majority of flight-intercept-captured Scarabaeinae were taken at the Country Club of South Carolina and Camden Country Club. I regularly observed more species of Scarabaeinae in the field in the eastern half of the state, suggesting the probability of higher catch rates and greater diversity at Camden Country Club and the Country Club of South Carolina. Theories for greater abundance of Scarabaeinae in the eastern half of the state may be formulated by considering food availability provided by regionally specific fauna. Additionally, variations in coprophagy may contribute to habitat restrictions based on local geology. Species in two genera frequently captured in this study (*Onthophagus* and *Phanaeus*) are known paracoprids, with life histories which involve burrowing tunnels beneath dung to create reproductive chambers (Bertone et al. no date). Looser, sandier soils found along the eastern half of the state combined with high rainfall/humidity may be more conducive to burrowing habits of paracoprophagous scarabaeines, and high moisture content may contribute to larval survival.

Taxa captured in high numbers in light traps and comparatively low numbers in flight-intercept traps may be attributable to more than the passive nature of flight-intercept traps. Many of the Dynastinae, Rutelinae, and Melonthinae are phytophagous taxa possessing foretarsi which are well-modified for clinging to vegetation to feed, compared to the Scarabaeinae, which are coprophagous and detritophagous, and frequently exhibit reduced or absent foretarsi. Poorly functional or absent foretarsi among the Scarabaeinae may inhibit the ability to cling to mesh fabric upon falling from an in-flight encounter with a flight-intercept trap, generating higher captures. The general lack of Aphodiinae in flight-intercept traps may be attributable to the small size of the subfamily. A smaller body size and lower weight may generate less momentum in flight, and allow the species to alight on the mesh fabric upon contact, rather than dropping after becoming abruptly impeded in flight.

Accurate population estimates for species were difficult to obtain from flight-intercept traps, as the traps were flooded regularly during the warmer, wetter months, which were also the months of peak scarabaeoid activity. Future studies may wish to modify the trap used in this study by creating several drainage holes along the length of the troughs immediately below the top margin. By covering these holes with a mesh fabric, excess water may drain without allowing any captured scarabaeoids to escape. Additionally, traps may be checked more frequently than once per week to account for flooding events. Water and soap mixtures may be replaced at this time, as specimens are frequently in an advanced state of decay and dismemberment within a week. To avoid bias which may result from any scarabs clinging to the mesh fabric used as an in-flight barrier, future studies may wish to replace the fabric with a light-weight, plastic pane with enough holes in it to reduce the likelihood of blow-down in high winds, a frequent occurrence in association with thunderstorms

Pitfall trap diversity and seasonal abundance

Pitfall trapping produced low numbers of species. The trap also produced fewer species which were already abundant in high numbers in light traps, most notably Aphodiinae, *D. morator* and *E. humilis*. Pitfall trapping seasonal abundance generally reflected periods of activity recorded from light traps. Although overall catch area of the pitfall trap design exceeded that of flight-intercept traps, PVC pipes funneling scarabeoids into the central collection bucket likely failed to capture and direct many scarabs to the central collection bucket, as the large size of many scarabs may have enabled them to pass easily over the pipes or to escape from the pipes. Additional issues with flooding resulted from rainwater channeling into the central collection bucket. This may have caused an underestimation of the true number of scarabs captured in pitfall traps, resulting in lower population totals and lower species diversity.

Few species in low numbers make an overall estimate of sex ratio difficult. For the few species captured in high numbers, a slight trend toward male bias was recorded. This trend contradicts the originally expected results, as more females were predicted to be captured due to oviposition-related burrowing behavior. A possible reason for the nearly equal numbers of males and females may be that species of scarabaeids frequently burrow into the soil during the day (UC IPM 2008).

Future studies may wish to use a more traditional pitfall trap design, which allows scarabs to wander into an open bucket as opposed to be being funneled through a PVC pipe. A well-covered traditional trap will also preclude many of the flooding issues associated with water being funneled through the PVC pipes into the central collection bucket. In additional, pitfall traps may be baited with dung or carrion to become "active" traps for luring Aphodiinae, Geotrupidae, Scarabaeinae, and Trogidae.

Diversity and seasonal abundance by location

Camden Country Club produced the greatest diversity of species among all sampled sites. Camden Country Club is located at one of the most unique regions of the state for physiographic variety (Fig. 2.01), where the Coastal Plain, the Sandhills, and the Piedmont are closest in distance to one another. Many species which may be unique or better adapted to certain regional fauna, climates, or geological conditions may share overlapping distributions in this area. In addition, overall east to west distributions may share some overlap at the geographically central Camden. Only three species collected in high abundance (*C. borealis, A. parvula,* and *S. georgiana georgiana*) which were present at all sites were represented by the highest totals at Camden Country Club. *Phyllophaga impar* was captured exclusively at Camden, and represented the only species captured in high abundance which was exclusive to one sampling site. Unlike other sites, all species collected in light traps in high abundance were collected at Camden Country Club.

The Cliffs CEGR captured 52 species of scarabaeoids, including several species which were not present throughout the rest of the state. Unique species included *D. linearis*, *E. lazarus*, *G. aphodiodes*, *M. angustatus*, *M. subspinosus*, *O. taurus*, *P.aemula*, *P. hirsuta*, *P. drakii*, *Polyphylla comes* Casey, *S. sericea*, and *X. jamaicensis.* Located in the Blue Ridge Mountains, and peripheral to the Southern Piedmont, the higher altitude and colder temperatures of this region may make it home to species better adapted to northern climates. This site captured the highest total numbers of *T. gibbosus gibbosus* and *M. castanea*. *Anomala flavipennis flavipennis*, *A. parvula*, and *C. borealis* were absent from Cliffs CEGR.

Maladera castanea was collected in high numbers at the Cliffs CEGR, and is a pest that is of greater economic importance in the northeastern United States. South Carolina represented the southern-most range of *Maladera castanea* until a recent discovery of larvae in damaged turfgrass in Alabama (Held and Ray 2009). I also noted higher populations of *P. japonica* at the Cliffs CEGR site than at any other locations. The pest status of *P. japonica* is more significant in North Carolina, and is of lesser importance in states south of South Carolina. The Japanese beetle is not reported as a pest problem in Florida as of 2010 (Gyeltshen and Hodges 2010). A comparision of latitudes between the native range of the Japanese beetle in Japan with that of established populations in the eastern half of the United States predicts the actualized range of the beetle within the eastern United States.

Species of Trogids, particularly the genus *Trox*, were captured more frequently at the Cliffs CEGR than at any other location in the state. Members of this genus are known to feed on keratin and the remains of animals in advanced states of decay (Harpootlian 2001). Along with reduced habitat fragmentation possibly supporting higher population densities of animals, and therefore animal remains, traps at the Cliffs CEGR were adjacent to a mountain stream, which may have served as a convergence zone for local animals seeking water.

The Country Club of South Carolina produced the second highest total (56) in terms of scarabaeoid species. Unique species included *C. pilularius*, *D. gibbosum gibbosum*, *S. pygmeae, P. igneus igneus, P. triangularis triangularis*, *P. vindex*, and *T. foveicollis*. This site captured the highest total numbers of *A. flavipennis flavipennis, A. marginata, D. morator, H. illigeri,* and *P. punctata*. One of the more abundant species (*D. morator*) captured within this study was captured in higher numbers at the Country Club of South Carolina than at any other site. This site is located along the border of the Southern Coastal Plain and the Atlantic Coast Flatwoods. Similar to Camden, much of the diversity at the Country Club of South Carolina may be explained by the convergence of physiographic regions. Furthermore, much of the diversity at the Country Club of South Carolina consisted of Scarabaeinae collected in flight-intercept traps. Highest species diversity at these locations suggests that scarabaeoid species richness may be highest in areas along the eastern half of the state.

The Walker Golf Course produced the lowest number of scarabaeoid species (32) among all sites. Species unique to this location included *A. histeroides*, *C. aeneus*, *D. brevis*, and *V. canaliculatus.* Compared to all other sites which border physiographic regions, the Walker Golf Course is more encompassed by a particular physiographic region, the Southern Piedmont. Additionally, the area surrounding the sampling site at the Walker Golf Course is more developed than at other sampling sites. Immediately adjacent to Clemson University, low species diversity may be explained by habitat fragmentation and higher levels of artificial lights which interfere with light trapping. *Anomala parvula* and *C. borealis* were absent from the Walker Golf Course.

The Walker Golf Course produced the highest abundance of *C. lurida* and *E. humilis*. *Cyclocephala lurida* is a notable economic pest for the turfgrass industry, and *E. humilis* is rapidly becoming one of the most abundant and enigmatic scarabs associated with turfgrass. A steadily increasing awareness of the species in turfgrass has developed within the last several years, but the species did not become extremely abundant throughout the Southeast until ~2009-2010. Explanations for the sudden overwhelming abundance of the species are lacking, but future studies may wish to correlate climatic variables such as temperature and rainfall to assess the possibility of future population explosions.

Whether the species will remain as a major presence on southeastern golf courses or the Southeast at large is unknown. Future studies focusing on scarabaeoids may wish to focus heavily on this species, particularly life history aspects involving feeding behavior of adults and larvae, susceptibility to insecticides, and female oviposition behaviors.

By examing trends in species diversity and abundance by location, the highest similarity in species abundance existed between Camden Country Club and the Country Club of South Carolina, distinct from similarity between the Walker Golf Course and the Cliffs CEGR. Camden Country Club and the Country Club of South Carolina supported the highest numbers of *A. flavipennis flavipennis, A. marginata, A. parvula, C. borealis,* and *D. morator*, and many species of Scarabaeinae, suggesting that these taxa may be more prevalent along the eastern half of the state. The Walker Golf Course and the Cliffs CEGR supported the highest numbers of *C. lurida* and *M. castanea*, suggesting that these species may be more prevalent along the western half of the state. *Euetheola humilis* ranked highest in total numbers at Camden Country Club and the Walker Golf Course. This species may prefer climatic or geographic conditions intermediate to the Country Club of South Carolina and the Cliffs CEGR. *Hybosorus illigeri*, *T. gibbosus gibbosus*, and *P. punctata* ranked inconsistently among Camden Country Club/ the Country Club of South Carolina and the Walker Golf Course/ the Cliffs CEGR groupings.

An overall trend in emergence from east to west is difficult to identify based on the data, as Camden Country Club, the Country Club of South Carolina, and the Walker Golf Course ranked inconsistently across sites and within species for peak periods of abundance. However, the Cliffs CEGR supported the greatest number of species exhibiting the latest peak abundance. Although the Cliffs CEGR lies to the east of the Walker Golf Course, the more northern location of the Cliffs CEGR within the Blue Ridge Mountains may create a colder climate due to altitude and produce later seasonal emergences. Predictions of seasonal abundance for species may be more accurate based on general averages of seasonal abundance across locations or on degree-days. Future studies may wish to collect on a daily basis during the broader range of peak abundance to record more minor trends in emergence between east-west locations within the state.

The use of only one trap type at each location precludes the possibility of statistical analyses, and future studies may wish to use multiple traps of each trap type per location to serve as replicates. Future studies may also wish to examine sites for more than two years to more adequately gauge changing trends in abundance, seasonal emergence, and species composition over time. Additionally, the identity and timing of pesticides on golf courses should be recorded and investigated as a potential confounding variable. If possible, trap types should be distributed at uniform distances among and between locations to eliminate any spatial differences which may result in differences in species composition and abundance.

Conclusion

Approximately 74,327 scarabaeoids in 7 families, 47 genera, and 104 species were captured among all locations and all trap types 2009-2010. Greatest diversity was found at Camden Country Club (63 species), followed by the Country Club of South Carolina (56 species), the Cliffs CEGR (52 species), and the Walker Golf Course (32 species). The most abundant species consisted of *C. lurida*, *D. morator*, *E. humilis*, and *H. illigeri*, and the most abundant genus (*Phyllophaga*) consisted of 22 total species. Light traps produced the majority of species and specimens, particularly among the Aphodiinae, Dynastinae, Melolonthinae, and Rutelinae. Flight-intercept traps produced more species than pitfall traps, but in lower numbers. Flight-intercept traps captured the majority of Scarabaeinae and roughly 1/3 of the Geotrupidae. The majority of Scarabaeine species and total numbers were collected at Camden Country Club and the Country Club of South Carolina, suggesting that Scarabaeinae may be more abundant and speciose in the eastern half of the state. Ceratocanthidae, Geotrupidae, and Trogidae were collected in low numbers. Predominately male-biased sex ratios were recorded. Many species displayed statewide distributions, whereas others were more restricted to particular regions, or even particular sampling sites. Several species were represented by single specimens, whereas others were collected by the thousands, indicating a wide range of natural population sizes per species. Seasonal activity periods were species specific, but the primary period of peak abundance for most scarabaeoids ranged from April to July. The Cliffs CEGR consistently ranked last in terms of peak abundance, suggesting that the mountaineous regions of South Carolian may display the most distinct difference in seasonal activity of scarabaeoids among all sampled sites. Future studies on Scarabaeinae may focus on refining collecting methods and developing a bioindication index for assessments of ecosystem health and biodiversity. Future studies may investigate details of the life history and seasonality of some of the more abundant species (*C. borealis*, *D. morator*, *E. humilis*, and *H. illigeri*) as well as the Aphodiinae to determine potential impacts in turfgrass.

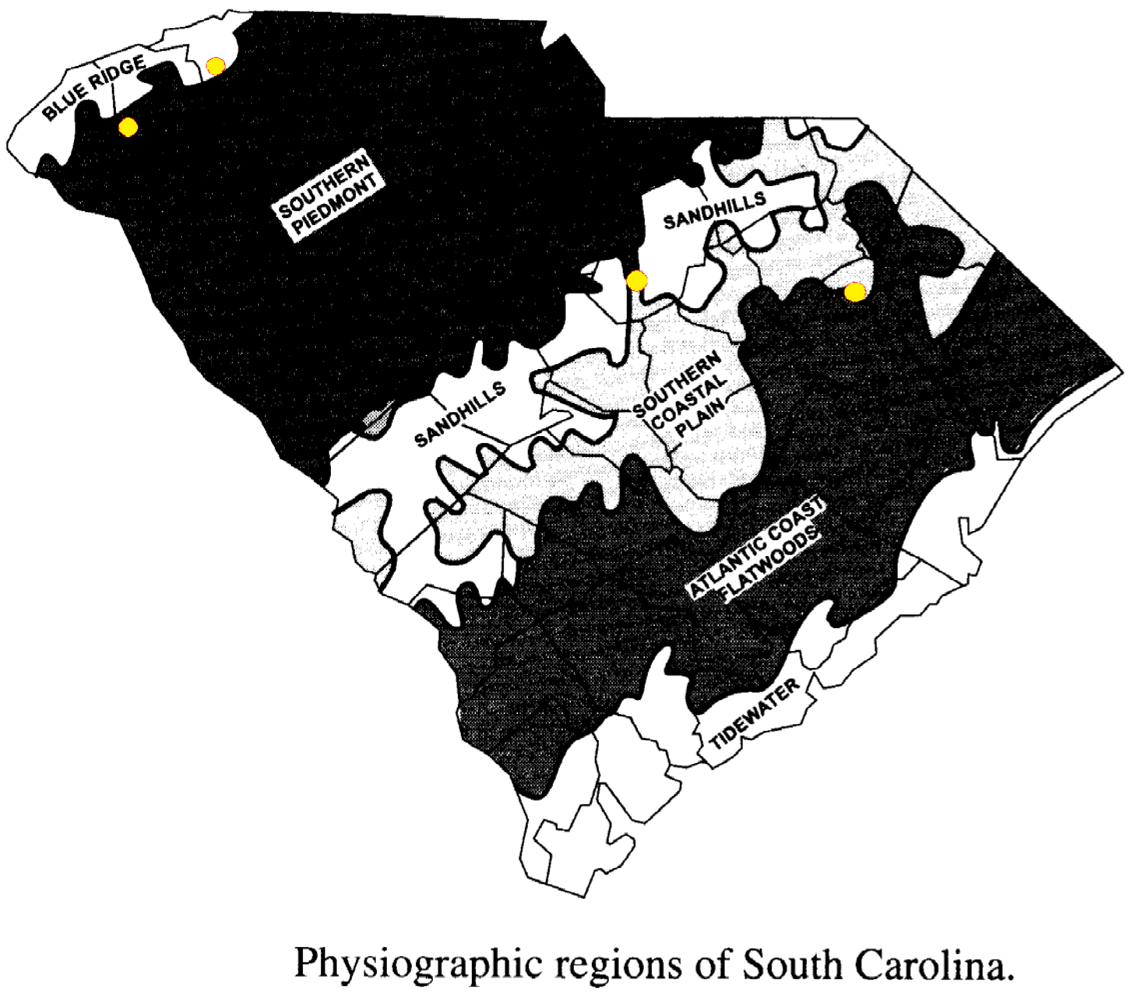

Figure 2.01. Map of South Carolina physiographic regions. Sampling sites are indicated with yellow dots.

