CARABID (COLEOPTERA: CARABIDAE) ECOLOGY IN AGROECOSYSTEMS OF THE SOUTHERN GREAT PLAINS

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TABLE OF CONTENTS

Chapter Page

LIST OF TABLES

Table Page

CHAPTER IV

Table Page

LIST OF FIGURES

Figure Page

CHAPTER III

Figure Page

CHAPTER IV

CHAPTER I

INTRODUCTION

Carabidae is the largest family in the coleopteran suborder Adephaga and one of the most successful of all beetle families world-wide. Members of this beetle family are highly adaptable, mostly epigeaic, and mostly polyphagous (Thiele 1977, Holland 2002). The Taxon Pulse hypothesis suggests the primitive wet-biotype carabids developed in the equatorial regions during the late Triassic and early Jurassic periods approximately 213 million years ago (Erwin 1981, 1982, 1985). By the late Paleocene, carabids had undergone a succession of rapid taxon pulses (Erwin 1979). These pulses resulted in carabid radiation into drier environments, higher latitudes, and higher altitudes (Darlington 1959, Darlington 1971, Erwin 1979). This radiation has led to present-day Carabidae consisting of 32,561 described species, approximately 100 tribes, and 1,859 genera world-wide (Erwin 1985, Lorenz 1998).

Extant carabids are found on all continents except Antarctica and on most remote oceanic islands. Carabids live in virtually all types of habitats, including environmental extremes such as glacial margins and caves (Thiele 1977). There are three reasons proposed for this great diversity and distribution: 1) most carabids face little or no competition from other ground-dwelling arthropods for their ecological niches; 2) carabids have retained a

generalized basic body plan: 3) in general, specialization occurs through niche selection, flexible physiological and behavioral traits not morphological changes (Thiele 1977). These characteristics along with other adaptations make carabids one of the most studied families of beetles (Lövei and Sunderland 1996, Holland 2002). Holland et al. (2005) considers carabids one of the most important ground-dwelling consumers of agricultural pests. Carabids are excellent organisms to study in agroecosystems because they react to environmental changes quickly and measurably (Thiele 1977, Fournier and Loreau 2002, Holland et al. 2005). This is due to their reproductive plasticity, flexible behavioral and environmental requirements (Thiele 1977, Holland 2002). These beetles are relatively easy to sample due to their foraging techniques and dispersal characterized by walking rather than flying (Thiele 1977, Fournier and Loreau 1999). Carabids are often abundant and persistent despite catastrophic disturbances in agroecosystems (Thiele 1977, Lövei and Sunderland 1996).

Throughout the 20th century, many ecological and biological studies of carabids were conducted by entomologists. In 1949, Carl H. Lindroth (1949) produced the first extensive study of carabid ecology and distribution. Hans-Ulrich Thiele's 1977 monograph on carabids focused on their ecology in natural and cultivated habitats from the 1950's to the mid 1970's. Since the early 1970's, more research has focused on carabid biology and ecology in agroecosystems (Luff 1987, Lövei and Sunderland 1996). Since Forbes's 1883 publication carabids have been considered beneficial predators in agroecosystems. Balduf (1935) and Kulman (1974) reviewed carabid biology as it related to predatory behavior and biological control. Additionally, Allen (1979) examined the occurrence and importance of carabids in agroecosystems with an emphasis on North America. Integrated pest management (IPM) practitioners readily recognize the polyphagous nature of carabids and the potential

implications of this feeding activity on the consumption of pest species. However, carabid biology within diverse agricultural systems of the Southern Great Plains is not well studied.

Since the early 1900's, large intensively managed and conventionally-tilled (CT) continuous monocultures (mostly winter wheat) have dominated farming practices in the prairies of the United States Plains (Unger and Baumhardt 2001). Continual soil degradation due to CT practices presents a growing environmental hazard along with decreased productivity and profitability (Pagliai et al. 2004). Conventionally-tilled monocultures also create homogeneous environmental conditions and abundant resources allowing explosive insect pest population growth (Brewer and Elliott 2004). Alternatively, these systems provide insect natural enemies with extremely limited resources because suitable habitats necessary for the completion of life cycles are often not present in monoculture landscapes. This alteration of the landscape reduces the ability of natural enemies to rapidly colonize annual cropping systems and suppress pest populations (Brewer and Elliott 2004). Natural enemies are further constrained by repeated tillage disturbances which can be catastrophic to ground-dwelling arthropod predators. Mechanical cultivation of the soil causes direct contact mortality and indirect mortality by destabilization of the soil's physical, chemical, and biological conditions that many ground-dwelling predators depend on for their survival. Additionally, refuge habitat outside cropped areas such as fence lines, non-cultivated pastures, riparian zones, and field margins are dramatically reduced in monoculture systems. This leaves ground dwelling Carabidae and many other predators without the diversified habitats necessary to complete their life cycles, thereby, reducing their efficacy as biological control agents (Los and Allen 1983, Marino and Landis 1996, Menalled et al. 1999a). Altogether, the conditions in agricultural landscapes dominated by CT monocultures: 1)

favor r-strategist insect pests that rapidly colonize and reproduce in disturbed habitats, and 2) suppress predators creating an imbalance in the food web and a loss of trophic structure (Hunter 2002, Titi 2003).

In the US Southern Great Plains (SGP), natural enemies have a regulating effect on pest populations in winter wheat, cotton, and sorghum (Kring et al. 1985, Rice and Wilde 1988, Giles et al. 2003). Carabidae constitute a major part of agricultural fauna and are an important part of the natural enemy assemblages in agroecosystems (Fox and MacLellan 1956, Rivard 1964, Whitcomb and Bell 1964, Rivard 1965, 1966, Frank 1971, Kirk 1971, Esau and Peters 1975, Kendall 2003). Carabids have been considered beneficial predators in agroecosystems since Forbes's 1883 publication. Balduf (1935) and Kulman (1974) reviewed carabid biology as it related to predatory behavior and biological control. Carabids are polyphagous opportunistic feeders often switching to the most abundant prey available (Hengeveld 1980b, Barney and Pass 1986). Known carabid prey include but are not limited to: aphids, noctuid caterpillars, pierid larvae, corn rootworm beetles as well as other beetles, wireworms, spiders, enchytraeid and lumbricid worms, fly larvae, harvestmen, centipedes, millipedes, mollusks, and snails (Lövei and Sunderland 1996, Menalled et al. 2007).

Carabid beetles are highly mobile predators in agroecosystems of the SGP and regularly move between cropping systems or between non-cultivated habitats and cropping systems in order to utilize these ephemeral habitats and their resources (Thomas et al. 2002). These beetles are relatively easy to sample due to their foraging techniques and dispersal characterized by walking rather than flying (Thiele 1977, Fournier and Loreau 1999). Movement among ephemeral and perennial habitats is termed cyclic colonization (Wiedenmann and Smith 1997). Factors such as physiological stimuli, changes in abiotic

factors, or farming practices may initiate carabid movement. Agricultural disturbances, such as tillage, harvesting operations, or application of pesticides, can cause carabids to leave crops in an effort to escape injury or death (Southwood 1962, den Boer 1970, Burkey 1989, den Boer 1990, Sherratt and Jepson 1993, Landis et al. 2000). In these situations, beetles need refuge habitats like grassy borders, pastures, hedgerows, fence rows, ditches, or semi-permanent crops. Elimination of natural vegetation or semi-permanent crops in monoculture systems can cause the extinction of many resident insect predators dependent on habitat diversity (van Emden 1965). Those involved in pest management research recognize the challenges associated with conservation of generalist insect predators such as carabids within agricultural landscapes and recommend vegetation diversity as one of many solutions. Diverse vegetation is recommended because complex habitats supply generalist predators with the necessary resources to maintain higher populations improving early colonization of crops before pest species reach economic thresholds (Coombes and Sotherton 1986, Marino and Landis 1996, Menalled et al. 1999b, Thies and Tscharntke 1999, Hunter 2002).

In the SGP region, alfalfa is considered a semi-permanent crop. Healthy stands can remain productive for five to 10 years with minimal disturbances (Berberet et al. 1987). Conversely, the most common annual crop vegetation (wheat and sorghum) is short-lived generally lasting only a few months and these crops usually require re-colonization by herbivores and natural enemies each season (Wiedenmann and Smith 1997, Wissinger 1997). Carabids persist within diverse agricultural landscapes (annual crops, semi-permanent, and non-crop habitat) and colonize crops when resources are available even at low densities and when the habitat is undisturbed (Southwood et al. 1983). Once crop resources are depleted or a disturbance (pesticides, harvesting, and/or tillage) occurs carabids return to refuge habitats

(Duelli et al. 1990, Sherratt and Jepson 1993, Kajak and Lukasiewicz 1994, Wissinger 1997). Carabids escaping frequent disturbances in annual cropping systems in the SGP may utilize semi-permanent alfalfa as refuge habitat. This refuge may provide carabids and other predators with abundant resources and diversified microhabitats in a relativity stable environment. Additionally, alfalfa supplies carabid adults and larvae with overwintering sites increasing their survival which increases spring biological control services (Ostrom et al. 1997, Landis et al. 2000).

Increasingly, stable carbon isotopes (SCI) have been used in ecological and biological studies to investigate the trophic ecology and movement of arthropods (Peterson and Fry 1987, Ehleringer and Rundel 1989, Tieszen and Boutton 1989, Zanden and Rasmussen 1999). Isotope data can reveal information on the dispersal patterns, foraging ranges, movement between habitats, dietary intake, and diet shifts in various life stages of animals (Hobson 1999, Gould et al. 2002, Oelbermann and Scheu 2002, Prasifka et al. 2004). In order to use stable carbon isotopes (SCI) in ecological studies some understanding of what isotopes are and how they are assimilated into various tissues is required. First, isotopes are different forms of the same element such as Carbon, Oxygen, Hydrogen, Nitrogen, and Sulfur. Each isotope of an element has a different number of neutrons producing a difference in mass and physical properties (Rubenstein and Hobson 2004). For example, ^{12}C has 12 neutrons and equals 98.9% of all carbon atoms whereas, ^{13}C has 13 neutrons and accounts for only 1.1% of all atoms (O'Leary 1988, Hood-Nowotny and Knols 2007). Secondly, the isotopes of an element interact with biological and biogeochemical processes differently which results in measureable variations in ^{13}C levels within the tissues of plants and animals. Accordingly, plants utilize one of two photosynthetic pathways to convert sunlight to energy resulting in

distinct ^{13}C signatures. One photosynthetic pathway used by plants produces three-carbon molecules and is called the Calvin cycle (C_3) (Calvin 1962). Other plants use the alternative Hack-Slack pathway (C_4) which produces four-carbon molecules (Hatch 1982, Ehleringer and Monson 1993). C_3 (-22 to -35‰) and C_4 (-9 to -19‰) plants have distinctly different carbon isotope ratios that provide a predictive relationship as ^{13}C is depleted or enriched (Craig 1954, Bender 1968, O'Leary 1981, 1988, Prasifka and Heinz 2004). Stable carbon isotope ratios (SCIRs) can be used to determine recent and past dietary intake by herbivores and predators; however, the system must have distinct ^{13}C sources (Prasifka and Heinz 2004). In addition, isotope data can reveal information on the foraging ranges, trophic structure, diet preferences, and diet shifts in various life stages of animals (Hobson and Clark 1992, Ostrom et al. 1997, Wassenaar and Hobson 1998, Fantle et al. 1999, Hobson 1999, Gould et al. 2002, Oelbermann and Scheu 2002, Prasifka and Heinz 2004).

Herbivores and predators within isotopically discrete habitats are naturally marked through the food they consume (Tieszen et al. 1983, Prasifka and Heinz 2004, Rubenstein and Hobson 2004, Gratton and Forbes 2006). Naturally occurring isotope markers avoid the disruption of the normal behavior of carabids caused by mark-release-re-trap techniques which are labor intensive, difficult to obtain in larger sample sizes, and lead to a loss of data due to low re-capture rates. Alfalfa (C_3) a semi-permanent crop, and sorghum (C_4) an annual summer crop, are isotopically discrete habitats within the SGP region. Resident herbivores exhibit the isotopic compositions of their respective host-crop and this transfer of isotopic composition carries through to the predators or parasitoids that consume these prey (DeNiro and Epstein 1978, Petelle et al. 1979, Ostrom et al. 1997, Oelbermann and Scheu 2002). Consequently, predators such as carabids reflect the isotopic signatures of the herbivores

preyed upon. Isotope compositions may also reflect diet mixing (-18.6 to -22.5‰) if carabids feed on a variety of discrete ^{13}C sources (Prasifka and Heinz 2004). Alternatively, movement from one isotopically discrete habitat to another accompanied by diet switching will cause isotope compositions to shift toward the new diet (Tieszen et al. 1983, Prasifka and Heinz 2004, Rubenstein and Hobson 2004, Gratton and Forbes 2006). Carabid natal origins, dispersal from natal origins revealing larval habitat utilization, and dietary histories can be re-constructed by determining the differences in SCIRs among carabids, herbivore prey, and host plants in isotopically discrete habitats (DeNiro and Epstein 1978, Hobson et al. 1994, Ostrom et al. 1997).

Stable isotopes are fractionated (enrichment or depletion) through the enzymatic transformation and assimilation of food within animal tissues at various rates (Tieszen and Boutton 1989, Hobson et al. 1993, Hobson 1999). Based on these variations, when utilizing SCIRs to document dispersal, diet switching, and natal origins, it is critical to select tissues appropriate to the spatial and temporal scales under investigation (Tieszen et al. 1983, Gratton and Forbes 2006, Hobson 2007). Several studies determined the isotopic turnover rates for various tissues and found that rates differed among tissues based on the metabolic activity (Tieszen et al. 1983, Ostrom et al. 1997, Webb et al. 1998, Prasifka et al. 2004, Hobson 2007). Researchers have generally chosen to use the whole body of insects or a single body part due to their small size (Ostrom et al. 1997, Ponsard and Arditi 2000, Prasifka and Heinz 2004). Gratton and Forbes (2006) determined the turnover rates for six tissue types (elytra, hind wing, legs, cuticular integument, reproductive, and fatty tissues) in *Harmonia axyridis* (Pallas) and *Coccinella septempunctata* (L.) lady beetles. This study found that after a diet switch from a C_3 to a C_4 food source the reproductive and fatty tissues

were more enriched (+10‰) compared to wings (+4‰) over the same time period in *Harmonia* (Gratton and Forbes 2006). Investigating dispersal, diet switching, and natal origins through dietary intake over various temporal scales should include metabolically active and metabolically inactive tissues as separate samples (Gratton and Forbes 2006, Hobson 2007). Carabid flight muscles, reproductive tissues, and soft organs are metabolically active and can reflect recent dietary turnover of carbon isotopes in a short period of time. These carabid tissues can be used as an R sub-sample (representing recent dietary intake) with the exclusion of the entire gut track. Based on the R sub-sample recent dietary intake accompanied by diet switching can indicate dispersal into a new habitat. In contrast, carabid elytra, wings, and pronotal exoskeleton are virtually metabolically inactive and since fractionation of ^{13}C is limited (≈0.1‰ enrichment) these tissues preserve carbon isotope compositions from adult and larval past dietary intake (DeNiro and Epstein 1978, Tallamy and Pesek 1996, Hobson 1999, Gratton and Forbes 2006). These inactive tissues can be used as a P sub-sample (representing past dietary intake of the larvae transferred to the adult). Based on the P sub-sample, long-term residency in alfalfa, sorghum, or field borders can be established for carabids. Movement to a new habitat and past dietary intake are revealed when P sub-samples are coupled with R-sub-samples and physical trapping data.

Research Objectives

My goal was to utilize standard pitfall trapping and stable carbon isotope analyses techniques to describe carabid dispersal, habitat use, and prey consumption within a diverse agricultural habitat. The three primary objectives of this dissertation research were:

1. Quantify carabid colonization of annual crops (sorghum) from a semi-permanent habitat (alfalfa) as it relates to disturbance (tillage) and wing morphology.

2. Elucidate carabid dispersal powers within and among habitats through the use of carbon isotope ratios of various tissues of carabid beetles and their diet.
3. Determine diet switching in adult carabids as it relates to natal origins and clarify larval habitat utilization.

Carabids are excellent organisms to study the impact of disturbance (tillage in this study) in agroecosystems because they react to environmental changes quickly and measurably (Thiele 1977, Fournier and Loreau 2002, Holland et al. 2005). This is due to their reproductive plasticity and flexible behavioral and environmental requirements (Thiele 1977, Makarov 1994, Fadl and Purvis 1998, Holland 2002). Carabids have been shown to depend on undisturbed soils and stable microclimates for survival at all life stages. These beetles are affected by the stability of factors such as soil temperature, humidity, pH (Gruttke and Weigmann 1990), soil type (Baker and Dunning 1975, Thiele 1977, Holopainen et al. 1995), substrate structure, and soil moisture retention (Hengeveld 1979a, Holland et al. 2007). Landscapes in the Southern Great Plains of the US are dominated by CT annual monocultures (primarily winter wheat); however, the impact of tillage on carabid biology within agroecosystems is not well studied.

This study also utilized alfalfa (C_3) and sorghum (C_4) as isotopically discrete habitats and their prey to elucidate carabid dispersal, diet switching, and natal origins *in situ* (Prasifka et al. 2004, Schallhart et al. 2009). Prey exhibit the isotopic compositions of their respective host-crop after feeding and this transfer of isotopic composition carries through to the predators or parasitoids that consume these prey (DeNiro and Epstein 1978, Petelle et al. 1979, Ostrom et al. 1997, Oelbermann and Scheu 2002). The differences in SCIRs among carabids, prey, and host-plants can be utilized to traced dispersal patterns and re-construct

dietary histories for carabids (DeNiro and Epstein 1978, Hobson et al. 1994, Ostrom et al. 1997). These data can document long-term residency or recent dispersal of carabid beetles within and among an annual crop, sorghum and a semi-permanent refuge habitat, alfalfa.

This general introduction is followed by a literature review, materials and methods, results and discussion, and general conclusions. Writing style follows the general guidelines of the Entomological Society of America.

CHAPTER II

REVIEW OF LITERATURE

Carabid Morphology, Development, and Biology

The generalist body plan of carabids is highly conserved and highly successful (Evans 1994). This body type allows carabids to adapt to most habitats without undergoing radical morphological changes (Evans 1994). When viewed in profile, carabids have a generalized wedge-shape body (head and prothorax) that facilitates movement into surface cracks and beneath litter for shelter and foraging (Evans 1977, Forsythe 1981, 1983, Evans and Forsythe 1984, Evans 1986, Forsythe 1991). Head articulation with the prothoraic box is facilitated by the cup-shaped anterior rim of the prothorax. Carabid heads have prominent prognathous mandibles supported by well-developed muscles and laterally placed compound eyes and filiform antennae (Thiele 1977, Evans 1994, Lövei and Sunderland 1996). The filiform antennal shape facilitates cleaning in the protibial antenna cleaner which is essential for proper chemosensory reception (Evans 1994, Lövei and Sunderland 1996). The elytra are tight-fitting, locked, or fused, and may possess microsculpture (Lindroth 1974, Evans 1994). Elytra provide protection to the wings and abdomen while increasing structural integrity (Hammond 1979). Flightless carabids retain elytra for protection of the abdomen, prevention of water

loss, and continued structural integrity (Hammond 1979). Flight-wing polymorphism and dispersal mechanisms in carabids will be discussed in another section of this chapter. Adult exoskeleton coloration ranges from black and brown to bright metallic colors (Lindroth 1974, Lövei and Sunderland 1996).

Metamorphosis

Carabids undergo complete metamorphosis or holometabolous development where the immature and adult forms look entirely different from one another (Thiele 1977; Luff 1987). Different life stages may have different niches, thereby reducing competition (Holland 2002). Development from newly laid eggs to adulthood takes approximately one year for most species; however, some species may take up to four years to complete development (Lövei and Sunderland 1996). Seasonal reproductive cycles were first examined in detail by Larsson (1939) who divided carabids into spring and autumn breeders based on 22honological characteristics. Lindroth (1949) proposed the terms larval and adult hibernators whereas Thiele (1971, 1977) suggested five to seven annual rhythms to classify breeding cycles. Paarmann (1979) distinguished four annual rhythms for the tropics and subtropics which were added to Thiele's (1977) classification system. Den Boer and den Boer-Daanje (1990) offered the terms summer and winter larvae.