Figure 2.02. Flight-intercept trap employed to collect scarabs at the sampled golf courses in Florence, Camden, Clemson and Marietta, SC. Traps measured 1.4 m in height by 1.54 m in length. Troughs were filled with ~1 teaspoon of dish soap mixed in 3.8 L of water.

Figure 2.03. Light trap outfitted with 22-W circline black light tube employed to collect scarab beetles at the sampled golf courses in Florence, Camden, Clemson and Marietta, SC. The traps were hung from trees or other structures at 1-1.5 m from the ground.

Figure 2.04. Pitfall trap employed to collect scarab beetles at the sampled golf courses in Florence, Camden, Clemson and Marietta, SC. Trap diameter measured 2.94 m.

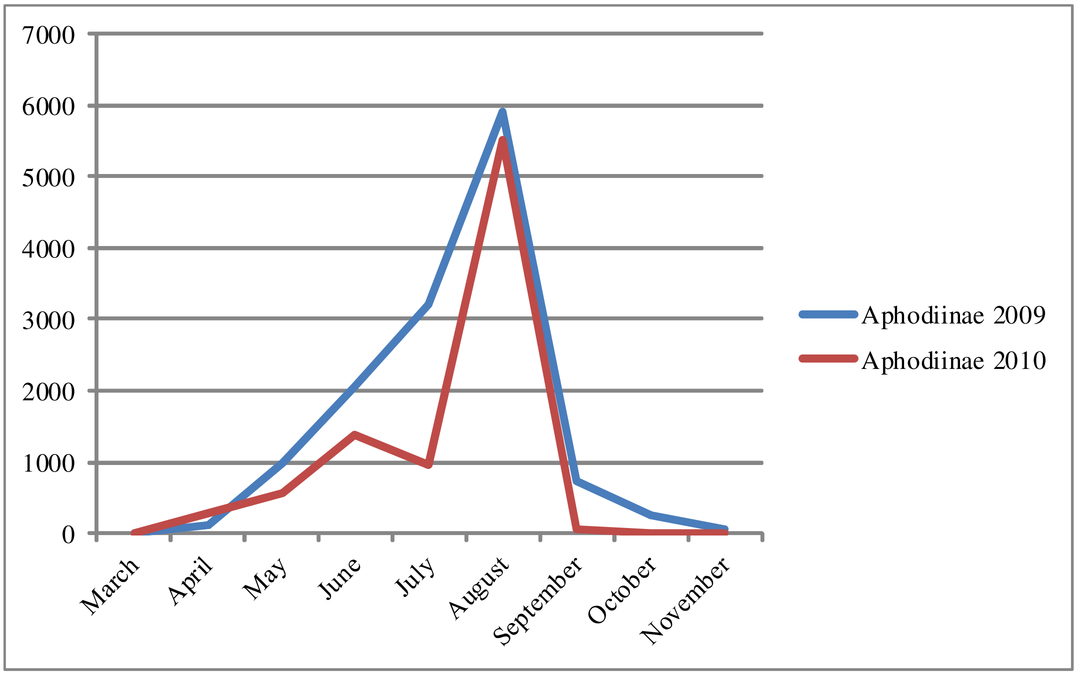

Figure 2.05. Number of specimens of Aphodiinae captured at lights at Camden Country Club 2009-2010.

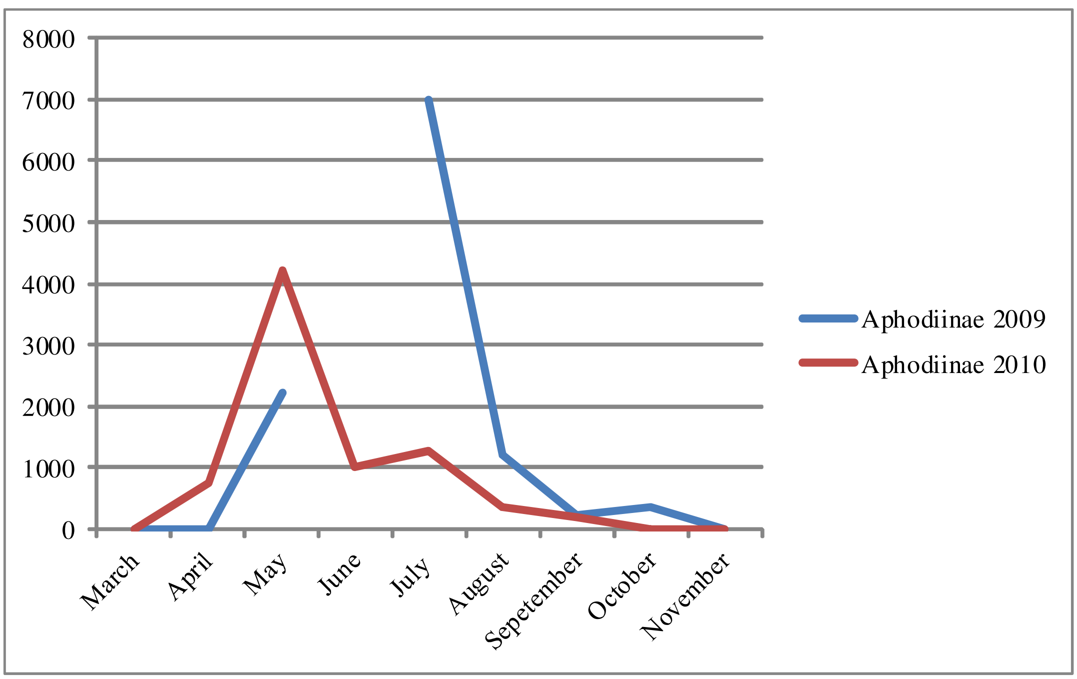

Figure 2.06. Number of specimens of Aphodiinae captured at lights at the Cliffs Center for Environmental Golf Research 2009-2010. Absence of data for 2009 due to light trap failure.

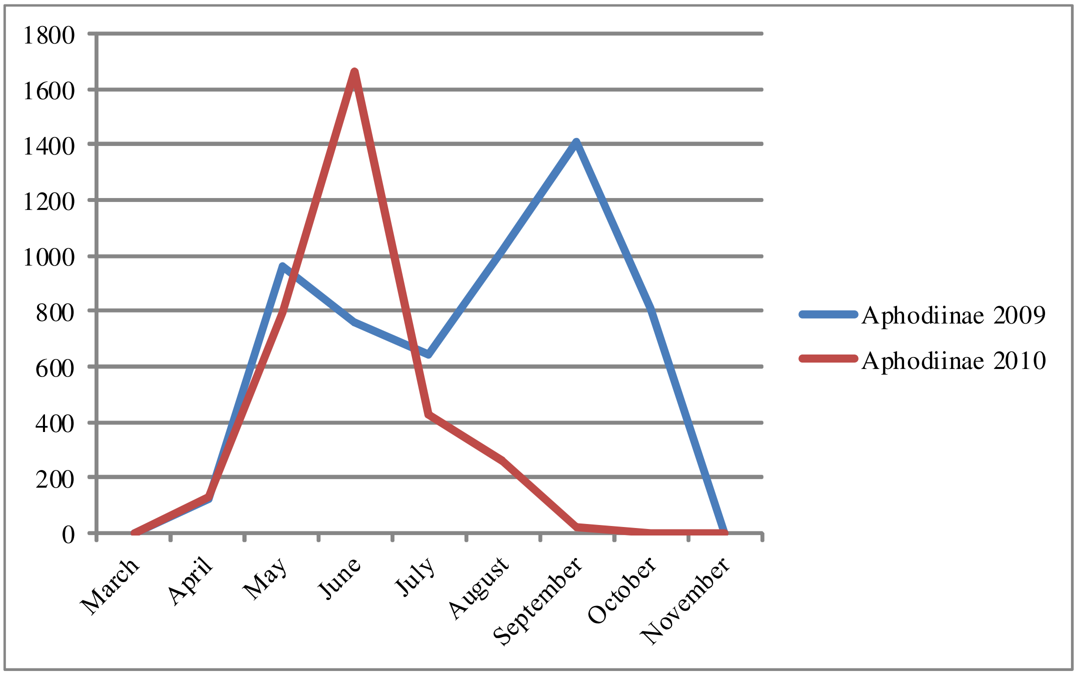

Figure 2.07. Number of specimens of Aphodiinae captured at lights at the Country Club of South Carolina 2009-2010.

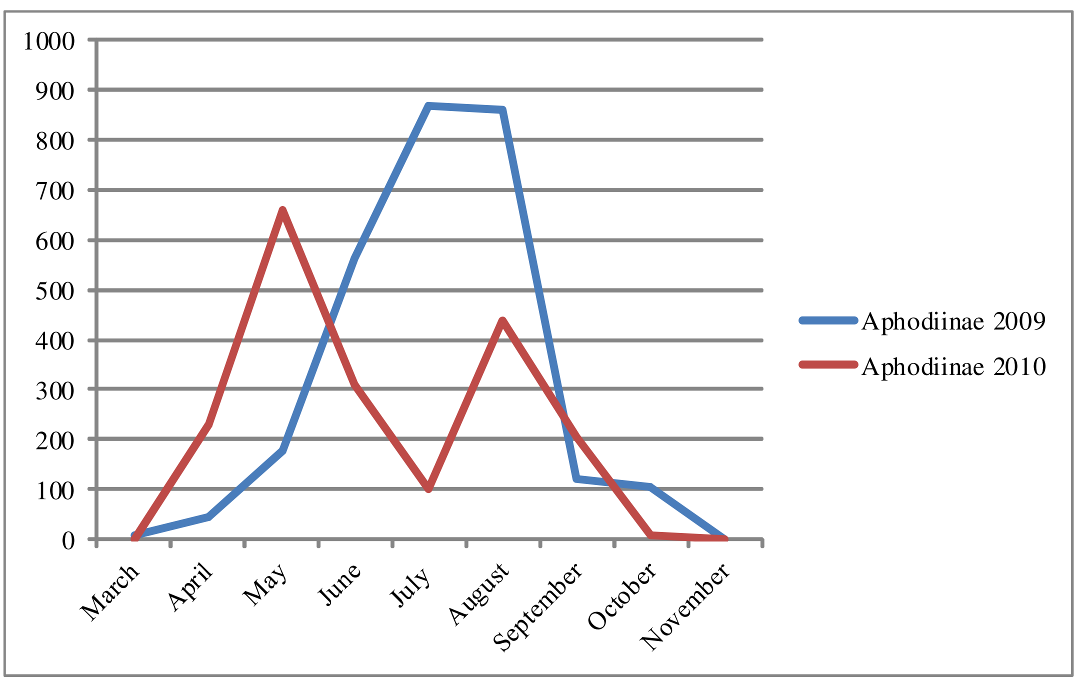

Figure 2.08. Number of specimens of Aphodiinae captured at lights at the Walker Golf Course 2009-2010.

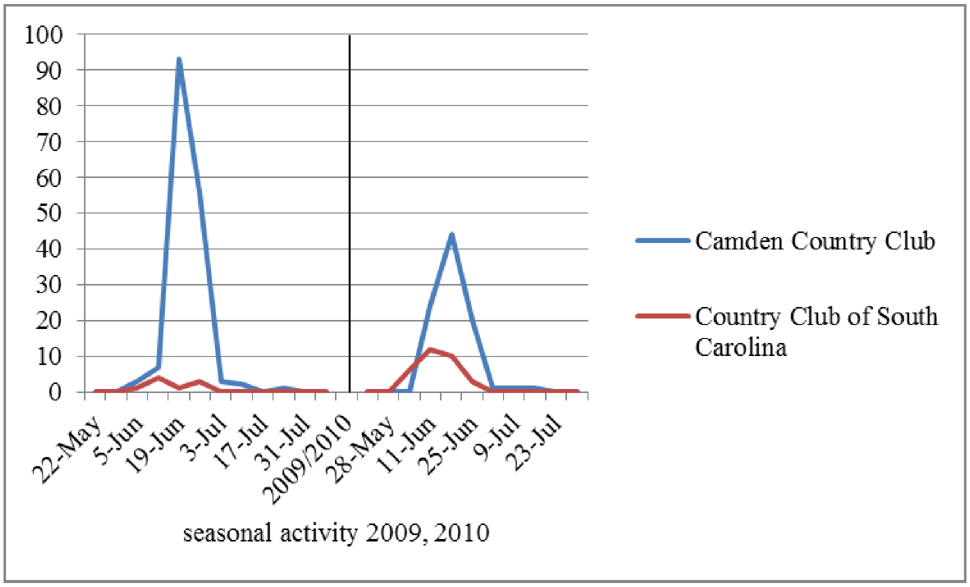

Figure 2.09. Number of specimens of *Cyclocephala borealis* captured in light traps at all locations in 2009 and 2010. No specimens of *C. borealis* were collected from the Walker Golf Course and the Cliffs CEGR.

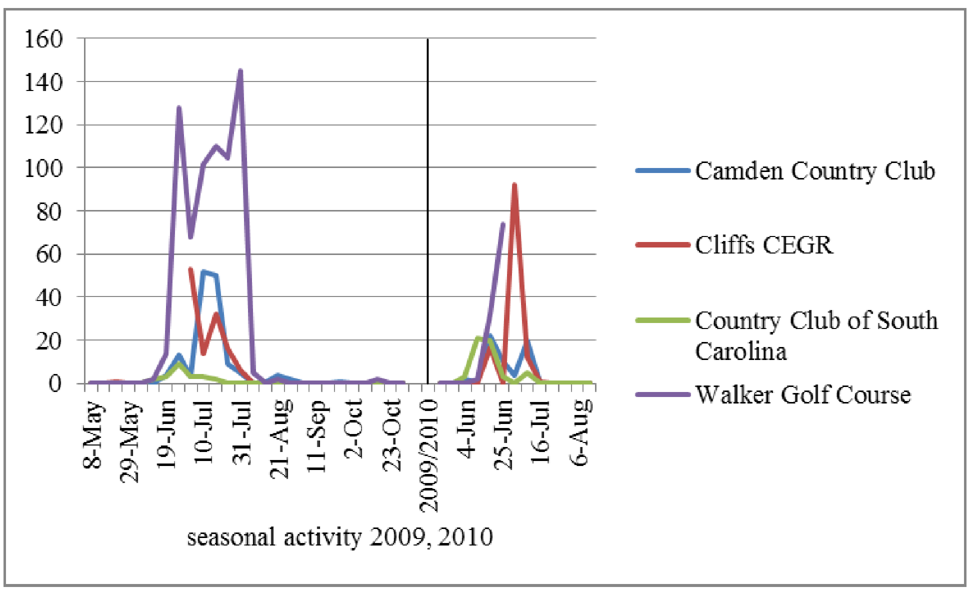

Figure 2.10. Number of specimens of *Cyclocephala lurida* captured in light traps at all locations in 2009 and 2010.

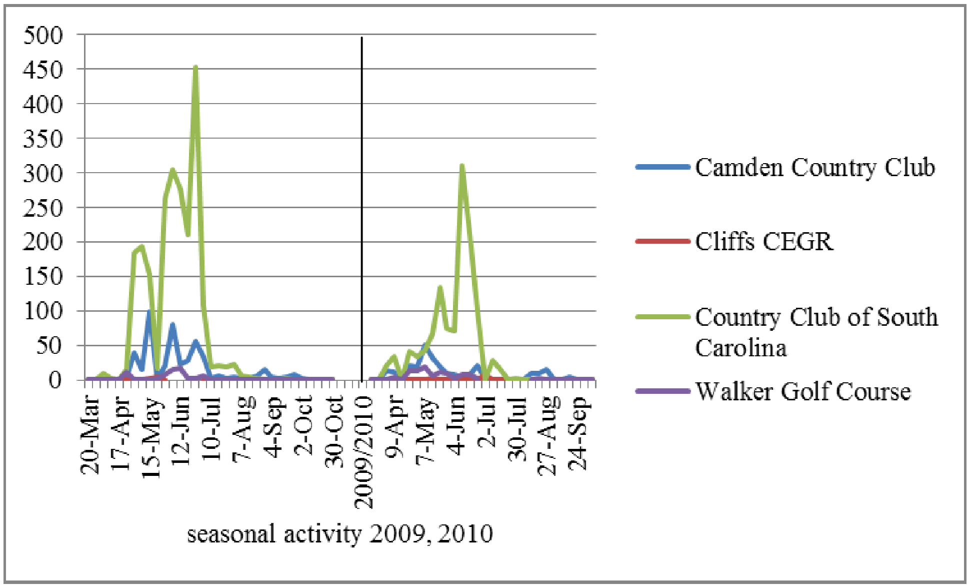

Figure 2.11. Number of specimens of *Dyscinetus morator* captured in light traps at all locations in 2009 and 2010.

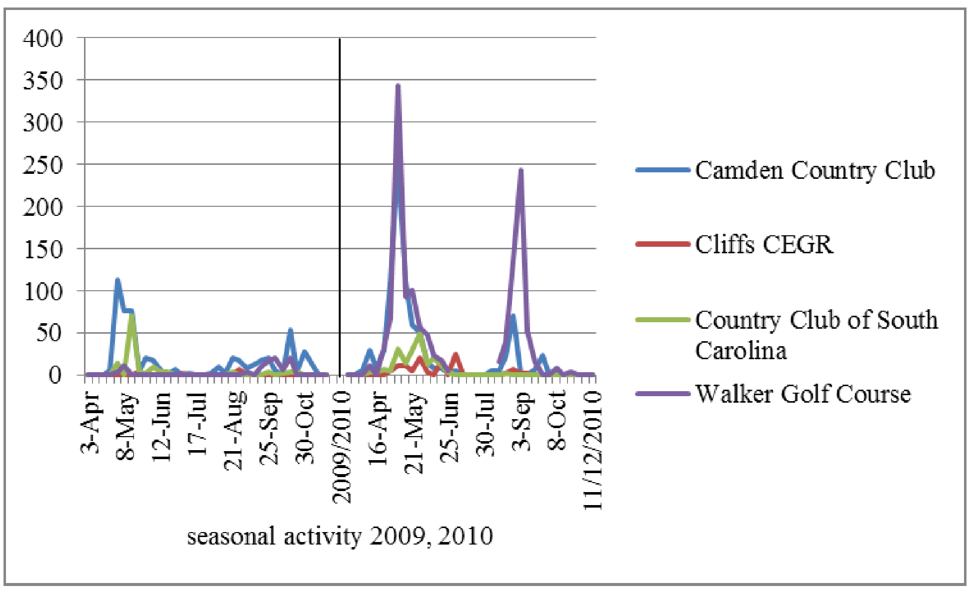

Figure 2.12. Number of specimens of *Euetheola humilis* captured in light traps at all locations in 2009 and 2010.

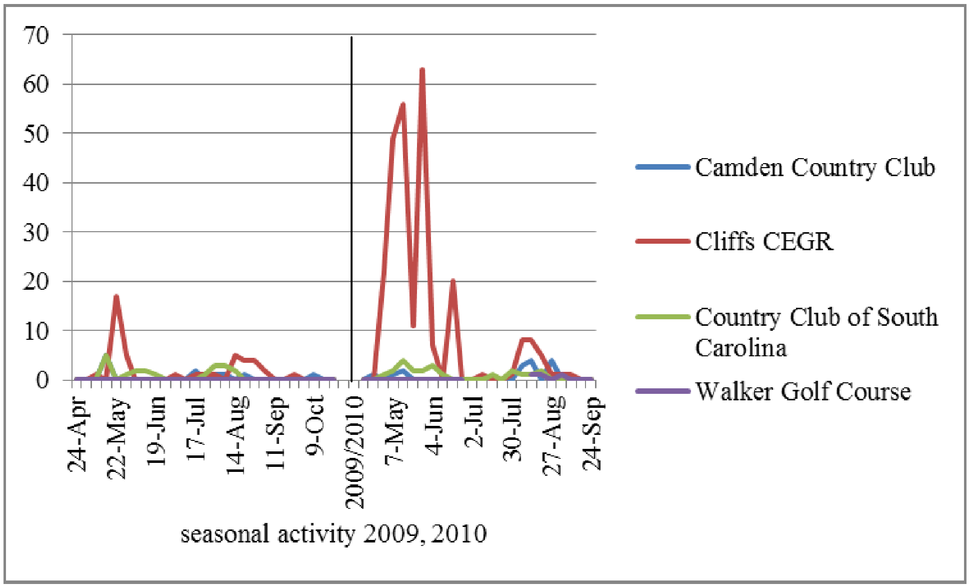

Figure 2.13. Number of specimens of *Tomarus gibbosus gibbosus* captured in light traps at all locations in 2009 and 2010.

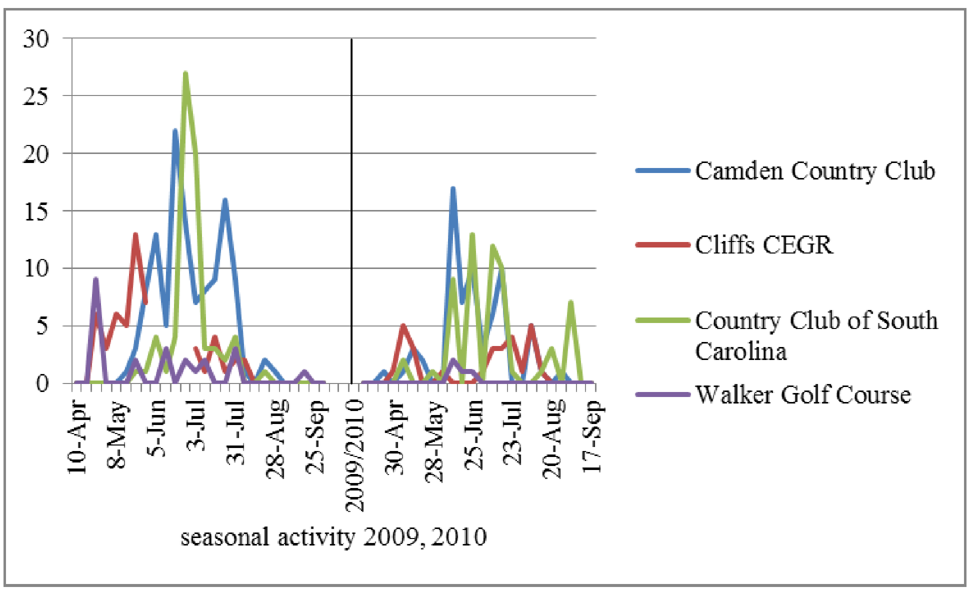

Figure 2.14. Number of specimens of *Phyllophaga* spp. (excluding *P. impar*) captured in light traps at all locations in 2009 and 2010.

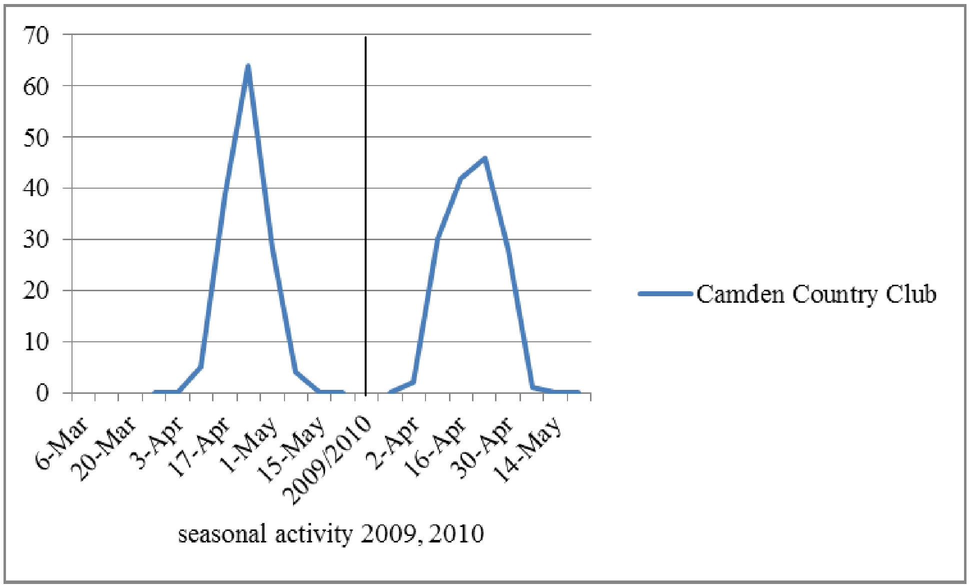

Figure 2.15. Number of specimens of *Phyllophaga impar* captured in light traps at Camden Country Club in 2009 and 2010. Specimens of *P. impar* were collected only at Camden Country Club.

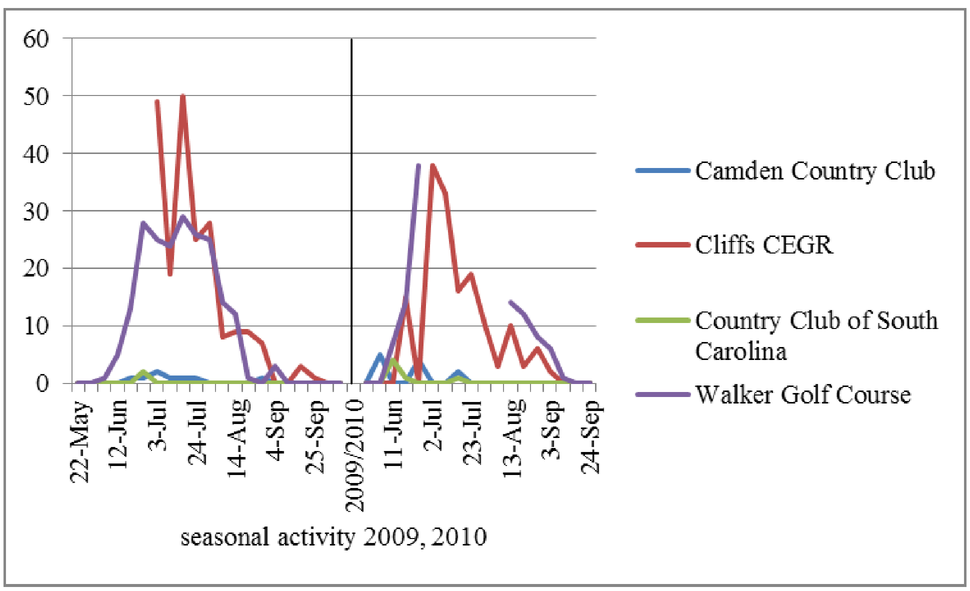

Figure 2.16. Number of specimens of *Maladera castanea* captured in light traps at all locations in 2009 and 2010.

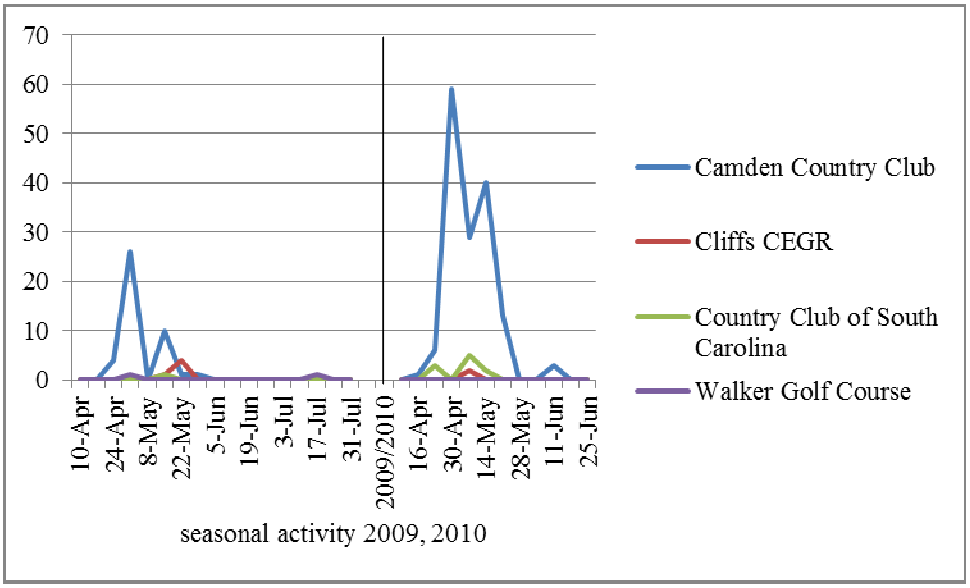

Figure 2.17. Number of specimens of *Serica georgiana georgiana* captured in light traps at all locations in 2009 and 2010.

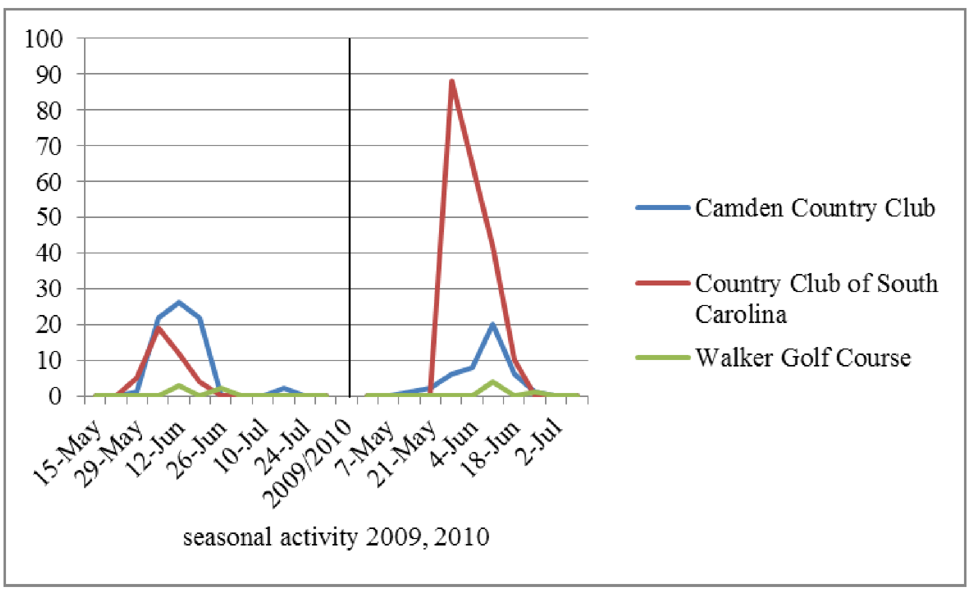

Figure 2.18. Number of specimens of *Anomala flavipennis flavipennis* captured in light traps at all locations in 2009 and 2010. No specimens of *A. flavipennis flavipennis* were collected at the Cliffs CEGR.

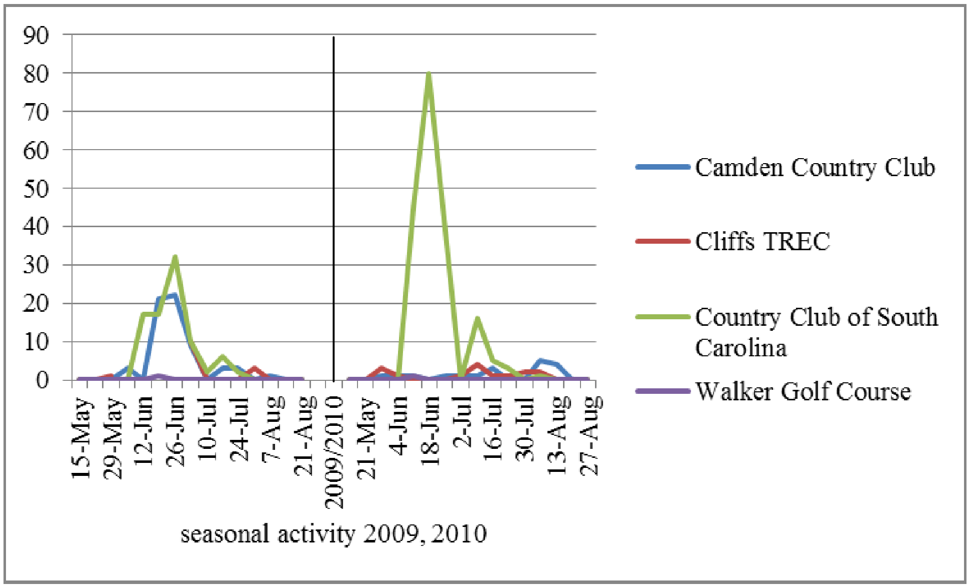

Figure 2.19. Number of specimens of *Anomala marginata* captured in light traps at all locations in 2009 and 2010.

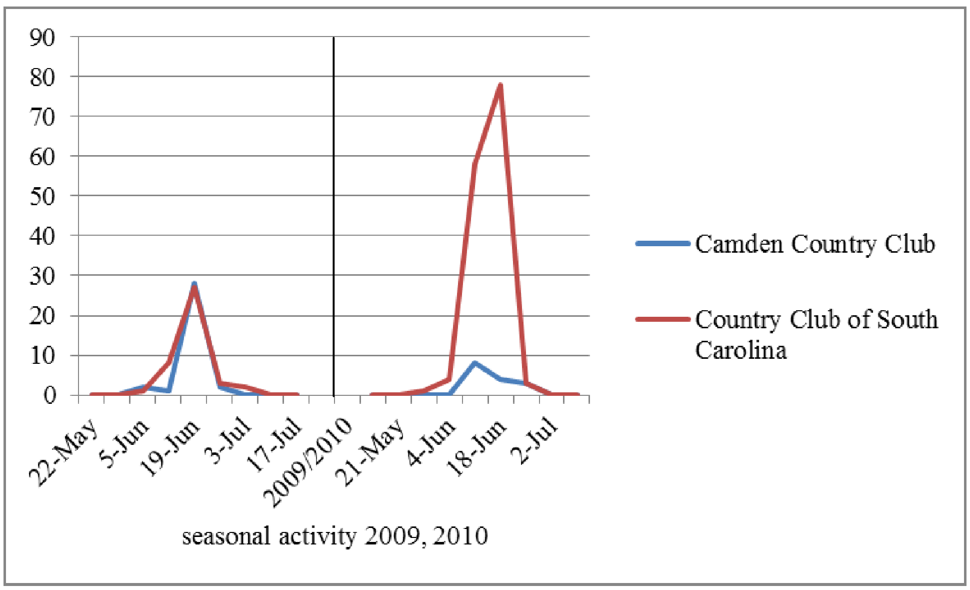

Figure 2.20. Number of specimens of *Anomala parvula* captured in light traps at all locations in 2009 and 2010. No specimens of *A. parvula* were collected at the Cliffs CEGR and the Walker Golf Course.