Fecundity and Reproductive Plasticity

Gonad development and dormancy in carabids is thought to be controlled by a uniform hormonal system based on the presence or absence of juvenile hormone (Paarmann 1979). Carabid may experience interrupted or flexible reproduction which

may be dependent on gonad development. For example, generally carabids over-winter as adults or larvae hibernating until spring in deep burrows making them vulnerable to early spring soil disturbances (Wallin 1987). However, Fadl and Purvis (1998) provide evidence that some species can alter their breeding cycles according to habitat disturbances. This work indicated carabids possess enough reproductive flexibility in relation to differences in annual weather patterns, geographic locations, and habitat type to modify breeding cycles. Polyvariance is the term Makarov (1994) used for this reproductive flexibility, whereas Thiele (1977) suggested that most carabids were univoltine. Other research proposes that summer aestivation can synchronize the life cycle of some carabids (Schaick Zillesen et al. 1986, Luff 1987). Adult fecundity is related to body mass, larval nutrition, and environmental conditions (Nelemans 1988, Ernsting et al. 1992, van Dijk 1994, Lövei and Sunderland 1996).

Pre-copulatory and mating behavior in the wild is virtually unknown for most carabid species. Mating studies have usually been conducted in the laboratory (Freitag et al. 1980, Wallin et al. 1992, Takami 2002, Weed and Frank 2005, Brouat et al. 2006). Males pursue the females vigorously chasing them until they can mount them or the female escapes. Mating can appear more like fighting in that the males grasp the females with mandibles and legs while mounting her and she resists by trying to run away or dislodge the male. Some male carabids use their antennae to rub the females' antennae or body which can have a calming effect on her. Once mounted, males extend their aedeagus and insert it into the female vaginal opening. Females avoid this insertion by turning their abdomen up or down. Actual copulation can last from a few seconds to many minutes. Carabid males may remain mounted on the female for some time after

withdrawing his aedeagus. Carabid beetles have species-specific coupling mechanisms, equivalent to a lock and key, which may control breeding between species. Carabids may utilize chemical and visual cues when searching for a mate.

Oviposition behavior ranges from simply depositing a single egg randomly in the soil as in *Harpalus pennsylvanicus* De Geer or *Pheropsophus aequinoctialis* (L.) which utilizes mole cricket tunnels when present (Tomlin 1975, Luff 1981, Weed and Frank 2005). For example *Poecilus koyi* (Germar) eggs have been found as deep as 3cm (Brandmayr 1973). Under laboratory conditions, *Pterostichus melanarius* (Illiger) deposited eggs side by side in a line in groups of 2 – 12 at the base of a burrow (Tomlin 1975). Once an appropriate habitat has been located, oviposition begins with the female using the distal end of her abdomen to excavate a small hole in the soil either just below the surface or deeper. Estimated fecundity in carabids may range from five to 374 eggs per breeding period (Brandmayr 1983); the mean and maximum oocyte data for several North American species was presented by Levesque, Pilon and Dubé (1980). Carabid eggs are generally ovoid, pale white, and often exhibit micro-sculpturing on the surface (Lindroth 1974, Luff 1981).

Some carabid species in Pterostichini exhibit parental care of their eggs by guarding the eggs and first instars until these instars disperse. Other carabids prepare a chamber in the soil for added egg protection or enclosing an egg in a cocoon of subsoil particles as in some Pterostichini species (Löser 1969, Brandmayr 1977, Thiele 1977, Brandmayr and Zetto-Brandmayr 1979, Luff 1987). Another form of parental care is provisioning the egg chamber with seeds for the newly emerged larvae to eat. Carabid beetles that do not provide any direct parental care of their eggs do maximize egg

survival through selection of appropriate microhabitats (Lövei and Sunderland 1996). Meissner (1984) found that soil particle size distribution may influence oviposition microhabitat selection by carabids.

Larval Morphology and Development

Larvae are generally campodeiform and mobile with long thoracic legs. Carabid larvae exhibit sclerotization with visible segmentation. Additionally, larvae have a multi-segmented paired urogomphi on the dorsal surface of abdominal segment nine. This characteristic can be used to separate carabid larvae from other beetle larvae. Carabid larvae typically undergo three larval stages before pupating, however, there are exceptions (Lövei and Sunderland 1996). For example, in the genera *Harpalus* and *Amara* some species have two larval instars and there are other environmentally specialized species with more than three instars (Lövei and Sunderland 1996).

Larvae may develop entirely underground; however, some species readily move to the soil surface and then burrow back underground to avoid desiccation. Summer larvae have higher survival rates in moist soils and are sensitive to subsurface soil temperatures above 10º C (Luff 1994, Holland 2002). Second or third stage larvae may undergo a period of hibernation or aestivation in subsoil layers depending on the reproduction cycle (Thiele 1969, Müller 1970). Surviving final instars typically burrow into the soil to prepare a pupal chamber where the pupa is described as resting ventral side up supported by dorsal setae (Lövei and Sunderland 1996). Unlike the larval stages the pupae lack mobility; therefore, they are vulnerable to soil disturbances, changing environmental conditions, and predation. Depending on the species, the pupal stage can

persist for extended time periods or last as little as five days (Lövei and Sunderland 1996).

Carabid Diet and Foraging

Carabid adults were previously thought to be exclusively predatory or exclusively phytophagous. Hengeveld (1980b) literature review of carabid foods indicated that most carabids are actually omnivore feeders; predatory beetles ate plant materials and phytophagous beetles ate animal materials. Hengeveld (1980a) classified carabids as specialists or generalists. The subfamily Carabinae includes specialists such as the tribe Cychrini which are mainly molluscan feeders and the tribes of Notiophilini, Loricerini, and several in Nebriini which are collembolan-feeders (Larochelle 1972, Green 1975, Hengeveld 1980c, Bauer 1982). Within Carabidae, the tribe Harpalini consists mainly of generalist feeders. For example, *Harpalus pennsylvanicus* De Geer will eat seeds and live or dead pests according to prey abundance (Barney and Pass 1986). Studies have found that carabids have eaten prey from diverse Arthropod taxa such as: Acarina, Araneida, Opiliones, Orthoptera, Diptera, Coleoptera, Isoptera, Lepidoptera, Formicidae, Aphidae, and also earthworms, fungus, pollen, grains, and seeds (Forbes 1883, Davies 1953, Cress and Lawson 1971, Luff 1987).

Larvae are known to actively search for food underground, on the soil surface, and occasionally climb plants (Giglio et al. 2003). In general, larval prey selection mirrors adult prey selection (Toft and Bilde 2002). For example, *Calosoma* adults and larvae feed on moth larvae, aphids, or insect eggs while *Loricera* adults and larvae feed on Collembola (Ball and Bousquet 2001). Larvae can be considered generalist carnivores, mollusk-feeding specialists, micro-arthropod specialists, granivores, and/or scavengers

(Toft and Bilde 2002). Cannibalism has been reported in many carabid larvae and may have a regulating effect on population densities (Heesen and Brunsting 1981, Lövei and Sunderland 1996).

Adult carabid hunting techniques include use of visual, tactile, and olfactory clues. Diurnal genera like *Calosoma*, *Cicindela*, and *Scarites* use visual cues, such as prey movement, along with tactile cues from the antennae. These species take advantage of higher daytime temperatures which contribute to higher body temperatures and greater agility for hunting (Toft and Bilde 2002). Luff (1978) concluded that most of the common temperate field species were nocturnal hunters that primarily use olfactory and tactile cues from prey. Successful daytime visual hunting by carabids is attributed to their visual acuity which enables them to accurately locate and track prey. Night time temperatures reduce the ability of day-active prey to avoid attack by nocturnal predators like carabids (Toft and Bilde 2002). The hunting techniques and dietary requirements of carabids in agroecosystems in the Southern Great Plains are not well studied.

Carabid and Prey Aggregation

In agroecosystems, carabids often search on the soil surface for common aphid pest species that have been dislodged from the plant (Thiele 1977, Allen 1979, Luff 1987, Winder 1990, Lövei and Sunderland 1996). Within cereal agricultural systems, aphids aggregate in ephemeral patches and carabids have been shown to be attracted to these prey aggregations and alter aphid densities (Bryan and Wratten 1984, Holland et al. 1999, Winder et al. 1999). Winder et al.(1999) examined the spatial and temporal distribution of the grain aphid, *Sitobion avenae* (Fabricius), and the rose-grain aphid, *Metopolophium dirhodum* (Walker) and their natural enemies and concluded that *Pterostichus*

melanarius, a carabid, did alter the rate of increase in these two aphids' populations. In fields where aphid densities were experimentally changed these carabids, *Agonum dorsale* (Pontoppidan), *Amara plebeja* (Gyllenhal), *Bembidion lampros* (Herbst), and *Bembidion obtusum* Serville demonstrated aggregation behavior toward these areas of high aphid density (Bryan and Wratten 1984). Other carabid prey items, such as Collembola, aggregate within fields and collembolan-feeding carabids have been shown to respond to these high density prey patches (Niemelä et al. 1986, Kielty et al. 1996, Alvarez et al. 1997, Holland et al. 1999, Bilde et al. 2000).

Carabid Defenses

Defenses displayed by carabids include regurgitation of foregut contents and stridulation (Forsythe 1980, Forsythe 1982) . Along with rapid running or quick flights, adult carabids use specialized paired pygidial glands to dispense defensive chemical liquids. The structure of these pygidial glands have been reviewed by Forsythe (1982). Moore and Wallbank (1968), Schildknecht et al. (1968), and Kanehisa and Murase (1977) have all studied the chemicals (acids, *m*-cresol, aldehydes, and benzoquinones) produced by these tissues. The classic example of this defensive mechanism is observed among *Brachinus* species, commonly known as the Bombardier beetles (Wautier 1971, Dettner 1987). When disturbed, *Calosoma* species secrete an acidic chemical that may have similar defensive functions. Some data indicate these chemicals may also act as sex pheromones or aggregative pheromones (Wautier 1971, Luff 1986).

Dispersal of Adult Carabids

In agricultural landscapes, carabids move between cropping systems or between non-cultivated habitats and cropping systems. These beetles may be motivated to disperse

by physiological stimuli, changes in abiotic factors, or farming practices such as tillage. The two primary means of dispersal utilized by carabids are flight and walking/running and the characteristic dispersal approach of a particular species is linked primarily to wing morphology.

Carabid morphology reveals flight-wing polymorphisms: macropterous, brachypterous, and dimorphic within and among populations (den Boer 1971, Harrison 1980, Liebherr 1988, Matalin 2003). Macropterous is defined as individuals with fully formed wings and brachypterous is an individual which is apterous or only has vestigial wings present throughout adult life. Dimorphic or polymorphic conditions can exist in individuals of one species or within a single population of individuals with fully developed wings existing alongside other individuals without wings or with vestigial wings (den Boer 1971, Thiele 1977, Harrison 1980, Liebherr 1988, Matalin 2003). Den Boer (1971) considered the fully winged state to be the primal condition and that winglessness developed later. Using lightships located between six and 30 km from a near-by coast, Heydemann (1967) demonstrated that some carabid species could fly long distances (e.g. *Trechus quadristriatus* (Schrank) and *Bradycellus collaris* (Paykull)). After collecting carabids in window traps, den Boer (1977) found 26 out of the 74 species caught, in natural and temporary habitats in Wijster, province of Drenthe, showed some flight activity. Seventeen out of the 26 were considered macropterous with at least some dispersal power and nine were dimorphic. After wing-surface relative to elytra surface measurements were taken it was found that six macropterous species had wings smaller than necessary to fly. These findings along with similar results from Lindroth (1945) suggest these six species had dispersal power that could be equated to dimorphic species

with limited number of winged individuals. Studying within the heath of Kralo in the Netherlands, den Boer (1971) used pitfall traps and window traps to examine dispersal powers of carabids from wooded areas into the heath. He found that flight seemed more adaptive for species of temporary habitats such as riparian areas, agricultural associated species, and temporary subpopulations.

Although flight capabilities may be limited or non-existent for some species, all carabids have legs and tarsi highly adapted for walking and running. The fixed coxa, which completely divides the first abdominal segment, is a morphologic diagnostic feature that places carabids in the suborder Adephaga. Carabid leg morphology is highly adapted for rapid running, digging, and burrowing (Erwin 1979, Sharova 1981, Evans 1982). These beetles have long legs and 5-5-5 segmented tarsi for rapid running. Thiele (1977) recorded the running speeds of 14 species from various habitats in controlled experiments. The results ranged from 3.9cm/s for *Molops piceus* (Paykull) (a forest species) to 10.6 cm/s for *Pterostichus cupreus* (L.) (an open field species). Thiele (1977) found that daily walking distances for marked and released carabids could vary from less than a meter to tens of meters. Kinnunen and Tiainen (1999) suggested that carabids could disperse several hundred meters to kilometers in a lifetime by walking/running. Wallin and Ekbom (1988) observed *Pterostichus niger* (Schaller) walking at up to 20 m h^{-1} in a cereal field. Wallin and Ekbom (1988) felt their data supported the idea that carabid dispersal was predominantly by walking/running on the ground.

Whether carabids walk and/or fly, depending on the time of year they regularly move into or out of agricultural fields in order to utilize these ephemeral habitats and their resources for completion of all or some of their life stages. Quantifying colonization

rates and dispersal capabilities among carabids with differing wing conditions will not only help to elucidate individual species' ability to enter a cropping system from refuge habitats but also further describe their biology in diverse agricultural landscapes.

Carabids and Agricultural Soil

Soil structure is determined by sand, silt, and clay particles forming aggregates of various sizes and shapes. Organic matter such as roots, fungi, and bacteria produce sticky glue-like substances that contribute to the formation of aggregates (Anonymous 2008). Pores are formed within and between aggregates which affect the movement of water and air throughout soil. Micropores are small pores (< 0.08mm) within the aggregates and macropores are large pores (> 0.08mm) between aggregates where water and air move easily (Anonymous 2008). Macropores are utilized by surface and sub-surface organisms and plants. The general factors affecting the size, shape and stability of aggregates are crop rotation and farming practices (Carter 2004). Properly functioning soil structure maintains biological productivity and ensures the continual movement of water, air, and nutrients through soil subsurface layers. Poor soil structure results in erosion, soil and nutrient loss, compaction, and/or surface crusting. In continuously tilled soils a plough pan develops at the lowest limits of the cultivation depths resulting in a reduction of water flow through the soil; this compacted plough pan increases flooding and standing surface water in fields (Pagliai et al. 2004, Roger-Estrade et al. 2004). Roger-Estrade et al. (2004) attribute structural changes in agricultural soils to three main factors: tillage operations, soil compaction from traffic, and natural processes such as weather.

Carabid habitat selection and survival is affected by the stability of factors such as soil temperature, humidity, pH, soil type, substrate structure, and soil moisture retention

(Baker and Dunning 1975, Thiele 1977, Gruttke and Weigmann 1990, Holland et al. 2007). Carabids utilize stable soils particularly cracks and pores to escape predation, extreme weather conditions, and as refuge from pesticide applications. Additionally, stable microhabitats sustain large quantities of prey at the soil surface and underground affording carabids greater foraging opportunities. Holopainen et al. (1995) listed soil factors important to carabids in order of significance: soil clay content, soil type, soil water content, soil organic content, and soil pH, but evidence suggests that soil moisture has the greatest influence on carabid microhabitat selection (Holopainen 1995, Sanderson et al. 1995, Luff 1996). Carabids that inhabit arable lands are more susceptible to water loss and are dependent on microhabitats for added protection from desiccation. The threat to carabids is similar in many agricultural systems, as mechanical cultivation inverts the soil thereby exposing subsurface layers to sudden destabilization and destroying microhabitats.

Soil cultivation can be considered a catastrophic event threatening the survival of all carabid life stages (Kendall 2003, Titi 2003). Studies have shown that the intensity and timing of tillage can negatively impact carabid development and their populations (Thiele 1977, House and All 1981, Luff 1987, Stinner and House 1990, Kromp 1999, Holland and Luff 2000, Landis et al. 2000, Menalled et al. 2007). Several reviews on farming practices have described a reduction in abundance and diversity of carabid assemblages due to deep tillage compared to shallow cultivation (Dubrovskaya 1970, Thiele 1977, House and All 1981, Luff 1987, Stinner and House 1990, Kromp 1999, Holland and Luff 2000). Conventional soil cultivation has been shown to reduce the abundance and activity of epigeal arthropod predators as much as 80% for the first few

weeks or months after tilling and planting (Kendall 2003). However, which carabid life stage is most at risk remains unclear.

Tillage Practices

Traditional conventional tillage (CT) starts with a moldboard plough which cuts into the soil to a depth of 20 – 25cm and then inverts the soil leaving virtually bare soil exposed (Kromp 1999). This inversion buries crop residues, creates clods, and provides some weed control. Next, disking integrates fertilizers into the soil in conjunction with breaking up clods in preparation for planting. Other objectives of CT are to change soil conditions such as aggregate size and distribution for better seed germination, increased water and air flow, and increased water storage capability (Carter 2004). Mechanical soil inversion can also destabilize the physical structure, chemical, and biological properties of the soil dramatically (Kladivko 2001). Pagliai et al.(2004) found that CT caused more damage to soil structure than with minimum tillage or ripper subsoiling. They concluded that CT reduced water flow, decreased porosity, created surface crusting, and produced a ploughpan. Studies have shown that deep tillage impacts the composition of carabid assemblages within the area of disturbance along with reducing carabid abundance and diversity (Thiele 1977, House and All 1981, Luff 1987, Stinner and House 1990, Kromp 1999, Holland and Luff 2000). These conclusions were supported by Stassart and Grégoire-Wibo (1983) analysis of pitfall data over several years in Belgium where they determined the depth of tillage was a major factor affecting field carabids; genera like *Harpalus* and *Pterostichus* were found at depths of 45cm. Fadl et al. (1996) found that when *Pterostichus melanarius* late larval or pupal instars were present at spring cultivation (compared with fall cultivation), adult emergence was reduced up to 80%.

Other studies have demonstrated similar impacts on carabid species following spring cultivation (Hance and Gregoire-Wibo 1987, Hance et al. 1990, Purvis and Fadl 2002).

No-till (NT) is the practice of not manipulating soil prior to planting. This maintains the soil structure and leaves the vegetation residue on the soil surface. Planting is accomplished by drilling the seeds into the soil through the previous crop residue. This process reduces soil erosion, preserves soil nutrients, and maintains microhabitat stability. Studies have shown that NT crops have a greater diversity of plants and minimal disturbance to predators (Luff 1987). Carabid abundance has been demonstrated to increase in NT systems, particularly systems studied in European NT crops and American NT soybeans (House and All 1981, Stassart and Gregoire-Wibo 1983, Ferguson and McPherson 1985). No-till can decrease the risks of injury or death to carabids from mechanical soil inversion and reduce or eliminate sudden changes in soil structure and physiochemical environment (Blumberg and Crossley 1988, Weiss et al. 1990). In addition, crop residue and litter assist in moderating extreme soil temperatures and stabilize moisture levels thus providing a more stable environment for early developmental stages (Cochran et al. 1994).

Carabids frequently show aggregation patterns of high and low densities based on vegetation canopy, structure, and density (Speight and Lawton 1976, Hengeveld 1979b, Cárcamo and Spence 1994, Holopainen et al. 1995, Thomas et al. 1998, Holland et al. 1999). Carabids have been found in higher numbers in weedy crops. For example, no-till fields encourage weeds thereby increasing organic material on the soil surface altering microclimates (Speight and Lawton 1976, Purvis and Curry 1984, Powell et al. 1985, Kromp 1989, Pavuk et al. 1997). The amount of crop canopy present over time may

influence changes in carabid assemblages by retaining more moisture as the canopy closes. All of these environmental factors alter resource and habitat availability to all carabid life stages and ultimately leads to discrete distributional patterns within and among fields (Holland and Luff 2000, Thomas et al. 2002).