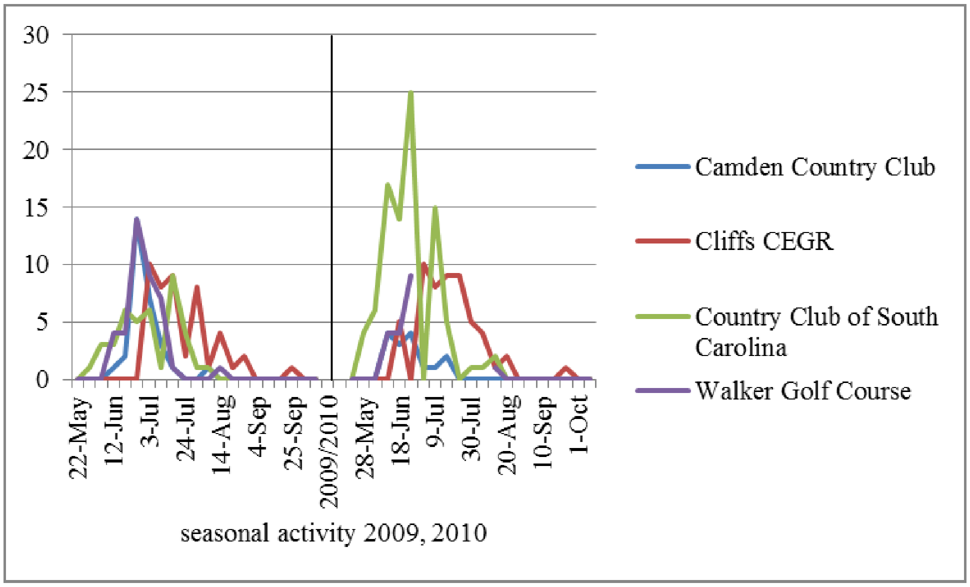

Figure 2.21. Number of specimens of *Pelidnota punctata* captured in light traps at all locations in 2009 and 2010.

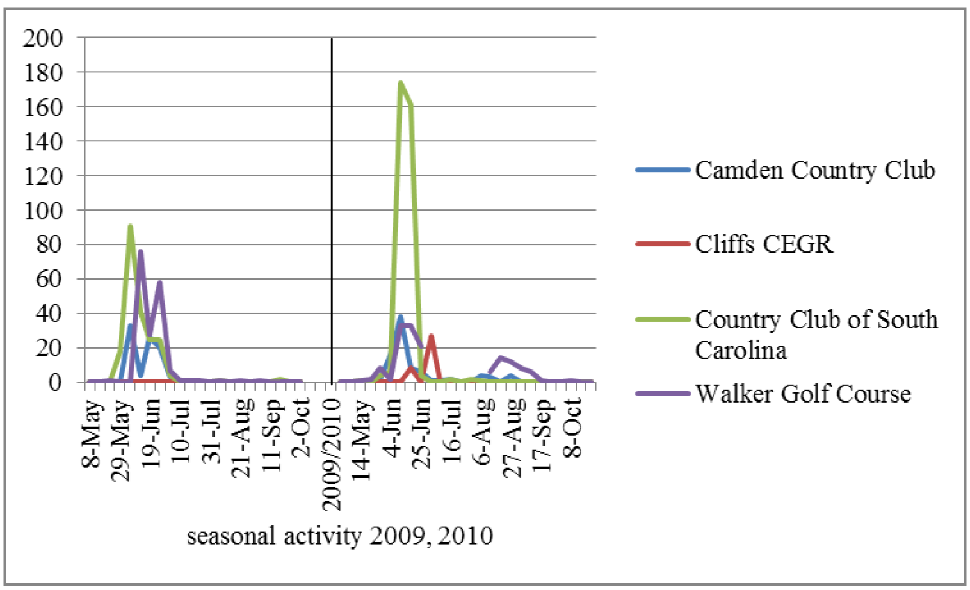

Figure 2.22. Number of specimens of *Hybosorus illigeri* captured in light traps at all locations in 2009 and 2010.

Table 2.1. Species of Scarabaeoidea captured in South Carolina during 2009-2010. Sex ratios per trap in 2009 are given as % males in rows listing species. Specimens captured in 2010 were not sexed. Percentage of specimens captured per trapping method is listed in rows beneath species by column.

Taxon	light	flight	pitfall	=total
Aphodiinae	55,690	48	1,764	57,502
	97%	<1%	>2%	
Ceratocanthidae	-	-	-	-
Ceratocanthus aeneus (MacLeay)	1(100%)	0	0	1
	100%	0%	0%	
Germarostes aphodioides (Illiger)	2(2010)	0	0	2
	100%	0%	0%	
Germarostes globosus (Say)	4(50%)	0	0	4
	100%	0%	0%	
Geotrupidae	-	-	-	-
Bolbocerasoma farctum (Fabricius)	2(2010)	2(2010)	0	4
	50%	50%	0%	
Bolboceras thoracicornis (Wallis)	1(100%)	4(2010)	0	5
	20%	80%	0%	
Eucanthus lazarus (Fabricius)	6(50%)	0	0	6
	100%	0%	0%	
Geotrupes blackburnii blackburnii (Fabricius)	5(25%)	2(100%)	1(100%)	8
	63%	25%	12%	
Geotrupes egeriei Germar	1(2010)	0	0	1
	100%	0%	0%	
Hybosoridae	-	-	-	-
Hybosorus illigeri Reiche	1,091 (34%)	8(75%)	72(52%)	1,171
	93%	1%	6%	
Lucanidae	-	-	-	-
Dorcus brevis (Say)	1(2010)	0	0	1
	100%	0%	0%	
Passalidae	-	-	-	-
Odontotaenius disjunctus (Illiger)	1(2010)	0	0	1
	100%	0%	0%	
Scarabaeidae	-	-	-	-
Anomala flavipennis flavipennis Burmeister	372(80%)	6(100%)	0	378
	98%	2%	0%	
Anomala innuba (Fabricius)	123(27%)	16(62%)	0	139
	88%	12%	0%	
Anomala marginata (Fabricius)	386(40%)	3(100%)	2(2010)	391
	<99%	0%	>1%	
Anomala oblivia Horn	2(2010)	3(0%)	0	5
	40%	60%	0%	
Anomala parvula Burmeister	233(97%)	4(100%)	0	237
	98%	2%	0%	
Anomala umbra Casey	82(91%)	7(100%)	0	89
	92%	8%	0%	

Table 2.1. continued				
Anomala undulata Melsheimer	41(29%)	1(2010)	1(2010)	43
	95%	5%	5%	
Aphonus castaneus (Melsheimer)	1(100%)	0	0	1
	100%	0%	0%	
Ateuchus histeroides Weber	1(2010)	0	0	1
	100%	0%	0%	
Canthon depressipennis LeConte	1(100%)	58(21%)	0%	59
	2%	98%	0%	
Canthon pilularius (L.)	0	5(2010)	0	5
	0%	100%	0%	
Canthon vigilans LeConte	23(100%)	19(73%)	0	42
	48%	52%	0%	
Copris minutus (Drury)	5(100%)	0	0	5
	100%	0%	0%	
Cotinis nitida (L.)	0	84(88%)	3(100%)	87
	0%	97%	3%	
Cyclocephala borealis Arrow	296(97%)	27(93%)	3(100%)	326
	91%	8%	1%	
Cyclocephala lurida Bland	1,316(98%)	56(98%)	1(100%)	1,373
	>99%	<1%	<1%	
Deltochilum gibbosum gibbosum (Fabricius)	0	5(0%)	0	5
	0%	100%	0%	
Dichelonyx linearis (Gyllenhal)	1(100%)	0	0	1
	100%	0	0	
Dichotomius carolinus (L.)	3(2010)	5(2010)	0	8
	38%	62%	0%	
Diplotaxis harperi Blanchard	1(2010)	0	0	1
	100%	0%	0%	
Diplotaxis liberta (Germar)	65(24%)	0	0	65
	100%	0%	0%	
Diplotaxis punctatarugosa Blanchard	5(100%)	0	0	5
	100%	0%	0%	
Dynastes tityus (L.)	4(0%)	0	0	4
	100%	0%	0%	
Dyscinetus morator (Fabricius)	4,413(43%)	30(53%)	212(49%)	4,655
	95%	1%	4%	
Euetheola humilis (Burmeister)	3,265(48%)	174(70%)	795(62%)	4,234
	75%	5%	20%	
Euphoria inda (L.)	0	17(71%)	0	17
	0%	100%	0%	
Euphoria herbacea (Olivier)	1(2010)	31(52%)	0%	32
	3%	97%	0%	
Euphoria sepulcralis (Fabricius)	0	62(76%)	0	62
	0%	100%	0%	
Macrodactylus angustatus (Beauvois)	17(75%)	0	0	17
	100%	0%	0%	
Macrodactylus subspinosus (Fabricius)	1(2010)	0	0	1
	100%	0%	0%	

Table 2.1. continued				
Maladera castanea (Arrow)	706(95%)	26(100%)	0	732
	96%	4%	0%	
Melanocanthon bispinatus (Robinson)	0	14(2010)	0%	14
	0%	100%	0%	
Onthophagus concinnus Laporte	0	61(2010)	0	61
	0%	100%	0%	
Onthophagus depressus Harold	14(57%)	0	0	14
	100%	0%	0%	
Onthophagus gazella (Fabricius)	81(58%)	0	0	81
	100%	0%	0%	
Onthophagus hecate hecate (Panzer)	0	288(44%)	53(49%)	341
	0%	84%	16%	
Onthophagus orpheus orpheus (Panzer)	0	3(100%)	0	3
	0%	100%	0%	
Onthophagus striatulus striatulus (Say)	0	2(100%)	0	2
	0%	100%	0%	
Onthophagus subaeneus (Beauvois)	0	18(2010)	0	18
	0%	100%	0%	
Onthophagus taurus (Schreber)	0	2(100%)	0	2
	0%	100%	0%	
Onthophagus tuberculifrons Harold	0	13(2010)	0	13
	0%	100%	0%	
Parastasia brevipes (LeConte)	5(100%)	0	0	5
	100%	0%	0%	
Pelidnota punctata (L.)	336(21%)	8(2010)	0	344
	74%	26%	0%	
Phanaeus igneus MacLeay	0	61(44%)	3(100%)	64
	0%	98%	2%	
Phanaeus triangularis triangularis (Say)	0	1(2010)	0	1
	0%	100%	0%	
Phanaeus vindex MacLeay	0	5(2010)	0	5
	0%	100%	0%	
Phileurus valgus valgus (L.)	1(0%)	0	0	1
	100%	0%	0%	
Phyllophaga aemula (Horn)	1(100%)	12(66%)	0	13
	8%	92%	0%	
Phyllophaga anxia (LeConte)	38(81%)	0	0	38
	100%	0%	0%	
Phyllophaga crenulata (Froelich)	78(100%)	0	0	78
	100%	0%	0%	
Phyllophaga diffinis (Blanchard)	1(2010)	0	0	1
	100%	0%	0%	
Phyllophaga drakii (Kirby)	2(100%)	0	0	2
	100%	0%	0%	
Phyllophaga ephilida (Say)	29(100%)	6(83%)	0	35
	82%	18%	0%	
Phyllophaga fervida (Fabricius)	10(88%)	0	0	10
	100%	0%	0%	

Table 2.1. continued				
Phyllophaga forsteri (Burmeister)	6(100%)	0	0	6
	100%	0%	0%	
Phyllophaga hirsuta (Knoch)	5(100%)	0	0	5
	100%	0%	0%	
Phyllophaga hirticula (Knoch)	1(2010)	0	0	1
	100%	0%	0%	
Phyllophaga ilicis (Knoch)	5(100%)	0	0	5
	100%	0%	0%	
Phyllophaga impar Davis	289(100%)	13(100%)	0	302
	94%	6%	0%	
Phyllophaga inepta Horn	3(100%)	0	0	3
	100%	0%	0%	
Phyllophaga knochii (Schonherr and Gyllenhal)	1(0%)	0	0	1
	100%	0%	0%	
Phyllophaga latifrons (LeConte)	59(31%)	7(71%)	0	66
	89%	11%	0%	
Phyllophaga mariana Fall	1(100%)	0	0	1
	100%	0%	0%	
Phyllophaga omani Sanderson	10(100%)	0	0	10
	100%	0%	0%	
Phyllophaga parvidens (LeConte)	2(100%)	0	0	2
	100%	0%	0%	
Phyllophaga prununculina (Burmeister)	84(64%)	3(66%)	0	87
	97%	3%	0%	
Phyllophaga quercus (Knoch)	42(94%)	0	0	42
	100%	0%	0%	
Phyllophaga ulkei (Smith)	1(2010)	0	0	1
	100%	0%	0%	
Phyllophaga uniformis (Blanchard)	45(77%)	16(82%)	1(100%)	62
	73%	26%	1%	
Plectris aliena Chapin	17(100%)	12(83%)	0	29
	59%	41%	0%	
Polyphylla comes Casey	9(100%)	0	0	9
	100%	0%	0%	
Polyphylla occidentalis (L.)	21(62%)	0	0	21
	100%	0%	0%	
Popillia japonica Newman	5(2010)	26(69%)	6(66%)	37
	14%	69%	17%	
Serica aspera Dawson	16(100%)	0	0	16
	100%	0%	0%	
Serica carolina Dawson	3(2010)	0	0	3
	100%	0%	0%	
Serica georgiana georgiana Leng	213(98%)	0	5(100%)	218
	98%	0%	2%	
Serica sericea (Illiger)	1(2010)	0	0	1
	100%	0%	0%	
Serica vespertina Gyllenhal	6(100%)	0	0	6
	100%	0%	0%	

Table 2.1. continued				
Stephanucha areata (Fabricius)	0	7(29%)	0	7
	0%	100%	0%	
Strategus splendens (Beauvois)	1(100%)	0	0	1
	100%	0%	0%	
Strigoderma pygmaea (Fabricius)	0	1(100%)	0	1
	0%	100%	0%	
Tomarus gibbosus gibbosus (De Geer)	386(56%)	28(46%)	2(100%)	416
	93%	<7%	>1%	
Tomarus neglectus (LeConte)	1(100%)	0	0	1
	100%	0%	0%	
Trichiotinus bibens (Fabricius)	0	3(50%)	0	3
	0%	100%	0%	
Trigonopeltastes delta (Forster)	0	9(66%)	0	9
	0%	100%	0%	
Valgus canaliculatus (Fabricius)	1(2010)	0	0	1
	100%	0%	0%	
Xyloryctes jamaicensis (Drury)	14(50%)	0	0	14
	100%	0%	0%	
Trogidae	**-**	**-**	**-**	**-**
Omorgus suberosus (Fabricius)	55(73%)	2(100%)	0	57
	96%	4%	0%	
Trox affinis Robinson	1(2010)	0	0	1
	100%	0%	0%	
Trox foveicollis Harold	0	1(2010)	0	1
	0%	100%	0%	
Trox hamatus Robinson	4(50%)	0	0	4
	100%	0%	0%	
Trox unistriatus Beauvois	4(100%)	0	0	4
	100%	0%	0%	
Trox variolatus Melsheimer	1(100%)	0	0	1
	100%	0%	0%	
Grand total excluding Aphodiinae:	-	-	-	-
7 families and 104 species in 47 genera	14,388	1,277	1,160	16,825
	85%	8%	7%	-
Total species captured per trap:	83 species	52 species	15 species	-
Grand total including Aphodiinae:	70,078	1,325	2,924	74,327
	94%	2%	4%	-

Table 2.2. Months during which scarabaeoid species were captured in flight-intercept traps at each sampling location.

	Florence	**Camden**	**Marietta**	**Clemson**
Aphodiinae	August	July	-	August
Anomala	-	-	-	-
flavipennis flavipennis	May-June	June	-	-
innuba	-	June	-	-
marginata	July	June	-	-
oblivia	June	-	-	-
parvula	-	June	-	-
umbra	-	June	-	-
undulata	April, July	April	April-May	-
Bolboceras	-	-	-	-
thoracicornis	-	March, May	-	-
Bolbocerasoma				
farctum	July-August	-	-	-
Canthon	-	-	-	-
depressipennis	Apr-May, Jul.-Aug	August	-	-
pilularius	May-July	-	-	-
vigilans	May-September	-	-	-
Copris	-	-	-	-
minutus	March	-	-	-
Cotinis	-	-	-	-
nitida	-	July	July-August	July-August
Cyclocephala	-	-	-	-
lurida	-	June-July	-	July

Table 2.2. continued				
	Florence	**Camden**	**Marietta**	**Clemson**
Deltochilum	-	-	-	-
gibbosum gibbosum	May	-	-	-
Dichotomius	-	-	-	-
carolinus	July-September	-	June	-
Dyscinetus	-	-	-	-
morator	June-July	-	-	-
Euetheola	-	-	-	-
humilis	March- October	March-October	March-November	March-November
Euphoria	-	-	-	-
herbacea	May, July	June- August	-	-
inda	March	March-June	April-May	April
sepulcralis	April-May	May	May-June	-
Geotrupes	-	-	-	-
blackburnii blackburnii	March	-	-	-
egeriei	-	July	-	-
Hybosorus	-	-	-	-
illigeri	May-June	June	-	-
Tomarus	-	-	-	-
gibbosus gibbosus	May-June, August	-	June	-
Maladera	-	-	-	-
castanea	-	May	July-August	July
Melanocanthon	-	-	-	-
bispinatus	April-August	June- August	-	-
-	-	-	-	-

Table 2.2. **continued**				
	Florence	**Camden**	**Marietta**	**Clemson**
Onthophagus	-	-	-	-
concinnus	March-April	March-August	-	-
hecate hecate	March-April, Aug.	March-August	April	-
orpheus orpheus	-	June, August	-	-
striatulus striatulus	-	August	April	-
subaeneus	-	March-April	-	-
taurus	-	-	April	-
tuberculifrons	-	March	-	-
Phanaeus	-	-	-	-
igneus	April-September	-	-	-
triangularis triangularis	August	-	-	-
vindex	May, July-August	-	-	-
Phyllophaga	-	-	-	-
aemula	-	-	June	-
ephilida	-	-	-	July
impar	-	April	-	-
latifrons	June	-	-	-
prununculina	May-June	June	-	-
uniformis	June-July	-	-	-
Plectris	-	-	-	-
aliena	June	-	-	-
Popillia	-	-	-	-
japonica	-	June	June	-
-	-	-	-	-

Table 2.2. continued				
	Florence	**Camden**	**Marietta**	**Clemson**
Serica	-	-	-	-
georgiana georgiana	-	May	-	-
Strigoderma	-	-	-	-
pygmeae	June	-	-	-
Trichiotinus	-	-	-	-
bibens	-	May	-	-
Trigonopeltastes	-	-	-	-
delta	-	June, August	-	-
Trox	-	-	-	-
foveicollis	April	-	-	-

Table 2.3. Months during which scarabaeoid species were captured in pitfall traps at each sampling location.

	Florence	**Camden**	**Marietta**	**Clemson**
Aphodiinae	March-November	March-November	March-November	March-November
Anomala	-	-	-	-
marginata	-	June	-	-
undulata	May	-	-	-
Canthon	-	-	-	-
vigilans	May, August, Oct.	August	-	-
Cotinis	-	-	-	-
nitida	-	-	-	August
Cyclocephala	-	-	-	-
borealis	-	June	-	-
lurida	-	-	-	July
Dyscinetus	-	-	-	-
morator	April	April-May	April-July	April-August
Euetheola	-	-	-	-
humilis	April-October	May-June,Oct- No.	June,July	April-October
Geotrupes	-	-	-	-
blackburnii blackburnii	-	-	October	-
Hybosorus	-	-	-	-
illigeri	August	July-August	July	-
Tomarus	-	-	-	-
gibbosus gibbosus	May	-	-	-
Onthophagus	-	-	-	-
hecate hecate	-	June-July	-	-
-	-	-	-	-

Table 2.3. continued				
	Florence	**Camden**	**Marietta**	**Clemson**
Phyllophaga	-	**-**	**-**	**-**
uniformis	June	**-**	**-**	**-**
Phanaeus	-	**-**	**-**	**-**
igneus	May	**-**	**-**	**-**
Popillia	-	**-**	**-**	**-**
japonica	-	**-**	**-**	**June**

CHAPTER THREE

NEW STATE RECORD FOR *PHYLLOPHAGA INEPTA* (HORN) (COLEOPTERA: SCARABAEIDAE: MELOLONTHINAE) FROM SOUTH CAROLINA

Phyllophaga (*sensu lato*) Harris is one of the most speciose genera of the family Scarabaeidae in the New World, consisting of 861 extant species in 10 subgenera (Evans and Smith 2009). Many species are significant pests of horticultural plants in the adult stage, and the larvae consume roots of turfgrasses and other plants. Evans and Smith (2009) recorded 214 species of *Phyllophaga* in eight subgenera from the United States. The most recent regional work listed 55 species occurring in the state of South Carolina (Harpootlian 2001).

Specimens of *P. inepta* were collected as part of a larger study examining species composition and seasonal abundance of Scarabaeoidea at golf courses in South Carolina. Samples were collected weekly for two years from pitfall, light, and flight-intercept traps at the Country Club of South Carolina (Florence, SC), Camden Country Club (Camden, SC), Walker Golf Course (Clemson, SC), and The Cliffs Center for Environmnetal Golf Research (Marietta, SC). Each sampling site is in a unique physiographic region of the state, from the coastal plain at the Country Club of South Carolina to the mountains at the Cliffs CEGR. Specimens were identified based on morphological descriptions and genitalia illustrations by Luginbill and Painter (1953), and were placed in the Clemson University Arthropod Collection.

On 23 July and 6 August 2010, one male specimen of *P. inepta* Horn was captured at the Cliffs CEGR (35°05’38.62” N, 82°27’59.95” W) in the southern Appalachian Mountains in Marietta, Greenville Co., South Carolina, using a light trap equipped with a 22 watt, circline, black-light tube. An additional male was captured on 20 August 2010 at the Country Club of South Carolina (34°14’59.81” N, 79°40’34.96” W) in Florence, Florence Co., South Carolina. These captures constitute a **new state record** for *P. inepta*.

Little is recorded on the distribution of *P. inepta*, although Luginbill and Painter (1953) listed the species as being taken mainly in the central Mississippi Valley. *Phyllophaga inepta* previously was reported from Alabama, Georgia, Indiana, Louisiana, Missouri, Nebraska, Ohio, Oklahoma, Tennessee, and Texas (Luginbill & Painter 1953). Two specimens were captured in Pontotoc Co., Oklahoma on 13 July 1937 (D. Arnold, personal communication). One male specimen was taken under an electric light in the vicinity of Manhattan, Kansas on 5 September 1917 (McColloch and Hayes 1919). An additional Kansas record comes from Riley Co., with no reference to date or number collected (Pike et al. 1977). One specimen was captured in Lancaster Co., Nebraska on 6 August 1969 at a mercury-vapor light (Ratcliffe 1974). An additional specimen was captured at lights in Richardson Co., Nebraska (Ratcliffe and Paulsen 2008). Fattig (1944) reported a male at a light from Prattsburg, Georgia on 24 July 1930, and Neiswander (1963) included light-trap captures from Adams and Warren counties, Ohio, with no reference to date or numbers collected. Specimens were collected with light traps in Boone, Cooper, Franklin, Jefferson, Laclede and St. Louis counties in Missouri, with records as early as 1937 (K. Simpson, personal communication). Additional collection records for Missouri can be found in the Enns Entomology Museum at the University of Missouri. Specific collection and locality data for reports in Alabama, Indiana, Tennessee and Texas cannot be located. *Phyllophaga inepta* is recorded as rare in southern Illinois (Forbes 1891). The numbers and frequencies of collection indicate that *P. inepta* is an uncommonly encountered species.

No information on the larvae of *P. inepta* exists in the literature, and little has been recorded on the feeding habits or life history of the adults. E.G. Riley (personal communication) reported the species to be abundant in flight with other summer species at a single locality in Baton Rogue, Louisiana. This site, located in the understory of a grove of mature forest, produced few light trap captures. Larger numbers of specimens from the same locality were taken feeding on the margins of hickory leaves.

CHAPTER FOUR

DISCUSSION OF ABUNDANT SCARABAEOIDS IN THREE SOUTHEASTERN STATES

No North American study examining species diversity and seasonal abundance has concentrated on the entirety of Scarabaeoidea or even of Scarabaeidae. Buss (2006) examined flight activity and relative abundance of phytophagous scarabs from two locations in Florida for three years using light traps and found species composition and abundance similar to those of the current study. The most abundant species found by Buss (2006) consisted of *H. illigeri* (12, 306 specimens). Additional species captured in high abundance by Buss (2006) and the current study included *C. lurida* and *D. morator*. *Tomarus cuniculus* Fabricius (a species restricted to Florida) was captured in high abundance by Buss (2006). This species may share a similar biology with *Tomarus gibbosus gibbosus*, a species which was captured in high adundance in this study. Buss (2006) captured very low totals of *E. humilis*, suggesting that this species may be less abundant in the extreme Southeast. Forschler and Gardner (1991) examined flight activity and relative abundance of phytophagous scarabs in Georgia using light traps. Two sites were examined in 1988, and four sites were examined in 1989. Captures consisted of >60,000 adult scarabs comprising 31 species and 8 genera. Adults in the genus *Cyclocephala* were the most numerous (>32,000 specimens), and the single most abundant species was *Anomala flavipennis flavipennis*, followed by *Tomarus gibbosus gibbosus*, *E. humilis*, and *D. morator*.

The northern and southern masked chafers (*C. borealis and C. lurida*, respectively) are well-known pests of turfgrasses. High *C. lurida* population densities detected in three southeastern states suggests that the economic importance of this species may have been underestimated. An understanding of the feeding behavior of larvae and adults of *E. humilis* and *D. morator* requires future study. However, irrespective of any direct damage due to feeding, the presence of large numbers of adults crawling and dying on golf courses has become a considerable nuisance to golf course superintendents. *Euetheola humilis* exhibits a bimodal flight pattern in South Carolina and treatment must be timed accordingly.

Despite being captured in large numbers in southeastern studies, the feeding habits of *Hybosorus illigeri* larvae are unknown, and require future study.

Buss (2006) captured 10 species of *Phyllophaga*, and Forschler and Gardner (1991) captured 21 species. One species captured in high numbers among all three studies is *P. prununculina*. *Phyllophaga prununculina* was the second most abundant *Phyllophaga* species (87 specimens) captured in this study. Little is known about the feeding behavior of either adults or larvae, and future studies need to investigate the life history of this species. The majority of *Phyllophaga* species and the greatest total numbers were captured at the Country Club of South Carolina and Camden Country Club. These findings suggest that *Phyllophaga* may be more abundant in the eastern half of the state. *Phyllophaga* spp. require 2-3 years to complete development, and the application of soil insecticides is effective for first instar larvae only. Third instar larvae often survive insecticidal treatments to emerge as adults the following spring. Regions with higher populations and greater diversity of *Phyllophaga* may need to treat the soil for at least two years to control overlapping generations of *Phyllophaga* larvae successfully.

According to Buss (2006) and Forschler and Gardner (1991), the most abundant scarabaeoids in the Southeast appear to be *Anomala* spp., *Cyclocephala* spp., *D. morator*, *E. humilis*, *H. illigeri*., *Tomarus* spp., and *Phyllophaga* spp. Despite the abundance of these taxa throughout the Southeast, little has been recorded on their biology and economic importance. The discovery of a species (*P. inepta*) uknown to the state by sampling four sites in South Carolina suggests that an understanding of the scarabaeoid diversity of South Carolina is still far from complete. These relatively new studies conducting basic assessments of diversity and abundance indicate that an understanding of scarabaeoid biology is still greatly lacking, even for the most common species. Future studies may wish to focus on specific genera or species captured in high abundance to initiate a more in-depth analysis of the biology and economic roles of Southeastern scarabaeoids.

APPENDICES

APPENDIX A

Total number of specimens collected in light traps per species, per date, per location during 2009-2010

Table A-1: Light trap collections of Scarabaeoidea from Camden Country Club (Camden, South Carolina) March-June, 2009.

	March				April				May					June			
	06	13	20	27	03	10	17	24	01	08	15	22	29	05	12	19	26
Anomala																	
flavipennis flavipennis	-	-	-	-	-	-	-	-	-	-	-	-	1	22	26	22	-
innuba	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14	38
marginata	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	21	22
parvula	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1	28	2
umbra	-	-	-	-	-	-	-	-	-	-	-	-	-	14	3	28	2
undulata	-	-	-	-	-	-	1	-	6	-	4	-	-	-	-	-	-
Aphonus																	
castaneus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
Canthon																	
vigilans	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Cyclocephala																	
borealis	-	-	-	-	-	-	-	-	-	-	-	-	-	3	7	93	56
lurida	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	13
Diplotaxis																	
liberta	-	-	-	-	-	-	-	-	-	-	2	-	-	1	-	-	1
Dyscinetus																	
morator	-	-	-	-	-	-	-	5	39	16	99	1	21	81	22	29	57
Euetheola																	
humilis	-	-	-	-	-	-	1	6	113	76	76	5	21	17	6	1	7
Hybosorus																	
illigeri	-	-	-	-	-	-	-	-	-	-	-	-	-	33	4	26	20
Maladera																	
castanea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
Omorgus																	
suberosus	-	-	-	-	-	-	-	-	1	-	1	-	2	1	1	3	-
Onthophagus																	
depressus	-	-	-	-	-	-	-	-	1	-	-	-	2	-	-	-	-
gazella	-	-	-	-	-	-	-	-	2	-	6	-	-	-	-	1	-
Pelidnota																	
punctata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2	14
Phileurus																	
valgus valgus	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Phyllophaga																	
crenulata	-	-	-	-	-	-	-	-	-	-	1	3	8	12	3	5	4
Phyllophaga																	
impar	-	-	-	-	-	5	39	64	28	4	-	-	-	-	-	-	-
knochii	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
latifrons	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	5
mariana	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
parvidens	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-

Table A-1 continued																	
	March				April				May					June			
	06	13	20	27	03	10	17	24	01	08	15	22	29	05	12	19	26
prununculina	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11	5
Polyphylla																	
occidentalis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	2
Serica																	
aspera	-	-	-	-	-	-	2	1	4	-	-	-	-	-	-	-	-
georgiana georgiana	-	-	-	-	-	-	-	4	26	-	10	1	1	-	-	-	-
vespertina	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
Tomarus																	
gibbosus gibbosus	-	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-	-

Table A-2: Light trap collections of Scarabaeoidea from Camden Country Club (Camden, South Carolina) July-September, 2009.

	July					August				September			
	03	10	17	24	31	07	14	21	28	04	11	18	25
Anomala													
flavipennis flavipennis	-	-	2	-	-	-	-	-	-	-	-	-	-
innuba	9	1	-	-	-	-	-	-	-	-	-	-	-
marginata	9	-	3	3	-	1	-	-	-	-	-	-	-
Bolboceras													
thoracicornis	1	-	-	-	-	-	-	-	-	-	-	-	-
Cyclocephala													
borealis	3	2	-	1	-	-	-	-	-	-	-	-	-
lurida	3	52	50	9	5	-	1	4	2	-	-	-	1
Diplotaxis													
liberta	1	-	-	-	-	-	-	-	-	-	-	-	-
Dyscinetus													
morator	34	3	6	2	4	3	2	6	16	4	2	4	8
Euetheola													
humilis	1	2	-	1	2	10	2	21	18	9	13	17	21
Hybosorus													
illigeri	3	1	-	-	-	-	-	-	-	-	-	-	-
Maladera													
castanea	2	1	1	1	-	-	-	-	1	-	-	-	-
Melanocanthon													
bispinatus	-	-	-	-	-	1	-	-	-	-	-	-	-
Omorgus													
suberosus	1	-	1	-	-	-	-	-	-	-	-	-	-
Onthophagus													
depressus		-	-	-	2	1	-	-	-	-	-	-	-
gazella	-	1	2	1	-	3	-	2	-	1	4	-	3
Pelidnota													
punctata	7	3	1	-	-	1	-	-	-	-	-	-	-
Phyllophaga													
crenulata	2	-	2	1	-	1	-	-	-	-	-	-	-
ephilida	-	1	-	-	-	-	-	-	-	-	-	-	-
latifrons	2	3	3	-	-	-	-	-	-	-	-	-	-
omani	-	-	-	-	2	-	-	-	-	-	-	-	-
prununculina	2	4	3	7	5	-	-	-	-	-	-	-	-
quercus	1	-	1	8	2	1	-	2	1	-	-	-	-
Serica													
aspera	-	-	-	-	1	-	-	-	-	-	-	-	-
Stragetus													
splendens	-	-	-	1	-	-	-	-	-	-	-	-	-
Tomarus													
gibbosus gibbosus	-	-	2	-	1	1	-	1	-	-	-	-	-

Table A-3: Light trap collections of Scarabaeoidea from Camden Country Club (Camden, South Carolina) October-December, 2009.