Importance of Carabidae in Agroecosystems

Monoculture crops dominate farming practices in the prairies of North America and monoculture systems can lead to an increase in pest pressures (Elliott et al. 1998, Ahern and Brewer 2002, Brewer and Elliott 2004, Men et al. 2004, Ribas et al. 2005). These homogeneous habitats increase the isolation and fragmentation of suitable habitats for natural enemies. Predators are generally thought to be more vulnerable to fragmentation of habitat than prey species (Kruess and Tscharntke 1994, Abensperg-Traun and Smith 1999, Kruess and Tscharntke 2000). This vulnerability can be expressed as a breakdown in food chains and loss of trophic structure within ecosystems (Hunter 2002). Additionally, habitat degradation and limited resources within these monocultures can diminish the ability of natural enemies such as carabids to decrease pest populations leading to a loss of crop and forage yields (Lys 1994).

In monocultures, producers use insecticides to address some pest problems; however, use of these products can cause a breakdown in the life cycle of natural enemies. This breakdown can lead to cycles of pest resurgence episodes that require additional insecticide applications, which increases input costs and can cause greater risk of insecticide resistance in pests. In the Central Plains of the US, some producers are diversifying their agricultural systems in an effort to reduce the negative effects associated with monocultures (Brewer and Elliott 2004, Keenan et al. 2005, Giles et al.

2008). The concept that diversification of agroecosystems increases and maintains natural enemy assemblages, which in turn increases the efficiency of these biological control agents is supported by growing data (Parajulee and Slosser 1999, Guerena and Sullivan 2003, Brewer and Elliott 2004). Carabids constitute a major part of the fauna and an important part of the natural enemy assemblages in agroecosystems (Fox and MacLellan 1956, Whitcomb and Bell 1964, Rivard 1965, 1966, Frank 1971, Kirk 1971, Esau and Peters 1975). Carabid richness has been positively correlated to small-scale landscape heterogeneity (Weibull et al. 2003). More complex habitats may supply carabids with the necessary resources to maintain higher populations allowing colonization of crops before pest species reach economic damage levels (Hunter 2002). This diversity provides increased richness, which increases the abundance and persistence of carabids which consume agricultural pests. Additionally, carabids are an important consumer of weed seeds due to their polyphagous nature (Forbes 1883, Lund and Turpin 1977, Thiele 1977). Genera like *Amara* and *Harpalus* have species that selectively consume weed seeds once they fall from the parent plant to the ground (Kirk 1973). This consumption of seeds can have a major influence on seed survival and therefore on plant community composition (Tooley and Brust 2002). In agroecosystems, carabids and rodents are considered the two major weed seed predators (Brust and House 1988, Marino et al. 1997, Westerman et al. 2003). Because carabids react to environmental changes quickly and measurably they may also be useful as bioindicators as well as biological control agents in agricultural systems (Thiele 1977, Norris and Kogan 2000, Fournier and Loreau 2002, Holland et al. 2005).

Use of Stable Isotopes to Elucidate Carabid Dispersal

It has been noted that carabids are important natural enemies and weed seed feeders in agricultural systems, however, little is known about dispersal powers between crops within these systems. Although many techniques are available, the use of stable carbon isotopes offers a unique quantitative approach to describing the carabid dispersal and prey consumption in diverse habitats (Teeri and Schoeller 1979, Boutton et al. 1983, Peterson and Fry 1987, Wada et al. 1987, Harrigan et al. 1989, Ostrom and Fry 1993). By determining the differences in isotope ratios between predators, prey, and host plants within agroecosystems the dispersal of carabids can be traced among habitats (Ostrom et al. 1997, Hobson et al. 1999). In diverse habitats, isotope ratio data can define the habitat type larvae and adult utilize for feeding grounds, breeding habitats, over-wintering refuge, and non-cultivated refuge. By understanding the environmental requirements of carabids, their conservation in diversified agricultural habitats may be enhanced.

Elements exist in nature as one or more isotopes. Isotopes are defined as atoms of the same element which have the same number of protons and electrons but different numbers of neutrons. These isotopes will have the same charge but different masses. It is this difference in mass that can be exploited for scientific study and since their discovery in the 1920's, ecological and biological studies have been using isotopic compositions at an increasing rate.

Fractionation is the term applied to isotopic variance and defined as the enrichment or depletion of a heavy isotope relative to a light (low mass) isotope (Broecker and Oversley 1976, Tieszen et al. 1983). Fractionation is the proportional difference between the isotopes' masses and these proportional differences represent very

small changes in the physical and chemical properties of each isotope within biological tissues (Parks and Epstein 1960, Broecker and Oversley 1976, Ehleringer and Rundel 1989). Enzymatic discrimination within tissues is defined as the utilization of one isotope at the exclusion of another isotope or the preferential use of one isotope before using another available isotope (Ehleringer and Rundel 1989). Isotopic composition absolute values can be measured accurately within a sample over the short-term; however, reliability over the long term is questionable (Hayes 1983). To provide high accuracy and repeatability over time, differences between a standard and sample must be measured (McKinney et al. 1950, Ehleringer and Rundel 1989). Differential analysis has been a standard procedure in isotope compositions since its introduction (McKinney et al. 1950). The reference material for carbon was the carbon found in the PeeDee limestone (belemnite, PDB); however, this material is now depleted. The current standard for carbon is the equivalent Vienna PeeDee Belemnite (VPDB) standard (Clark and Fritz 1997, Kendall and Caldwell 1998). Use of VPDB indicates the standard has been calibrated to 0‰ according to the International Atomic Energy Agency (IAEA) guidelines (Coplen 1996). Expression of isotopic composition uses differential notation, in other words, terms of δ values (parts per thousand differences from a standard):

$$\delta X_{std} = [(R_{sample}/R_{standard}) - 1] \times 10^3, \qquad (2.1)$$

where X is ^{13}C, the isotope ratio reported in delta units relative to a standard; $R_{sample}/R_{standard}$ is the absolute isotope ratios of the sample and standard, $^{13}C/^{12}C$ (Peterson

and Fry 1987, Ehleringer and Rundel 1989, Hobson et al. 1994). Multiplying by 1000 (‰) expresses values as "parts per thousand" or "per mil" allowing very small differences between samples to be examined more clearly (Peterson and Fry 1987, Ehleringer and Rundel 1989).

Carabid dispersal can be traced among habitats using isotope ratios because of fundamental biological processes. Plants convert sunlight, water, and carbon dioxide to organic materials thereby storing sunlight as usable energy within plant tissues. Plants use two distinct pathways to accomplish this energy conversion. One photosynthetic pathway used by plants (e.g. alfalfa) produces three-carbon molecules and is called the Calvin cycle (C_3) (Calvin 1962). Other plants (e.g. sorghum) use the alternative Hack-Slack pathway (C_4) which produces four-carbon molecules (Hatch and Slack 1966). C_3 and C_4 plants have distinctly different carbon isotope ratios that provide a predictive relationship with $\delta^{13}C$ values as ^{13}C depletion continues (Bender 1968). In C_3 plants, the accumulated levels of ^{12}C are higher than ^{13}C (-20 to -35‰) compared to atmospheric CO_2 (ca. -7.7‰). C_4 plants have measurably higher ^{13}C levels (-9 to -18‰) compared to C_3 plants. Alfalfa (C_3) and sorghum (C_4) have specific aphid species that only feed on these particular plants. Based on this relationship, carabid consumption and utilization of these aphids can be determined using stable carbon isotope ratios within the carabid tissues. This transfer of isotope ratios would be found in any prey item that had been feeding on C_3 or C_4 plants.

Animal tissues that reflect a predictable carbon isotope enrichment or depletion rate when compared to dietary intake are used to reconstruct diet histories. Evidence of migration between isotopically discrete food webs can be retained in animal tissues for a

period of time depending on elemental turnover rates. Stable isotopes are fractionated (enrichment or depletion) through the enzymatic transformation and assimilation of food within animal tissues. DeNiro and Epstein (1978) used mice to demonstrate that $\delta^{13}C$ values were similar in whole-animal vs. bulk dietary intake; however, they found that $\delta^{13}C$ values in tissues differed in a sequential pattern. Tieszen et al. (1983) verified these results using gerbils by demonstrating that by switching the diet from corn (C_4) to wheat (C_3) carbon replacement in gerbil tissues was dependent on tissue type (e.g. liver half-life = 6.4 days vs. muscle half-life = 27.6 days). These rates are dependent on fast or slow turnover of isotopic compositions. Carabid flight muscles and soft organs are metabolically active and can reflect recent dietary turnover of carbon isotopes in a short period of time. In contrast, carabid elytra, wings, and pronotal exoskeleton are basically metabolically inactive. Therefore, these tissues retain carbon isotope compositions from the beetles past dietary intake. These inactive components retain larval compositions indicating natal origins (DeNiro and Epstein 1978, Hobson et al. 1999, Gratton and Forbes 2006, Hood-Nowotny et al. 2006).

Examination of carabid movement or dispersal based on carbon isotope ratios can only be done within systems with distinct ^{13}C sources (Prasifka and Heinz 2004). Herbivores and plant parts (seeds) will exhibit isotopic signatures of the crop type (C_3 or C_4) they are consuming. Consequently, carabids will reflect the isotopic signatures of aphids and plant materials that make up a large portion of their diet. Boutton et al. (1983) demonstrated termite preferences for C_4 or C_3 plants at two locations in the grasslands of East Africa . This work demonstrated that within colonies termites focused on one vegetation type while between locations vegetation utilized varied.

CHAPTER III

METHODS AND MATERIALS

Experimental Design and Carabid Sampling

This study was conducted at the South Central Research Station (SCRS) in Chickasha, Oklahoma over two growing seasons (2006-2007). General landscape influences consist of riparian habitat of the Washita River and the urban area of Chickasha (Fig. 1). There were three replications labeled Blocks A, B, and C. Each field consisted of one mature (>3 years in production) alfalfa field (167.64m x 182.88m) and five plots of sorghum (each 15.24m x 45.72m) representing different sorghum production/tillage treatments (Fig. 2). These blocks were isolated from other on-farm activity by unused land, roadways, and/or regular mechanical tillage. No-till (no soil preparation, Fig. 3) and Conventional tillage (CT) plots were planted by a two-row crop planter pulled with a Massey Ferguson 245 tractor after soil preparation in CT. All seed was planted into good soil moisture at a rate of 1.36kg to 1.81kg per 0.04 hectare with 76.2cm row spacing. Conventional tillage consisted of deep plowing and disking in preparation for year 1 of the study (Fig.4). The spring sorghum tillage treatments were: Plot NT1) No-till throughout the study; Plot CT2) CT throughout the study; Plot CT3) CT

throughout the study; Plot CT4) CT to the northern half throughout the study and when sorghum was harvested from the first season, the southern half (15.24m x 22.86m) remained fallow for the rest of the study; Plot CT5) CT the first year and no-till in second year (Fig. 5). Following the first year of sorghum production, winter tillage treatments (from October to April) were: Plot NT1) No tilling; Plot CT2) Soil was prepared for spring planting by CT; Plot CT3) The soil was prepared for planting by CT throughout the strip but only the southern half (15.24m x 22.86m) was planted into winter wheat and the northern half remained unplanted; Plot CT4) The northern half was prepared for spring planting by CT and then left to over-winter as is and the southern half remained fallow; Plot NT5) (previously CT5) No tillage occurred and sorghum debris remained on the soil surface (Fig. 3).