	October					November				December			
	02	09	16	23	30	06	13	20	27	04	11	18	25
Diplotaxis													
liberta	1	-	-	-	-	-	-	-	-	-	-	-	-
Dyscinetus													
morator	3	-	1	-	-	-	-	-	-	-	-	-	-
Euetheola													
humilis	6	-	54	4	28	13	-	-	-	-	-	-	-
Geotrupes													
blackburnii blackburnii	-	-	-	-	-	-	-	-	1	-	-	-	-
Onthophagus													
gazella	2	-	-	-	-	-	-	-	-	-	-	-	-
Tomarus													
gibbosus gibbosus	-	1	-	-	-	-	-	-	-	-	-	-	-
neglectus	-	-	-	-	-	-	-	-	1	-	-	-	-

Table A-4: Light trap collections of Scarabaeoidea from the Cliffs Center for Environmental Golf Research (Marietta, South Carolina) March-June, 2009: "X" indicates light trap failure.																
	March				April				May					June			
	06	13	20	27	03	10	17	24	01	08	15	22	29	05	12	19	26
Anomala																	
marginata	-	-	-	-	-	-	-	-	-	-	-	-	1	X	X	X	X
undulata	-	-	-	-	-	-	-	-	-	1	-	-	-	X	X	X	X
Cyclocephala														X	X	X	X
lurida	-	-	-	-	-	-	-	-	-	-	-	1	-	X	X	X	X
Dichelonyx														X	X	X	X
linearis	-	-	-	-	-	-	-	-	-	-	-	1	-	X	X	X	X
Dyscinetus														X	X	X	X
morator	-	-	-	-	-	-	-	-	1	1	2	5	-	X	X	X	X
Eucanthus														X	X	X	X
lazarus	-	-	-	-	-	-	-	-	-	-	-	2	-	X	X	X	X
Euetheola														X	X	X	X
humilis	-	-	-	-	-	-	-	-	-	-	1	3	-	X	X	X	X
Germarostes														X	X	X	X
globosus	-	-	-	-	-	-	-	-	-	-	-	1	-	X	X	X	X
Omorgus														X	X	X	X
suberosus	-	-	-	-	-	-	-	-	-	1	-	3	-	X	X	X	X
Phyllophaga														X	X	X	X
anxia	-	-	-	-	-	-	-	3	2	5	5	10	7	X	X	X	X
crenulata	-	-	-	-	-	-	-	-	-	-	-	1	-	X	X	X	X
drakii	-	-	-	-	-	-	-	-	-	-	-	1	-	X	X	X	X
fervida	-	-	-	-	-	-	-	1	-	-	-	-	-	X	X	X	X
hirsuta	-	-	-	-	-	-	-	2	1	1	-	1	-	X	X	X	X
Serica														X	X	X	X
georgiana georgiana	-	-	-	-	-	-	-	-	-	-	1	4	-	X	X	X	X
Tomarus														X	X	X	X
gibbosus gibbosus	-	-	-	-	-	-	-	-	-	1	-	17	5	X	X	X	X
vespertina	-	-	-	-	-	-	-	-	-	-	1	-	-	X	X	X	X
Trox														X	X	X	X
hamatus	-	-	-	-	-	-	-	-	-	-	-	2	-	X	X	X	X

Table A-5: Light trap collections of Scarabaeoidea from the Cliffs Center for Environmental Golf Research (Marietta, South Carolina) July-September, 2009.													
	July					August				September			
	03	10	17	24	31	07	14	21	28	04	11	18	25
Anomala													
innuba	7	-	2	-	-	-	-	-	-	-	-	-	-
marginata	10	-	-	-	3	-	-	-	-	-	-	-	-
Cyclocephala													
lurida	53	14	32	16	6	-	-	-	-	-	-	-	-
Dynastes													
tityus	-	-	-	-	1	-	-	-	-	-	-	-	-
Eucanthus													
lazarus	-	-	-	-	-	-	-	1	-	-	-	1	-
Euetheola													
humilis	2	1	1	-	-	-	-	-	7	-	-	-	1
Hybosorus													
illigeri	-	1	-	-	-	-	-	-	-	-	-	-	-
Macrodactylus													
angustatus	3	-	5	-	-	-	-	-	-	-	-	-	-
Maladera													
castanea	49	19	50	25	28	8	9	9	7	-	-	3	1
Omorgus													
suberosus	6	2	-	1	-	-	-	2	-	-	-	-	-
Onthophagus													
depressus	-	-	-	-	-	-	-	1	-	-	-	-	-
gazella	-	-	-	-	-	1	-	-	-	-	-	-	-
Parastasia													
brevipes	-	-	-	-	1	-	1	-	-	-	-	-	-
Pelidnota													
punctata	10	8	9	2	8	1	4	1	2	-	-	-	1
Phyllophaga													
aemula	-	-	1	-	-	-	-	-	-	-	-	-	-
crenulata	-	-	1	-	-	-	-	-	-	-	-	-	-
ephilida	1	1	2	1	2	2	-	-	-	-	-	-	-
fervida	1	-	-	-	-	-	-	-	-	-	-	-	-
forsteri	1	-	-	-	-	-	-	-	-	-	-	-	-
Polyphylla													
comes	-	1	1	-	-	-	-	-	-	-	-	-	-
Tomarus													
gibbosus gibbosus	1	-	1	1	1	-	5	4	4	2	-	-	1
Trox													
unistriatus	1	-	-	-	-	-	-	-	-	-	-	-	-
Xylorectes													
jamaicensis	-	2	-	-	-	-	-	-	2	-	-	-	-

Table A-6: Light trap collections of Scarabaeoidea from the Cliffs Center for Environmental Golf Research (Marietta, South Carolina) October-December, 2009.													
	October					November				December			
	02	09	16	23	30	06	13	20	27	04	11	18	25
Geotrupes													
blackburnii blackburnii	-	-	-	1	1	-	-	-	-	-	-	-	-

Table A-7: Light trap collections of Scarabaeoidea from the Country Club of South Carolina (Florence, SC) March-June, 2009.

	March				April				May					June			
	06	13	20	27	03	10	17	24	01	08	15	22	29	05	12	19	26
Anomala																	
flavipennis flavipennis	-	-	-	-	-	-	-	-	-	-	-	-	5	19	12	4	-
marginata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	17	17	32
parvula	-	-	-	-	-	-	-	-	-	-	-	-	-	1	8	27	3
undulata	-	-	-	-	-	-	-	1	2	2	1	-	-	-	-	-	-
Canthon																	
vigilans	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
Cyclocephala																	
borealis	-	-	-	-	-	-	-	-	-	-	-	-	-	1	4	1	3
lurida	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	3	9
Diplotaxis																	
liberta	-	-	-	-	-	-	-	-	-	2	5	-	9	8	7	3	13
punctatarugosa	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-
Dyscinetus																	
morator	-	-	-	-	10	2	-	16	184	194	152	18	263	305	278	210	454
Euetheola																	
humilis	-	-	-	-	-	-	-	-	14	-	70	3	2	10	3	4	1
Germarostes																	
globosus	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
Hybosorus																	
illigeri	-	-	-	-	-	-	-	-	-	-	-	-	18	91	41	25	25
Maladera																	
castanea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Omorgus																	
suberosus	-	-	-	-	-	-	-	-	2	-	4	-	-	1	-	1	-
Onthophagus																	
depressus	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
gazella	-	-	-	-	-	-	-	-	-	1	4	1	2	1	2	-	-
Pelidnota																	
punctata	-	-	-	-	-	-	-	-	-	-	-	-	1	3	3	6	5
Phyllophaga																	
anxia	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
crenulata	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	1
forsteri	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
latifrons	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	4
omani	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	3
prununculina	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7
uniformis	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	3	12

Table A-7 continued																
	March				April				May					June			
	06	13	20	27	03	10	17	24	01	08	15	22	29	05	12	19	26
Plectris																	
aliena	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	
Polyphylla																	
occidentalis	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1	-	2
Serica																	
aspera	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
georgiana	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
Tomarus																	
gibbosus gibbosus	-	-	-	-	-	-	-	-	-	-	5	-	1	2	2	1	-

Table A-8: Light trap collections of Scarabaeoidea from the Country Club of South Carolina (Florence, SC) July-September, 2009.													
	July					August				September			
	03	10	17	24	31	07	14	21	28	04	11	18	25
Anomala													
marginata	10	2	6	2	-	-	-	-	-	-	-	-	-
parvula	2	-	-	-	-	-	-	-	-	-	-	-	-
Cyclocephala													
lurida	3	3	2	-	-	-	-	-	-	-	-	-	-
Diplotaxis													
liberta	2	-	-	-	-	-	-	-	-	-	-	-	-
Dyscinetus													
morator	109	19	21	19	23	6	5	3	-	-	-	3	-
Euetheola													
humilis	-	-	-	1	-	-	1	4	-	1	1	-	4
Hybosorus													
illigeri	4	-	1	-	-	1	-	-	-	-	-	2	-
Omorgus													
suberosus	2	-	1	-	-	1	1	-	-	-	-	-	-
Onthophagus													
gazella	-	-	-	-	-	1	-	1	-	1	-	1	1
Parastasia													
brevipes	1	-	1	-	-	-	-	-	-	-	-	-	-
Pelidnota													
punctata	6	1	9	4	1	1	-	-	-	-	-	-	-
Phyllophaga													
latifrons	9	-	1	-	-	-	-	-	-	-	-	-	-
omani	-	-	-	-	2	-	-	1	-	-	-	-	-
prununculina	10	-	-	-	-	-	-	-	-	-	-	-	-
uniformis	1	3	2	2	2	-	-	-	-	-	-	-	-
Tomarus													
gibbosus gibbosus	-	-	-	1	3	3	2	-	-	-	-	-	-

Table A-9: Light trap collections of Scarabaeoidea from the Country Club of South Carolina (Florence, SC) October-December, 2009.													
	October					November				December			
	02	09	16	23	30	06	13	20	27	04	11	18	25
Canthon													
vigilans	-	-	1	-	-	-	-	-	-	-	-	-	-
Euetheola													
humilis	-	2	3	4	1	1	-	-	-	-	-	-	-
Geotrupes													
blackburnii blackburnii	-	-	-	-	-	-	-	-	1	-	-	-	-

Table A-10: Light trap collections of Scarabaeoidea from the Walker Golf Course (Clemson, South Carolina) March-June, 2009.																	
	March				April				May					June			
	06	13	20	27	03	10	17	24	01	08	15	22	29	05	12	19	26
Anomala																	
flavipennis flavipennis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	2
innuba	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	3	5
marginata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
undulata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6
Ceratocanthus																	
aeneus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Copris																	
minutus	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-
Cyclocephala																	
lurida	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	14	128
Dyscinetus																	
morator	-	-	-	-	-	-	-	12	-	-	-	2	7	15	17	2	2
Euetheola																	
humilis	-	-	-	-	-	-	-	1	3	11	1	1	-	-	1	-	1
Germarostes																	
globosus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Hybosorus																	
illigeri	-	-	-	-	-	-	-	-	-	-	-	1	-	-	76	28	58
Maladera																	
castanea	-	-	-	-	-	-	-	-	-	-	-	-	-	1	5	13	28
Pelidnota																	
punctata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	4	14
Phyllophaga																	
crenulata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-
ephilida	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	2
fervida	-	-	-	-	-	-	-	8	-	-	-	-	-	-	-	-	-
forsteri	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
ilicis	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-
Serica																	
georgiana georgiana	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-

Table A-11: Light trap collections of Scarabaeoidea from the Walker Golf Course (Clemson, South Carolina) July-September, 2009.													
	July					August				September			
	03	10	17	24	31	07	14	21	28	04	11	18	25
Anomala													
innuba	7	3	-	-	-	-	-	-	-	-	-	-	-
Cyclocephala													
lurida	68	102	110	105	145	5	-	2	-	-	-	-	-
Dynastes													
tityus	-	1	-	-	-	1	-	-	-	-	-	-	-
Dyscinetus													
morator	6	-	-	-	1	-	-	-	-	-	-	-	-
Euetheola													
humilis	-	-	-	-	-	-	-	-	-	3	-	10	17
Hybosorus													
illigeri	7	1	1	1	-	1	-	1	-	1	-	-	-
Maladera													
castanea	25	24	29	26	25	14	12	1	-	3	-	-	-
Omorgus													
suberosus	-	-	-	-	-	-	-	-	1	-	-	-	-
Onthophagus													
gazella	-	-	-	-	-	-	1	-	-	-	-	1	1
Pelidnota													
punctata	9	7	1	-	-	-	1	-	-	-	-	-	-
Phyllophaga													
ephilida	1	2	-	-	3	-	-	-	-	-	-	-	-
prununculina	-	-	-	-	-	-	-	-	-	-	-	1	-
Serica													
georgiana georgiana	-	-	1	-	-	-	-	-	-	-	-	-	-

Table A-12: Light trap collections of Scarabaeoidea from the Walker Golf Course (Clemson, South Carolina) October-December, 2009.													
	October					November				December			
	02	09	16	23	30	06	13	20	27	04	11	18	25
Cyclocephala													
lurida	-	-	2	-	-	-	-	-	-	-	-	-	-
Euetheola													
humilis	21	7	21	-	-	-	-	-	-	-	-	-	-

Table A-13: Light trap collections of Scarabaeoidea from Camden Country Club (Camden, South Carolina) March-June, 2010.

	March			April					May				June			
	12	19	26	2	9	16	23	30	7	14	21	28	4	11	18	25
Anomala																
flavipennis flavipennis	-	-	-	-	-	-	-	-	-	1	2	6	8	20	6	1
innuba	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-
marginata	-	-	-	-	-	-	-	-	-	-	-	1	1	1	-	1
oblivia	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
parvula	-	-	-	-	-	-	-	-	-	-	-	-	-	8	4	3
umbra	-	-	-	-	-	-	-	-	1	2	-	-	-	22	-	-
undulata	-	-	-	-	2	-	-	-	1	2	-	-	-	-	-	11
Aphonus																
castaneus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Canthon																
depressipennis	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Copris																
minutus	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cyclocephala																
borealis	-	-	-	-	-	-	-	-	-	-	-	-	-	24	44	20
lurida	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1	22
Diplotaxis																
harperi	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
liberta	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
punctatarugosa	-	-	-	-	-	-	1	-	-	2	-	-	-	-	-	-
Dyscinetus																
morator	-	-	-	14	12	4	21	19	51	32	19	10	8	5	7	21
Euetheola																
humilis	-	-	-	6	29	8	30	110	252	112	60	51	15	9	8	4
Geotrupes																
blackburnii blackburnii	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Germarostes																
globosus	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Hybosorus																
illigeri	-	-	-	-	-	-	-	-	-	-	-	2	16	38	8	6
Maladera																
castanea	-	-	-	-	-	-	-	-	-	-	-	-	5	-	-	4
Odontotaenius																
disjunctus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Omorgus																
suberosus	-	-	-	-	-	-	-	-	-	1	-	-	-	1	-	-
Onthophagus																
depressus	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
gazella	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-

Table A-13 continued																
	March			April					May				June			
	12	19	26	2	9	16	23	30	7	14	21	28	4	11	18	25
Pelidnota																
punctata	-	-	-	-	-	-	-	-	-	-	-	-	-	4	3	4
Phyllophaga																
crenulata	-	-	-	-	-	-	-	-	-	2	2	-	-	7	5	1
diffinis	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
hirticula	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
impar	-	-	-	2	30	42	46	28	1	-	-	-	-	-	-	-
latifrons	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	6
prununculina	-	-	-	-	-	-	-	-	-	-	-	-	-	9	2	3
ulkei	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
Polyphylla																
occidentalis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Serica																
aspera	-	-	-	-	-	-	-	-	-	1	-	1	5	-	-	-
carolina	-	-	-	-	-	1	-	-	-	1	-	-	-	-	-	-
georgiana georgiana	-	-	-	-	-	1	6	59	29	40	13	-	-	3	-	-
vespertina	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
Tomarus																
gibbosus gibbosus	-	-	-	-	-	-	1	-	1	2	-	-	-	-	-	-

Table A-14: Light trap collections of Scarabaeoidea from Camden Country Club (Camden, South Carolina) July-September, 2010.													
	July					August				September			
	02	09	16	23	30	06	13	20	27	03	10	17	24
Anomala													
flavipennis flavipennis	-	-	-	-	-	-	-	-	-	-	-	-	-
innuba	-	1	2	-	-	-	-	-	-	-	-	-	-
marginata	1	1	3	-	-	5	4	-	-	-	-	-	-
oblivia	-	1	-	-	-	-	-	-	-	-	-	-	-
Cyclocephala													
borealis	1	1	1	-	-	-	-	-	-	-	-	-	-
lurida	10	4	20	-	-	-	-	-	-	-	-	-	-
Dichotomius													
carolinus	-	-	-	-	-	-	-	-	2	-	-	-	-
Dyscinetus													
morator	2	1	1	-	-	1	10	9	16	-	-	4	1
Euetheola													
humilis	5	0	1	1	-	6	6	22	71	-	-	7	23
Germarostes													
globosus	-	-	-	-	-	-	-	-	-	-	-	-	-
Hybosorus													
illigeri	1	1	2	-	-	4	3	-	4	-	-	-	-

Table A-14 continued													
	July					August				September			
	02	09	16	23	30	06	13	20	27	03	10	17	24
Maladera													
castanea	-	-	2	-	-	-	-	-	-	-	-	-	-
Omorgus													
suberosus	-	-	1	-	-	-	-	-	1	-	-	-	-
Onthophagus													
depressus	-	-	2	-	-	2	1	-	-	-	-	-	-
gazella	-	-	2	-	-	3	4	2	5	-	-	-	5
Pelidnota													
punctata	1	1	2	-	-	-	-	-	-	-	-	-	-
Phyllophaga													
crenulata	1	-	-	-	-	2	1	-	1	-	-	-	-
latifrons	1	2	2	-	-	-	-	-	-	-	-	-	-
prununculina	1	1	3	-	-	2	-	-	-	-	-	-	-
quercus	-	3	5	-	-	1	-	-	-	-	-	-	-
Tomarus													
gibbosus gibbosus	-	-	-	-	-	3	4	-	4	-	-	-	-

Table A-15: Light trap collections of Scarabaeoidea from the Cliffs Center for Environmental Golf Research (Marietta, South Carolina) March-June, 2010.																
	March			April					May				June			
	12	19	26	2	9	16	23	30	7	14	21	28	4	11	18	25
Anomala																
innuba	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
marginata	-	-	-	-	-	-	-	-	-	-	-	3	1	-	-	-
undulata	-	-	-	-	-	-	-	-	1	-	-	-				
Cyclocephala																
lurida	-	-	-	-	-	-	-	-	-	-	-	-	-	-	17	-
Dyscinetus																
morator	-	-	-	-	-	-	-	-	-	3	-	-	1	-	1	-
Euetheola																
humilis	-	-	-	-	-	-	-	5	11	11	5	20	4	-	18	-
Germarostes																
aphodioides	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-
Hybosorus																
illigeri	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8	-
Macrodactylus																
angustatus	-	-	-	-	-	-	-	-	-	--	-	-	-	-	-	5
subspinosus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Maladera																
castanea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	15	-
Omorgus																
suberosus	-	-	-	-	-	-	-	-	1	-	-	-	2	-	-	-
Pelidnota																
punctata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-
-																
-																

Table A-15 continued																
	March			April					May				June			
	12	19	26	2	9	16	23	30	7	14	21	28	4	11	18	25
Phyllophaga																
anxia	-	-	-	-	-	-	-	1	3	1	-	-	-	-	-	-
drakii	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
forsteri	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
ilicis	-	-	-	-	-	-	-	-	1	1	-	-	1	-	-	-
Popillia																
japonica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-
Serica																
georgiana georgiana	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-
sericea	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
vespertina	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
Tomarus																
gibbosus gibbosus	-	-	-	-	-	-	-	22	49	56	11	63	7	-	20	-
Trox																
hamatus	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-
unistriatus	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-
variolatus	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Xyloryctes																
jamaicensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2

Table A-16: Light trap collections of Scarabaeoidea from the Cliffs Center for Environmental Golf Research (Marietta, South Carolina) July-September, 2010.													
	July					August				September			
	02	09	16	23	30	06	13	20	27	03	10	17	24
Anomala													
innuba	22	-	-	-	-	-	-	-	-	-	-	-	-
marginata	1	4	1	1	2	2	-	-	-	-	-	-	-
umbra	5	-	-	-	-	-	-	-	-	-	-	-	-
Bolbocerosoma													
farctum	-	-	-	2	-	-	-	-	-	-	-	-	-
Cyclocephala													
lurida	92	12	1	-	-	-	-	-	-	-	-	-	-
Dichotomius													
carolinus	-	-	-	-	-	-	1	-	-	-	-	-	-
Dynastes													
tityus	-	-	1	-	-	-	-	-	-	-	-	-	-
Dyscinetus													
morator	8	-	-	-	-	-	-	-	-	-	-	-	-
Eucanthus													
lazarus	-	-	-	-	-	-	1	-	-	-	-	1	-
Euetheola													
humilis	25	-	-	-	-	-	-	2	7	2	2	1	1

Table A-16 continued													
	July					August				September			
	02	09	16	23	30	06	13	20	27	03	10	17	24
Euphoria													
herbacea	-	-	-	-	-	-	1	-	-	-	-	-	-
Hybosorus													
illigeri	27	-	-	-	-	-	-	-	-	-	-	-	-
Macrodactylus													
angustatus	-	4	-	-	-	-	-	-	-	-	-	-	-
Maladera													
castanea	38	33	16	19	10	3	10	3	6	2	-	-	-
Omorgus													
suberosus	-	-	-	-	-	1	1	1	-	-	-	-	-
Pelidnota													
punctata	10	8	9	9	5	4	1	2	-	-	-	-	1
Phyllophaga													
ephilida	1	3	2	3	1	-	-	-	-	-	-	-	-
forsteri	-	-	1	-	-	1	-	-	-	-	-	-	-
inepta	-	-	-	1	-	1	-	-	-	-	-	-	-
quercus	-	-	-	-	-	3	1	-	-	-	-	-	-
Polyphylla													
comes	-	3	3	1	-	-	-	-	-	-	-	-	-
Tomarus													
gibbosus gibbosus	-	1	-	-	1	8	8	5	1	1	1	-	-
Trox													
hamatus	-	-	-	-	-	-	-	-	-	-	-	-	-
unistriatus	-	-	-	-	-	1	-	-	-	-	-	-	-
variolatus	-	-	-	-	-	-	-	-	-	-	-	-	-
Xyloryctes													
jamaicensis	-	5	-	1	1	-	1	-	-	-	-	-	-

Table A-17: Light trap collections of Scarabaeoidea from the Country Club of South Carolina (Florence, South Carolina) March-June, 2010.

	March			April					May				June			
	12	19	26	2	9	16	23	30	7	14	21	28	4	11	18	25
Anomala																
flavipennis flavipennis	-	-	-	-	-	-	-	-	-	-	-	88	65	42	10	-
marginata	-	-	-	-	-	-	-	-	-	-	-	-	-	45	80	39
parvula	-	-	-	-	-	-	-	-	-	-	-	1	4	58	78	3
umbra	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-
Canthon																
vigilans	-	-	-	-	-	-	-	-	-	-	-	1	-	11	-	1
Copris																
minutus	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cyclocephala																
borealis	-	-	-	-	-	-	-	-	-	-	-	-	6	12	10	3
lurida	-	-	-	-	-	-	-	-	-	-	-	-	3	21	20	3
Diplotaxis																
liberta	-	-	-	-	-	-	-	-	-	-	6	-	-	2	-	-
Dyscinetus																
morator	-	-	-	20	33	-	41	34	44	68	134	74	71	311	213	101
Euetheola																
humilis	-	-	-	-	4	3	7	6	31	14	29	50	13	20	11	4
Hybosorus																
illigeri	-	-	-	-	-	-	-	-	-	1	-	4	6	174	161	4
Maladera																
castanea	-	-	-	-	-	-	-	-	-	-	-	-	-	4	1	-
Omorgus																
suberosus	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	1
Pelidnota																
punctata	-	-	-	-	-	-	-	-	-	-	-	4	6	17	14	25
Phyllophaga																
crenulata	-	-	-	-	-	-	-	-	2	-	-	1	-	-	-	-
latifrons	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	3
prununculina	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	2
quercus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
uniformis	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	7
Plectris																
aliena	-	-	-	-	-	-	-	-	-	1	5	6	1	2	-	-
Polyphylla																
occidentalis	-	-	-	-	-	-	-	-	-	-	2	-	1	-	1	-
Popillia																
japonica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Serica																
aspera	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
georgiana georgiana	-	-	-	-	-	-	3	-	5	2	-	-	-	-	-	-
vespertina	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-
Tomarus																
gibbosus	-	-	-	-	-	-	-	1	2	4	2	2	3	1	-	-

Table A-18: Light trap collections of Scarabaeoidea from the Country Club of South Carolina (Florence, South Carolina) July-September, 2010.													
	July					August				September			
	02	09	16	23	30	06	13	20	27	03	10	17	24
Anomala													
flavipennis flavipennis	-	-	-	-	-	-	-	-	-	-	-	-	-
marginata	-	16	5	3	-	1	-	-	-	-	-	-	-
Canthon													
vigilans	-	-	-	-	1	-	2	1	-	-	-	-	-
Cyclocephala													
lurida	-	5	-	-	-	-	-	-	-	-	-	-	-
Diplotaxis													
liberta	-	1	-	-	-	-	-	-	-	-	-	-	-
Dyscinetus													
morator	-	29	15	1	3	-	-	1	-	-	-	-	-
Euetheola													
humilis	-	-	-	-	-	-	-	2	-	1	-	-	-
Hybosorus													
illigeri	-	-	2	-	2	1	-	-	-	-	-	-	-
Maladera													
castanea	-	-	1	-	-	-	-	-	-	-	-	-	-
Onthophagus													
gazella	-	-	2	-	-	1	-	1	-	-	-	-	2
Parastasia													
brevipes	-	-	-	-	-	-	1	-	-	-	-	-	-
Pelidnota													
punctata	-	15	5	-	1	1	2	-	-	-	-	-	-
Phyllophaga													
inepta	-	-	-	-	-	-	-	1	-	-	-	-	-
latifrons	-	2	6	-	-	-	-	-	-	-	-	-	-
prununculina	-	1	1	-	-	-	-	-	-	-	-	-	-
quercus	-	-	1	1	-	-	1	2	-	7	-	-	-
uniformis	-	9	1	-	-	-	-	-	-	-	-	-	-
Tomarus													
gibbosus gibbosus	-	-	1	-	2	1	1	2	-	-	-	-	-

Table A-19: Light trap collections of Scarabaeoidea from the Country Club of South Carolina (Florence, South Carolina) October-December, 2010.													
	October					November				December			
	01	08	15	22	29	05	12	19	26	3	10	17	24
Onthophagus													
gazella	1	-	-	-	-	-	-	-	-	-	-	-	-

Table A-20: Light trap collections of Scarabaeoidea from the Walker Golf Course (Clemson, South Carolina) March-June, 2010.																
	March			April					May				June			
	12	19	26	2	9	16	23	30	7	14	21	28	4	11	18	25
Anomala																
flavipennis flavipennis	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	1
innuba	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-
marginata	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
umbra	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Copris																
minutus	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cyclocephala																
lurida	-	-	-	-	-	-	-	-	-	-	-	-	-	2	32	74
Dorcus																
brevis	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Dyscinetus																
morator	-	-	-	-	5	1	13	14	19	6	12	10	3	8	8	2
Euetheola																
humilis	-	-	-	-	11	1	33	68	344	93	101	57	48	24	17	5
Hybosorus																
illigeri	-	-	-	-	-	-	-	-	-	1	2	8	2	33	33	21
Maladera																
castanea	-	-	-	-	-	-	-	-	-	-	-	-	-	7	14	38
Pelidnota																
punctata	-	-	-	-	-	-	-	-	-	-	-	-	-	4	4	9
Phyllophaga																
crenulata	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1	1
Serica																
carolina	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
Trox																
affinis	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
Valgus																
canaliculatus	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-

Table A-21: Light trap collections of Scarabaeoidea from the Walker Golf Course (Clemson, South Carolina) July-September, 2010.													
	July					August				September			
	02	09	16	23	30	06	13	20	27	03	10	17	24
Ateuchus	X	X	X	X		X							
histeroides	X	X	X	X	-	X	1	-	-	-	-	-	-
Cyclocephala	X	X	X	X		X							
lurida	X	X	X	X	4	X	-	-	-	-	-	-	-
Dyscinetus	X	X	X	X		X							
morator	X	X	X	X	-	X	1	2	-	-	-	-	-
Euetheola	X	X	X	X		X							
humilis	X	X	X	X	1	X	16	39	136	244	53	16	-
Hybosorus	X	X	X	X		X							
illigeri	X	X	X	X	-	X	6	14	12	8	2	1	0
Maladera	X	X	X	X		X							
castanea	X	X	X	X	10	X	14	12	8	6	1	-	-
Onthophagus	X	X	X	X		X							
gazella	X	X	X	X	1	X	-	-	-	-	-	2	-
Pelidnota	X	X	X	X		X							
punctata	X	X	X	X	2	X	1	-	-	-	-	-	-
Tomarus	X	X	X	X		X							
gibbosus gibbosus	X	X	X	X	-	X	1	1	-	1	-	-	-

Table A-22: Light trap collections of Scarabaeoidea from the Walker Golf Course (Clemson, South Carolina) October-December, 2010.													
	October					November				December			
	01	08	15	22	29	05	12	19	26	3	10	17	24
Euetheola													
humilis	-	8	1	4	1	-	-	-	-	-	-	-	-
Hybosorus													
illigeri	-	1	-	-	-	-	-	-	-	-	-	-	-

REFERENCES

Arnett, R.H., Jr., M.C. Thomas, P.E. Skelley and J.H. Frank. 2002. American Beetles Volume 2. Polyphaga: Scarabaeoidea through Curculionoidea. CRC Press LLC, Boca Raton, Florida.

Baker, C. W. 1968. Larval taxonomy of the Troginae in North America with notes on biologies and life histories (Coleoptera: Scarabaeidae). US Nat. Mus. Bull. 279: 1-79.

Baxendale, F. 2006. Management of Japanese Beetle Adults. http://www.ianrpubs.unl.edu/epublic/live/g1623/build/g1623.pdf

Bennet, D.G., and J.C. Patton. 2008. A Geography of the Carolinas. Parkway Publishers, Inc. Boone, North Carolina.

Bernadi, O., M.S. Garcia, U.S. Cunha, E.C. Back, D. Bernardi, G.A. Ramiro and E. Finkenauer. 2008. Occurrence of *Euetheola humilis* (Burmeister) (Coleoptera: Scarabaeidae) in *Eucalyptus saligna* Smith (Myrtaceae), in Rio Grande do Sul State, Brazil. Neotrop. Entomol. 37(1):100-3.

Bertone, M., Watson, W., Stringham, M., Green, J., Washburn, S., Poore, M., and M. Hucks. Dung beetles of central and eastern North Carolina pastures. NC State University. http://www.ces.ncsu.edu/depts/ent/notes/forage/guidetoncdungbeetles.pdf

Bixby, A., S.R. Alm, K. Power, P. Grewal and S.R. Swier. 2007. Susceptibility of four species of turfgrass-infesting scarabs (Coleoptera: Scarabaeidae) to *Bacillus thuringiensis* serovar *japonensis* strain Buibui. J. Econom. Entomol. 100(5): 1604-10.

Black, S.H., M. Shepard and M.M. Allen. 2001. Endangered invertebrates: the case for greater attention to invertebrate conservation. Endangered Species UPDATE 18: 42-50.

Bowden, J. 1982. An analysis of factors affecting catches of insects in light traps. Bull. Entomol. Res. 72: 535-556.

Bravo, A. and S. Mario. 2008. How to cope with insect resistance to Bt toxins? Trends Biotechnol. 26(10): 573-9.

Britannica Encyclopedia. 2011. Osiris http://www.britannica.com/EBchecked/topic/433922/Osiris

Browne, D.J., and C.H. Scholtz. 2008. Phylogeny of the families of Scarabaeoidea (Coleoptera) based on characters of the hindwing articulation, hindwing base and wing venation. Syst. Entomol. 2(3): 145-173.

Buss, E.A. 2006. Flight activity and relative abundance of phytophagous scarabs (Coleoptera: Scarabaeoidea) from two locations in Florida. Fla. Entomol. 89(1): 32-40.

Cambefort, Y. 1994. Beetles as Religious Symbols. Cultural Entomology Digest. http://www.insects.org/ced1/beetles_rel_sym.html

Ciegler, J. 2007. Leaf and Seed Beetles of South Carolina. Clemson University Press. Clemson, South Carolina.

Costa, C., Vanin, S.A., and S.A. Casari-Chen. 1988. Larvas de Coloeptera do Brasil. Museu de Zoologia, Universidade de Sao Paulo, Sao Paulo.

Crutchfield B.A., and D.A. Potter. 1994. Preferences of Japanese beetle and southern masked chafer (Coleoptera: Scarabaeidae) grubs among cool-season turfgrasses. J. Entomol. Sci. 29: 398-406.

Crutchfield, B.A., and D.A. Potter. 1995a. Damage relationships of Japanese beetle and southern masked chafer (Coleoptera: Scarabaeidae) grubs in cool-season turfgrasses. J. Econ. Entomol. 88: 1049-56.

Crutchfield B.A., and D.A. Potter. 1995b. Feeding by Japanese beetle and southern masked chafer grubs on lawn weeds. Crop Sci. 35: 1681-84.

Crutchfield B.A., and D.A. Potter. 1995c. Irrigation and nitrogen fertilization effects on white grub injury to Kentucky bluegrass and tall fescue turf. Crop Sci. 35: 1122–1126.

Crutchfield B.A., and D.A. Potter. 1995 d. Tolerance of cool-season turfgrasses to feeding by Japanese beetle and southern masked chafer (Coleoptera: Scarabaeidae) grubs. J. Econ. Entomol. 88: 1380–1387.

Dawson, R. W. 1967. New and little known species of *Serica*, X. J. NY Entomol. Soc. 75: 161-178.

Dellacasa, M. 1987. Contribution to a world-wide catalogue of Aegialiidae, Aphodiidae, Aulonocnemidae, Termitotrogidae (Coleoptera Scarabaeoidea). Mem. Soc. Entomol. Ital. 66: 1-455.