Sorghum production/tillage plots were surrounded by open tracks (7.62m on each side) on the east, west and south sides. Open tracks were maintained by periodic undercutting (disking) to a depth of approximately 10.2cm. The north end of all sorghum plots interfaced with the alfalfa allowing carabid movement between crops (Fig. 6). Silt fencing was installed in the open tracks at a distance of 7.62m from each sorghum plot in an effort to limit migration among plots (Lee et al. 2001). Fencing was buried 15.2cm underground and extended 45.72cm above soil line (Fig. 7). All plots were managed under recommended farming practices for Oklahoma; however, insecticides were not used. Seed cultivar remained consistent throughout the study: alfalfa ‘OK49’, winter wheat ‘OK101’ (15.24m x 22.86m winter treatment in Plot 3 of each plot), and sorghum

'SG/Garrison 828'. During the spring and summer, alfalfa was cut, dried and baled approximately every 28 days depending on field conditions and weather, but left to over-winter without further treatments from October through April. No insecticides were applied to the alfalfa fields.

Pitfall Traps and Activity-Density

Carabids were sampled by standard pitfall trapping methods in experimental plots over a two year period (Luff 1996). Pitfall traps are regularly utilized to capture carabid beetles and other ground-dwelling arthropods (Spence and Niemelä 1994). Pitfall traps measure a species' population density as well as relative activity (Thiele 1977). The vegetation structure and composition within a habitat can enhance or impede carabid movement and impacts their likelihood of coming in contact with a pitfall trap. Because of these limitations, relative activity and population density are combined for a measure of carabid activity-density (A-D) due to the influence of habitat characteristics on trap catches (Thiele 1977).

Traps were constructed from a 946.4ml plastic cup buried in soil so that the lip was at ground level, a five ounce plastic cup containing one ounce of 50/50 mix of low-toxic antifreeze (propylene glycol based formula) and water, and a plastic funnel-shaped cup with the bottom removed placed inside the rim of a larger cup over the killing fluid (Fig. 8). Traps were closed by using a plastic 946.4ml cup filled with dirt in place of the funnel cup which completely filled the cup in the ground keeping any insects from entering the trap. Each trap "unit" consisted of a metal guide (15.2cm x 121.9cm) with a trap placed at both ends

(Fig. 9). Samples from each trap within a unit were pooled into a labeled 50 ml polypropylene tube in the field and returned to the laboratory for processing.

In alfalfa, two trap units were placed along the west and east outer boundaries along with one unit approximately 36.6m from the crop interface along the northern boundary. Trap units were also placed in sorghum plots at 1.52m and 4.57m from the alfalfa/sorghum interface. Additional units were then placed every 9.14m for the entire length of the plot for a total of 10 trap units per plot (Fig. 10). All traps were to be opened immediately after the sorghum planting; however, in 2006, there was a delay of seven days between planting sorghum and opening pitfall traps due to installation problems. In 2007, trap installation only required two days; however, it rained on the third day after planting so traps were opened on the fourth day after planting.

Once traps were opened, sampling took place every 24 hours for the first 15 days. During sampling events, all insects were removed from each trap and processed as previously described, and traps were "recharged" with antifreeze and water as needed. Collecting continued every 48 hours on days 16-30, and after 30 days traps were closed for 72 hours and then opened for 96 hours. This procedure of 72 hours closed and 96 hours open trapping continued each week until sorghum harvest. Following harvest, trapping took place in all plots from October through April using one 96 hour sampling period per month. During these months sampling time was determined by weather conditions.

Samples were washed with water and placed in lysis buffer for long-term storage in the laboratory. Carabids were identified to species and a voucher collection was placed in the K. C. Emerson Entomology Museum at Oklahoma State University, Stillwater, Oklahoma (Lindroth 1961-1969, Freitag 1969, Gidaspow 1995, Freitag 1999, Ball and Bousquet 2001, Noonan 2001).

Colonization and Tillage

Temporal colonization of an annual crop (sorghum) by carabids from a semi-permanent agricultural refuge (alfalfa) was measured each year during the first seven sampling dates of pitfall trapping. All genera trapped were included in this study. Samples were collected every 24-hours as previously described. All beetles were identified to genus and by wing morphology (Macropterous, MA; Brachypterous, BR; Dimorphic, DI).

The impact of tillage on the activity-density (A-D) and habitat selection of eight predatory carabid genera, *Calosoma*, *Cicindela*, *Cratacanthus*, *Cyclotrachelus*, *Pasimachus, Poecilus*, *Scarites*, and *Tetracha* was measured from June through September in 2006 and May through September in 2007. All eight of these genera are predators in agroecosystems of the Southern Great Plains and because of their pest suppression behavior represent an important sub-sample of the total number of beetles trapped in each season. In Block B, the NT1 plot was tilled up in the spring of 2007 during farming operations so plot data from this treatment area was excluded from further tillage treatment analysis.

Stable Carbon Isotope Field Study

Utilized alfalfa (C_3) and sorghum (C_4) as isotopically discrete habitats and their prey beetle movement was reconstructed such that beetles with distinctly different SCIRs from the local habitat were considered recent arrivals or residents of a habitat if their SCIRs were similar to that habitat (Prasifka and Heinz 2004). The isotope evaluation focused on eight common cropland genera of carabids: *Calosoma*, *Cicindela*, *Cratacanthus*, *Cyclotrachelus*, *Pasimachus*, *Poecilus*, *Scarites*, and *Tetracha* which were collected within experimental plots as previously described and used for isotope investigation. Beetles selected for analysis were from a sub-set of traps numbered three, five, six or seven in Plot NT1 or trap numbers ending in three, five, six or seven in treatment plots CT3, CT4, CT/NT5. Samples from all five traps in the accompanying alfalfa fields were utilized in this study. One individual from each genera found in a sample was selected for dissection and isotope processing. These selected carabid beetles were dissected into two sub-samples to distinguish past dietary intake (P = elytra, wings, and pronotal exoskeleton) and recent dietary intake (R = flight muscles, reproductive tissues and soft organs) (Fig. 11). Contents of the gut track can confound the isotope results due to presence of undigested food and were excluded from analysis. Each sub-sample was placed into a microcentrifuge tube and dried in a mechanical convection oven at 40 ˚C for a minimum of one week. All labeled beetle samples were shipped for isotope processing to the University of Arkansas Stable Isotope Facility, Fayetteville, Arkansas.

During 2006 and 2007, aphid sampling occurred throughout all plant types. Four species of aphids that feed on alfalfa include the spotted alfalfa aphid, *Therioaphis trifolii* (Bockton), pea aphid, *Acyrthosiphon pisum* (Harris), blue alfalfa aphid, *Acyrthosiphon kondoi* Shinji, and the cowpea aphid, *Aphis craccivora* Koch. The two most abundant aphids found in alfalfa during the present study were pea and cowpea aphids (known collectively as alfalfa aphids in this dissertation). The corn leaf aphid, *Rhopalosiphum maidis* (Fitch), was abundant on sorghum throughout the study and was collected in sorghum during summer plant growth. In each crop, aphids were collected by hand in the fall of 2006, spring and fall of 2007, and in the summer and fall of 2008, identified to species, and combined by species and location into labeled glass vials by species and location for each sample date to provide sufficient material for processing. Aphid samples were placed in a mechanical convection oven to dry at 40 ˚C for a minimum of one week then 1.5 mg of material was transferred to a microcentrifuge tube and sent for isotope processing.

Two plant samples were also taken from each treatment plot of sorghum and five from each alfalfa field once in the spring and fall of 2006 and 2007. Each alfalfa plant collected was cut at the soil surface, placed inside a labeled plastic bag for transport and stored in a freezer until processed. Sorghum plants were collected from each sorghum plot and placed in a labeled plastic bag for transport and freezer storage. Plant samples were dried in a mechanical convection oven set at 65 to 70 ˚C for a minimum of 48 hours and preliminarily ground by hand. Sample material was initially ground by hand. Approximately 4.5 mg of this

roughly ground material and a 6 mm glass bead were placed in a 2.0 ml Screw Cap Microtube (Quality Scientific Plastics) and ground for 180 seconds using a Mini-Beadbeater 3110BX resulting in a fine powder suitable for stable carbon isotope processing. All labeled aphid and plant samples were sent to the University of Arkansas Stable Isotope Facility, Fayetteville, Arkansas to be processed for stable carbon isotope ratios.

Diet Switching and Natal Origins

Diet switching and natal origins were documented for eight common cropland genera of carabids: *Calosoma, Cicindela, Cratacanthus*, *Cyclotrachelus*, *Pasimachus, Poecilus, Scarites,* and *Tetracha* all collected in 2006 and 2007 from experimental plots previously described and used for additional isotope investigation. Isotope ratios from the data set utilized in the field isotope study were further analyzed to document diet switching and natal origins.

Beetle diet switching between alfalfa and sorghum was determined such that beetles with distinctly different SCIRs from the local habitat were considered recent arrivals or residents of a habitat if their SCIRs were similar to that habitat (Prasifka and Heinz 2004). Placement in the mixed category resulted from SCIRs indicating the possible mixing of C_3 and C_4 food sources or tissues were shifting from the isotope composition of the old diet to the new diet in an isotopically different habitat (Podlesak et al. 2005, Gratton and Forbes 2006).

Baseline Feeding Study to Estimate Isotopic Turnover Rates in Tissues

Baseline stable carbon isotope ratios were to be established for selected carabid genera from each crop type and common aphid species. Baseline ratios estimated under controlled conditions would allow comparisons between the field-caught carabids and lab-fed carabids. These data can be used to estimate the rate of isotopic turnover within the sub-sample tissues of each beetle.

To ensure comparability, soil was collected in 18.927L buckets from each sorghum strip and each alfalfa field in Blocks A, B, and C and returned to the laboratory. Six labeled 6-inch pots were filled with soil previously collected from individual sorghum treatment plots and alfalfa fields. On the soil surface of each pot, three parallel 1cm wide furrows were cut using the tip of a metal chemical scoop at the correct depth for each seed type. Twenty-five 'OK49' alfalfa seeds were planted five mm below the alfalfa soil surface and 12-15 'SG/Garrison-82' sorghum seeds were planted one cm below the soil surface in corresponding pots. Furrows were back filled and the pots were placed in a growing room located at the Noble Research Center (NRC), Oklahoma State University in Stillwater, Oklahoma. This growth room was maintained at 23-26 ˚C, a light/dark cycle of 12L/12D, and relative humidity of 40%. Plants were watered as needed. At approximately 4.57 – 50.8cm in height, sorghum plants were moved to aphid colony environmental chambers in the NRC. New seeds were planted every 30-60 days to maintain a continuous supply of plant material for aphid colonies.

In a separate growth room fine mesh double-walled cages were used to house aphid colonies. The following plant and aphid communities were

maintained: 1) sorghum and corn leaf aphids, 2) alfalfa and cowpea aphids, and 3) alfalfa and pea aphids. This growth room was operated at 23-26 ˚C and a light/dark cycle of 12L/12D. Aphids were collected from the field when possible or from existing colonies located at the NRC.

The following carabid genera *Cicindela*, *Cratacanthus*, *Poecilus*, and *Scarites* were live-trapped on the edges of the Oklahoma State University Agronomy Research Station in Stillwater, Oklahoma. These four genera are attracted to lights so it made it possible to trap several individuals simultaneously. Standard florescent lights and mercury vapor lights were used to attract the carabids. *Calosoma* beetles were caught by hand in alfalfa field located near Bison and Hennessey, Oklahoma.

Individual beetles were housed in a paper food cups (9cm diameter and 4.5cm deep) with a fine-mesh screen covered lids. One 90mm filter paper was torn into quarters and all four pieces were placed in each cup with the beetle to provide hiding spaces. This procedure reduced stress in carabids which exhibit thigmotrophic behaviors; burrowing or hiding in soil cracks. A cotton ball soaked with water was placed in each cup daily. All replicates were maintained in the growth room at 23 – 26 ˚C, a light/dark cycle of 12L/12D hours, and 40% relative humidity.

All beetles were starved for seven days and then fed *ad libitum* aphids from designated laboratory colonies during the study. One carabid was frozen after the seven day starvation period at zero hours for each species replicate. Corn

leaf and cowpea aphids were fed to carabids at consumption periods of 1, 2, 3, 4, 5, 6, and 7 days. A set of eight beetles of each species (n = 5 species), for a total of 40 beetles, were required for one replication with corn leaf aphids. Another set of eight beetles of each species (n = 5 species), for a total of 40 beetles, were needed for one replication with cowpea aphids. Corn leaf and pea aphids were fed to the carabids at consumption periods of 1, 2, 3, 4, 5, 6, 7, and 8 days. This trial required nine beetles of each species (n = 5 species), a total of 45 beetles, presenting one replicate with corn leaf aphids and the same number, 45, was required for one replicate with pea aphids. Beetles from each 24-hour period were frozen and then later thawed for dissection into sub-samples for isotope testing.

Colonization Data Analysis

Trap catches for the first seven 24-hour sample days during the start of each growing season provided data for research on colonization by carabids. During the colonization study, traps were checked at 24-hour intervals with all catches identified to genus. Multiple ANOVAs were used to evaluate the effect of carabid wing morphology and distances within the plots over the seven day colonization period for each year. Distances were measured from the crop interface with traps set a 0m, 1.52m, 4.57m, 9.14m, 18.3m, 27.43m, 36.6m, and 45.72m. In addition, counts of specific genera captured were compared between years, between distances and across days using t-tests or ANOVA combined with Tukey's post hoc analysis.

Tillage Data Analysis

Statistical tests and resulting conclusions are based upon carabid counts by plot for each sample day. Using per plot count data allows for distinguishing the plots as treatments during statistical analysis. Count data was obtained from trap catches for the 2006 and 2007 growing seasons. The 2006 trapping period provided 24 sampling days for three replications (Blocks A, B, C) with one no-till plot (NT1), four conventional-till plots (CT2 through CT5), and one alfalfa plot per replication. Thus, with plots as the experimental unit and sample day catches as observations for the plots, the 2006 statistical analysis was performed using 72 observations of carabid counts for the no-till and alfalfa treatments each while conventional-till had 288 observations. The 2007 trapping period had 23 sample days for Blocks A, B, and C. Each block contained one alfalfa field, two CT plots (CT2 and CT3), two NT plots (NT1, NT5) and one split-plot (CT4 and Fallow). Excluding the split-plot which was analyzed separately, the 2007 statistical analysis included 69 alfalfa observations, 138 CT observations and 115 NT observations.

Counts were adjusted proportionally to correct for uneven sampling effort within treatment plots across the growing season. Habitat selection by the eight selected carabid genera was examined between years, blocks, and treatment plots over the entire growing seasons using one-way ANOVA's combined with Tukey's post-hoc comparisons. T-tests were utilized to evaluate differences between treatment plots NT1 2006 and NT1 2007, NT1 and NT5 in 2007 and for differences among CT4 North and Fallow 4South. Pearson's correlation

coefficients were used to examine the linear relationship between beetle counts and weather variables in 2006 and 2007. All colonization and tillage statistical analyses were completed in IBM SPSS Statistics 19 (IBM Corporation 1994-2011).

Stable Carbon Isotope Data Analysis

Fractionation is the proportional difference between the isotopes' masses. These proportional differences represent very small changes in the physical and chemical properties of each isotope within tissues (Parks and Epstein 1960, Broecker and Oversley 1976, Ehleringer and Rundel 1989). Enzymatic discrimination within tissues is the utilization of one isotope and not the other or the use of one isotope before another isotope (Ehleringer and Rundel 1989). Mass spectrometry is used to measure isotopic differences relative to an international standard and expressed in differential notation:

$$\delta X_{std} = [(R_{sample}/R_{standard}) - 1] \times 10^3, \quad (2.1)$$

where X is ^{13}C, the isotope ratio reported in delta units relative to a standard; $R_{sample}/R_{standard}$ is the absolute isotope ratios of the sample and standard, $^{13}C/^{12}C$ (Peterson and Fry 1987, Ehleringer and Rundel 1989, Hobson et al. 1994). Multiplying by 1,000 (‰) expresses values as "parts per thousand" or "per mil" allowing very small differences between samples to be examined more clearly (Peterson and Fry 1987, Ehleringer and Rundel 1989). An isotope ratio change between a consumer and its diet is denoted by Δ. The reference material for

carbon was the carbon found in the PeeDee limestone (belemnite, PDB); however, this material is now depleted. The current standard for carbon is the equivalent Vienna PeeDee Belemnite (VPDB) standard (Clark and Fritz 1997, Kendall and Caldwell 1998). Use of VPDB indicates the standard has been calibrated to 0‰ according to the International Atomic Energy Agency (IAEA) guidelines (Coplen 1996, International Atomic Energy Agency 2003-2004). Isotope ratios are either negative or positive when compared to this standard 0‰ calibration. The natural abundance range for most natural isotopes is +50 to -100‰. Stable isotope analysis routinely utilizes an autosampler connected to an Elemental Analyzer (precision > 0.2% for C) through a GC interface all connected by a Conflo II to a Delta Plus mass spectrometer (Révész and Qi 2006).

For beetles with mixed diets or undetermined dispersal patterns, one of two models can be used to determine the relative contribution from each food source to the food web base of the carabid. First, there is the geometric (Euclidian distance) mixing models, secondly, there are linear mixing models derived from mass balance equations (Ostrom et al. 1997, Ben-David and Schell 2001, Phillips 2001, Phillips and Gregg 2001). Evidence suggests the linear mixing models are more robust in providing correct proportion estimates (Phillips 2001, Phillips and Koch 2002). To estimate the proportional contributions from two food sources in a mixed diet, a two-source linear mixing model based on mass balance equations was used according to Fry (2006) as follows:

$$\delta^{13}C_B = f_A\delta^{13}C_A + f_S\delta^{13}C_S$$
$$1 = f_A + f_S, \qquad (3.1)$$

where $\delta^{13}C_B$, $\delta^{13}C_A$, and $\delta^{13}C_S$ represent SCI signatures for the beetle (*B*) and sources alfalfa (*A*) and sorghum (*S*), respectively, and f_A and f_S are the proportionate contributions of the food sources *A* and *S* to the beetle's diet, *B* (Fry et al. 1978, Fry 2006). To calculate the proportions of each source, *A* and *S*, the following equation was used:

$$f_A = \delta^{13}C_B - \delta^{13}C_S \,/\, \delta^{13}C_A - \delta^{13}C_S$$
$$f_S = 1 - f_A, \qquad (3.2)$$

Carabid movement within and among habitats was established by utilizing isotope categories that placed carabid P and R sub-sample ratios into one of three categories: alfalfa (-22.6 to -35‰), sorghum (-9 to -18.5‰), or mixed (-18.6 to -22.5‰) (O'Leary 1988). From this information, beetle movement was reconstructed such that beetles with distinctly different SCIRs from the local habitat were considered recent arrivals or residents of a habitat if their SCIRs were similar to that habitat (Prasifka and Heinz 2004). Placement in the mixed category resulted from SCIRs indicating possible mixing of C_3 and C_4 food sources within a habitat (Podlesak et al. 2005, Gratton and Forbes 2006). Sorting carabids into movement categories was accomplished with a formula developed for this data set in Microsoft Excel® 2010 as follows:

```
=IF(AND(K2<-22.5,K3<-22.5,(OR(B2="AA",B2="BA",B2="CA"))),"Stayed in
Alfalfa",IF(AND(K2>-22.5,K2<-18.6),"Undetermined",IF(AND(K2<-22.5,K3<-
22.5,(OR(B2="A",B2="B",B2="C"))),"Alfalfa to Sorghum",IF(AND(K2<-
22.5,K3>-18.6,(OR(B2="AA",B2="BA",B2="CA"))),"Return to Origin
Alfalfa",IF(AND(K2<-22.5,K3>-18.6),"Alfalfa to Sorghum",IF(AND(K2>-
```