Dellacasa, M. 1988a. Contribution to a world-wide catalogue of Aegialiidae, Aphodiidae, Aulonocnemidae, Termitotrogidae (Coleoptera Scarabaeoidea) Part II. Mem. Soc. Entomol. Ital. 67: 1-229.

Dellacasa, M. 1988b. Contribution to a world-wide catalogue of Aegialiidae, Aphodiidae, Aulonocnemidae, Termitotrogidae (Coleoptera Scarabaeoidea). Addenda et corrigenda (First note). Mem. Soc. Entomol. Ital. 67: 291-316.

Dellacasa, M. 1991. Contribution to a world-wide catalogue of Aegialiidae, Aphodiidae, Aulonocnemidae, Termitotrogidae (Coleoptera Scarabaeoidea). Addenda et corrigenda (Second note). Mem. Soc. Entomol. Ital. 70: 3-57.

Dellacasa, M. 1995. Contribution to a world-wide catalogue of Aegialiidae, Aphodiidae, Aulonocnemidae, Termitotrogidae (Coleoptera Scarabaeoidea). Addenda et corrigenda (Third note). Mem. Soc. Entomol. Ital. 74: 159-232.

Eaton, E., and K. Kaufman. 2007. Kaufman Field Guide to Insects of North America. Hillstar Editions L.C., New York, NY.

Endrödi, S. 1966. Monographie der Dynastinae (Coleoptera, Lamellicornia). Tiel 1. Ent. Abh. Mus. Tierk. 33: 1-460.

Endrödi, S. 1985. The Dynastinae of the World. Dr. W. Junk Publisher, London, England.

Evans, A.V., and C.L. Bellamy. 1996. An Indordinate Fondness for Beetles. Henry Holt and Company, New York, New York.

Evans, A. V., and A.B.T. Smith. 2009. An Electronic Checklist of the New World Chafers (Coleoptera: Scarabaeidae: Melolonthinae). Version 3. Updated March 16, 2009. Electronically published, Ottawa, Canada.

Fattig, P.W. 1944. The *Phyllophaga* or May beetles of Georgia. Emory University Museum Bulletin II. Emory University, Atlanta, GA.

Fleming, W.E. 1968. Biological Control of the Japanese beetle. USDA Tech. Bull. No. 1449:1-129. United States Department of Agriculture, Washington, DC.

Fleming, W.E. 1976. Integrating control of the Japanese beetle—a historical review. USDA Tech. Bulletin No. 1545. United States Department of Agriculture, Washington, DC.

Forbes, S.A. 1891. On the common white grubs (*Lachnosterna* and *Cyclocephala*), pp. 30-53. *In*: Seventeenth report of the state entomologist on the most noxious and beneficial insects of the state of Illinois. Sixth report of S.A. Forbes for the years 1889 and 1890. Transactions of the Department of Agriculture of the state of Illinois, vo. 28.

Forschler, B.T., and W.A. Gardner. 1991. Flight activity and relative abundance of phytophagous Scarabaeidea attracted to blacklight traps in Georgia. J. Agric. Entomol. 8(3): 179-187.

Frank, D., and S. Bambara. 2009. Japanese beetle. Ornamentals and turf: Department of Entomology Insect Note. North Carolina State University Cooperative Extension. http://www.ces.ncsu.edu/depts/ent/notes/O&T/flowers/note44/note44.html

Gaugler, R., and M.G. Klein 1998. "Insect Parasitic Nematodes: Tools for Pest Management". 30 Minute Video. The Ohio State University, Ohio Agricultural Research and Development Center, Wooster, OH.

Gaugler, R., Y.I. Wang and J.F. Campbell. 1994. Aggressive and evasive behaviors in *Popillia japonica* (Coleoptera: Scarabaeidae) larvae: Defenses against entomopathogenic nematode attack. J. Invertebr. Pathol. 64(3): 193-199.

Gibb, T.J. 2008. New White Grub Pests of Indiana. Purdue University Landscape and Ornamentals: Entomology Department. Purdue Extension E-259-W. http://extension.entm.purdue.edu/publications/E-259.pdf

Gordon, F.C., and D.A. Potter. 1985. Efficiency of Japanese beetle (Coleoptera: Scarabaeidae) traps in reducing defoliation of plants in the urban landscape and effect on larval densityin turf. J. Econ. Entomol. 78: 774-778.

Gordon F.C., and D.A. Potter. 1986. Japanese beetle (Coleoptera: Scarabaeidae) traps: evaluation of single and multiple arrangements for reducing defoliation in urban landscapes. J. Econ. Entomol.79: 1381–1384.

Gyeltshen, J., and A. Hodges. 2010. Japanese Beetle, *Popillia japonica* Newman (Insecta: Coleoptera: Scarabaeidae). Entomology and Nematology Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. http://edis.ifas.ufl.edu/in630

Hammond, R.B., and B.R. Stinner. 1987. Soybean foliage insects in conservation tillage systems: effects of tillage, previous cropping history, and soil insecticide application. Environ. Entomol. 16:524–531.

Hanksi, I. 1989. Dung Beetles. Ecosystems of the World, 14b, Tropical Forests. H. Lieth and J.A. Wagner (eds.) Elsevier, Amsterdam.

Hanski, I., and Y. Cambefort. 1991. Dung Beetle Ecology. Princeton University Press, Princeton, NJ.

Harpootlian, P.J. 2001. Scarab beetles (Coleoptera: Scarabaeidae) of South Carolina. Biota of South Carolina Vol. 1. Clemson University Press, Clemson, SC.

Heller, P.H. 2007. Green June Beetle. Penn State Entomology. http://www.turffiles.ncsu.edu/insects/Sugarcane_Beetle.aspx

Held, D.W., and C.H. Ray. 2009. Asiatic garden beetle *Maladera castanea* (Coleoptera: Scarabaeidae) grubs found in damaged turf in Alabama. Fla. Entomol. 92(4): 670-672.

Hodgson, E. 2007. Japanese beetle: Not just another pretty bug. http://utahpests.usu.edu/htm/utah-pests-news/spring07/

Hodgson, E., and D. Alston. 2006. Japanese Beetle. http://extension.usu.edu/files/publications/factsheet/ENT-100-06PR.pdf

Holter, P., C.H. Scholtz and K.G. Wardhaugh. 2002. Dung feeding in adult scarabaeines (tunnellers and endocoprids): even large dung beetles eat small particles. Ecol. Entomol. 27(2): 169-176.

Jackson, T.A., and M.G. Klein. 2006. Scarabs as pests: A continuing problem. Coleopt. Soc. Monogr. 5: 102-119.

Kazier, M.A., and M. Statham. 1962. The behavior and habits of the myrmecophilous scarab *Cremastocheilus stathamae cazier* with notes on other species (Coleoptera: Scarabaeidae). J. NY Entomol. Soc. 70(3): 125-149.

Klausnitzer, B. 1981. Beetles. Exeter Books, New York, NY.

Koppenhofer A.M., and E.M. Fuzy. 2003. Biological and chemical control of the Asiatic garden beetle, *Maladera castanea* (Coleoptera:Scarabaeidae). J. Econ. Entomol. 96(4): 1076-82.

Lai, J., and K. Hsin-ping. 2008. For the Love of Rhinoceros and Stag Beetles, second edition. Morning star publishers, Taiwan.

Larsen, T.H., A. Lopera, A. Forsyth and F. Genier. 2009. From coprophagy to predation: a dung beetle that kills millipedes. Biol. Lett. 5(2): 152-155.

Lawrence, J.F., and A.F. Newton. 1995. Families and subfamilies of Coleoptera (with selected genera, notes, references, and data on family-group names). Biology, Phylogeny, and Classification of Coleoptera. Warszawa, pp. 779-1006 *in* Pakaluk, J.; Slipinski, S.A. (eds.) Biology, phylogeny, and classification of Coleoptera: papers celebrating the 80th birthday of Roy A. Crowson. Museum i Instytut Zoologii PAN, Warszawa, Poland.

Lockwood, A., and R. Brandenburg. 2011. Sugarcane beetle *Euetheola humilis*, a new pest in North Carolina turfgrass. NC State University TurfFiles Center. http://www.turffiles.ncsu.edu/insects/Sugarcane_Beetle.aspx

Luginbill, P., and H.R. Painter. 1953. May Beetles of the United States and Canada. U.S. Department of Agriculture Technical Bulletin. 1060. USDA, Washington, DC.

Lund, V., and J. Goksøyr. 1980. Effects of water fluctuations on microbial mass and activity in soil, Microb. Ecol. 6: 115–123.

McColloch, J.W., and W.P. Hayes. 1919. The *Lachnosterna* of the vicinity of Manhattan, Kansas. Trans. Kansas Acad. Sci. 30: 184-195.

McNamara, J. 2004. Canadian National Collection of Insects, Arachnids, and Nematodes-Family Scarabaeidae. http://www.canacoll.org/Coleo/Checklist/checklist.htm

Morón, M.A., and R. Arce. 2003. Description of third instar larvae and pupae of *Ceratocanthus relucens* (Bates) (Coleoptera: Scarabaeidae: Ceratocanthinae). Coleopt. Bull. 57(3): 245-253.

Morse, J.C., D.W. Brooks, P.H. Carlson, J.F. Cornell, H.B. Douglass, E.W. King, V.H. McCaskill, T.E. Skelton, and J.Spooner. 1976. Status report Arthropoda other than Crustacea. Pp. 46-51, in D.M. Forsythe and W.B. Ezell, Jr., editors, Proceedings of the First South Carolina Endangered Species Symposium. South Carolina Wildlife and Marine Resources Department, Columbia, South Carolina. 201 pp.

Myers, N. 2003. Biodiversity hotspots revisited. Bioscience 5: 916-917.

Neiswander, C.R. 1963. The distribution and abundance of May beetles in Ohio. Ohio Agricultural Experimental Station Research Bulletin 951.

Nichols, E., T. Larsen, S. Spector, A.L.V. Davis, F. Escobar, M. Favila, and K. Vulinec. In Press. Dung beetle response to tropical forest medication and fragmentation: a review and meta-analysis. Biol. Conserv.

Ocampo, F.C. 2000. Hybosoridae, monographic research and revision of the New World genera. http: //www.museum.unl.edu/research/entomology/obj-Hybos-htm.

Ocampo, F.C. 2002. Hybsoroids of the United States and expanding distribution of the introduced species *Hybosorus illigeri* (Coleoptera:Scarabaeidae: Hybosoridae). Ann. Entomol. Soc. Am. 95(3): 316-322.

Ocampo, F.C. 2006. Phylogenetic analysis of the scarab family Hybosoridae and monographic revision of the New World subfamily Anaidinae (Coleoptera: Scarabaeoidea). Bull. Univ. Nebr. State Mus. 19: 13-177.

Pierce, C.M.F. 2010. Indiana's Most Unwanted Invasive Plant Pests. Indian Cooperative Agricultural Pest Survey (CAPS) Program. http://extension.entm.purdue.edu/caps/pestInfo/orientalBtl.htm

Pike, K.S., R.L Rivers and Z.B. Mayo. 1977. Geographical distribution of the known *Phyllophaga* and *Cyclocephala* species in the North Central States. Nebraska Agricultural Experiment Station. Miscellaneous Publication 34.

Potter, D.A. 1998. Destructive Turfgrass Insects. Biology, Diagnosis, and Control. Ann Arbor Press, Chelsea, MI.

Potter D.A., and S.K. Braman. 1991. Ecology and management of turfgrass insects. Annu. Rev. of Entomol. 36: 383-406.

Potter, D.A., and D.W. Held. 2002. Biology and management of the Japanese beetle. Annu. Rev. Entomol. 47: 175-205.

Potter, D.A., C.G. Patterson and C.T. Redmond. 1992. Influence of turfgrass species and tall fescue endophyte on feeding ecology of Japanese beetle and southern masked chafer grubs (Coleoptera: Scarabaeidae). J. Econ. Entomol. 85: 900-909.

Potter, D.A., A.J. Powell, P.G. Spicer and D.W. Williams. 1996. Cultural practices affect root-feeding white grubs (Coleoptera: Scarabaeidae) in turfgrass. J. Econ. Entomol. 89: 156-64.

Price, D. 2004. Species diversity and seasonal abundance of scarabaeoid dung beetles (Coleoptera: Scarabaeidae, Geotrupidae and Trogidae) attracted to cow dung. J. NY Entomol. Soc. 112: 334-347.

Ratcliffe, B. C. 1974. New distribution records for eleven species of *Phyllophaga* (Coleoptera: Scarabaeidae). Entomol. News 85(3): 72-75.

Ratcliffe, B.C. 1991. The Lucanidae and Passalidae (Insecta: Coleoptera) of Nebraska. Great Plains Res. 1: 249-282.

Ratcliffe, B.C. 2005. Generic Guide to New World Scarab Beetles. http://www.unl.edu/museum/research/entomology/Guide/Guide-introduction/Guideintro.html

Ratcliffe, B.C. 2006. Scarab beetles in human culture. Coleopt. Soc. Monogr. 5: 85-101. http://digitalcommons.unl.edu/entomologypapers/94/

Ratcliffe, B. C., and M. J. Paulsen. 2008. The scarabaeoid beetles of Nebraska (Coleoptera: Scarabaeoidea). Bull. Univ. Nebr. State Mus. 22: 1-570.

Reitter, E. 1961. Beetles. G. P. Putnam's Sons, New York, NY.

ScarabNet. 2006. ScarabNet Glolbal Taxon Database. www.scarabnet.org

Scholtz, C.H. 1986. Phylogeny and systematics of the Trogidae (Coleoptera:Scarabaeoidea). Syst. Entomol. 11: 355-363.

Scholtz, C.H. and D.J. Browne. 1996. Polyphyly in the Geotrupidae (Coleoptera: Scarabaeoidea): a case for a new family. J. Nat. Hist. 30: 597-614.

Schuster, J.C. 1975. Comparative Behaviour, Acoustical Signals, and Ecology of New World Passalidae (Coleoptera). PhD dissertation. University of Florida, Gainesville.

Schuster, J.C. 1994. *Odontotaenius floridanus* new species (Coleoptera: Passalidae): a second U.S. passalid beetle. Fla. Entomol. 77: 474-479.

Simmons, B. 2000. Differences in turfgrass arthropod diversity in golf course fairways and roughs as a factor in outbreaks of *Ataenius spretulus* and *Aphodius granarius* (Coleoptera:Scarabaeidea). http://archive.lib.msu.edu/tic/mitgc/article/2000127.pdf

Smith A.W., R.B. Hammond and B.R. Stinner. 1988. Influence of rye-cover crop management on soybean foliage arthropods. Environ. Entomol.17: 109–14.

Spector, S. 2006. Scarabaeine dung beetles (Coleoptera: Scarabaeidae: Scarabaeinae): An invertebrate focal taxon for biodiversity research and conservation. Coleopt. Bull. 60(supplement 5): 71-83.

Stebnicka, Z. 2001. Aphodiinae (Insecta:Coleoptera:Scarabaeidae). Fauna of New Zealand. Manaaki Whenua Press, Canterbury, New Zealand. 64 pp.

Stein, B.A., L.L. Master and L.E. Morse. 2002. Taxonomic bias and vulnerable species. Science 297: 1807.

Stock, S.P., and A.M. Koppnehofer. 2003. *Steinernema scarabaei* n. sp. (Rhabditida:Steinernematidae), a natural pathogen of scarab beetle larvae (Coleoptera: Scarabaeidae) from New Jersey, U.S.A. Nematology 5: 191-204.

Suiter, D.R. 2010. Invading Black Scarab Beetles. Upstate Horticulture: Clemson Extension.

http://www.facebook.com/note.php?note_id=487977231797

UCIPM. 2008. Avocado June Beetles. http://www.ipm.ucdavis.edu/PMG/r8300811.html

University of Minnesota Extension. 2009. Managing lawn and turf insects: Root feeding: white grubs, a general name. http://www.extension.umn.edu/distribution/horticulture/components/1008_02.html

Verdu, J.R., E. Galante, J. Lumaret and F.J. Cabrero-Sanudo. 2004. Phylogenetic analyses of Geotrupidae (Coleoptera, Scarabaeoidea) based on larvae. Syst. Entomol. 29: 509-523.

Wicknick, J.A., and S. A. Miskelly. 2009. Behavioral interactions between non-cohabiting bess beetles, *Odontotaenius disjunctus* (Illiger) (Coleoptera: Passalidae). Coleopt. Bull. 63(1): 108-116.

Woodruff, R.E. 1968. The present status of *Plectris aliena* Chapin in the United States. Florida Department of Agriculture, Entomology Circular No. 68.

Woodruff, R. E. 1973. The scarab beetles of Florida (Coleoptera: Scarabaeidae). Part 1.The Laparosticti. Arthropods of Florida and Neighboring Land Areas 8: 1–220.

Young, M. 1998. Family Ceratocanthidae.
http://entomology.wisc.edu/~young/scarab/ceratoca/ceratoca.html