18.6,K3>-18.6,(OR(B2=”AA”,B2=”BA”,B2=”CA”))),”Sorghum to Alfalfa”,IF(AND(K2>-18.6,K3<-22.5,(OR(B2=”AA”,B2=”BA”,B2=”CA”))),”Sorghum to Alfalfa”,IF(AND(K2>-18.6,K3<-22.5),”Return to Sorghum”,IF(AND(K2>-18.6,K3>-18.6),”Stayed in Sorghum”,IF(AND(K2>-18.6,K3<-22.5),”Sorghum to Alfalfa”,IF(AND(K2<-22.5,(OR(B2=”AA”,B2=”BA”,B2=”CA”))),”Stayed in Alfalfa”,IF(K2<-22.5,”Alfalfa to Sorghum”,IF(AND(K2>-18.6,(OR(B2=”AA”,B2=”BA”,B2=”CA”))),”Sorghum to Alfalfa”,”Stayed in Sorghum”))))))))))))

(Rector 2011b) (3.3)

Diet Switching and Natal Origins Data Analysis

Placement in the mixed diet category resulted from SCIRs indicating possible mixing of C_3 and C_4 food sources within a habitat (Podlesak et al. 2005, Gratton and Forbes 2006). Sorting carabids into diet switching categories was accomplished with a diet switching formula developed for this data set in Microsoft Excel® 2010 as follows:

=IF(AND(-22.5<K2, K2<-18.6, -18.6>K3, K3>-22.5),
“Undetermined”, IF(AND(K2>-18.6, K3>-18.6),
“Stayed in Sorghum”, IF(AND(K2<-22.5, K3<-22.5),
“Stayed in Alfalfa”, IF(AND(K2>-18.6, K3<-22.5),
“Sorghum to Alfalfa”, IF(AND(K2<-22.5, K3>-18.6),
“Alfalfa to Sorghum”, “Mixed”)))))

(Rector 2011a) (3.4)

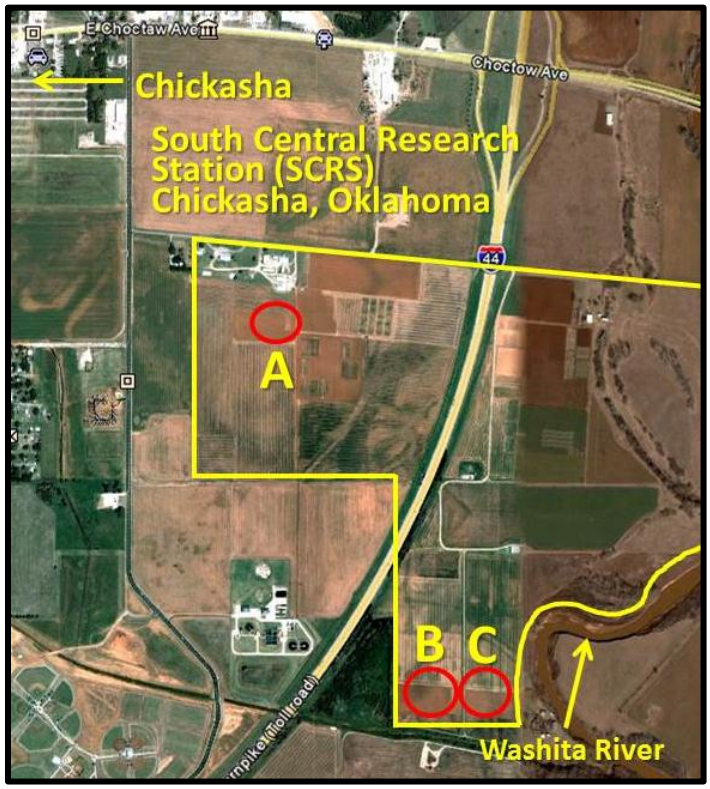
Natal origins were determined from the P sub-sample valves as they reflected alfalfa (-22.6 to -35‰) or sorghum (-9 to -18.5‰) isotope ranges.

Descriptive statistics and frequency graphs were constructed in Microsoft Excel 2010. Categorical data was analyzed based on untransformed counts. A chi-square test was performed to test for differences in A-D between years for each

genus. Statistical analyses included the Kruskal-Wallis test. The determination of mean SCIRs ($\delta^{13}C \pm SD$) and trophic level changes ($\Delta\delta^{13}C$) for field samples were calculated in Microsoft Excel 2010.

Figure 1

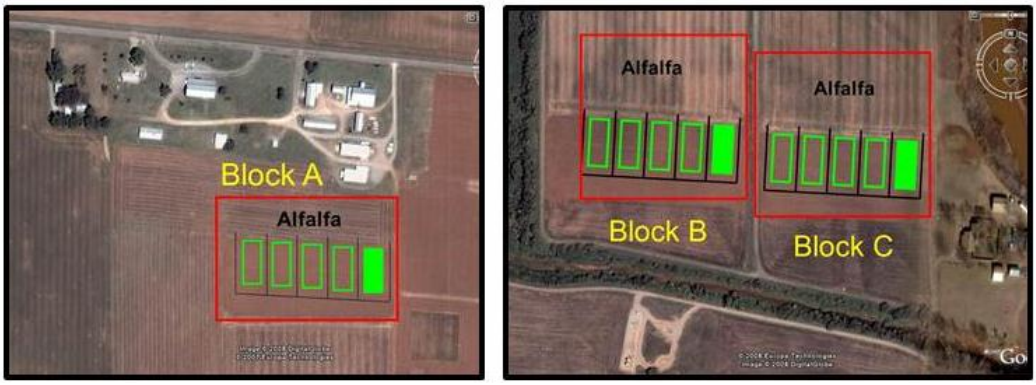
The South Central Research Station (SCRS) is located off I-44 in Chickasha, Oklahoma.



(Google Earth 2011)

Figure 2

This was the block layout for both years with the solid green rectangle indicating where the no-till plot was located.



(Google Earth 2011)

Figure 3

No-till requires no soil preparation with seeds planted by drilling through the surface vegetation and crop residue

Figure 4

Conventional tillage consist of soil inversion to bury the crop residue and disking to prepare the seed bed.

Figure 5

This block diagram shows the placement of the plots and the treatments applied per year. The silt fencing is indicated by the red lines. (Not to scale)

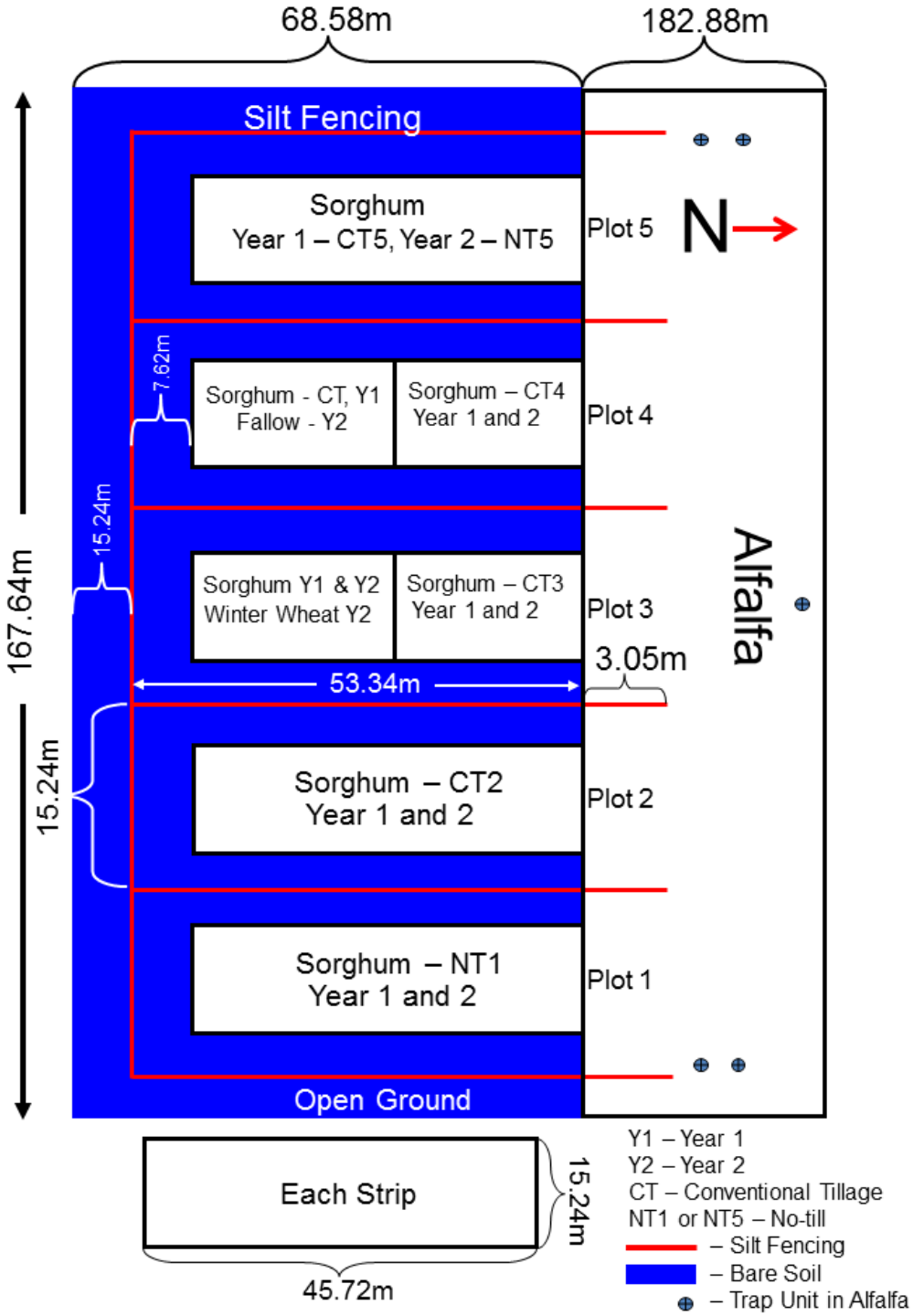


Figure 6

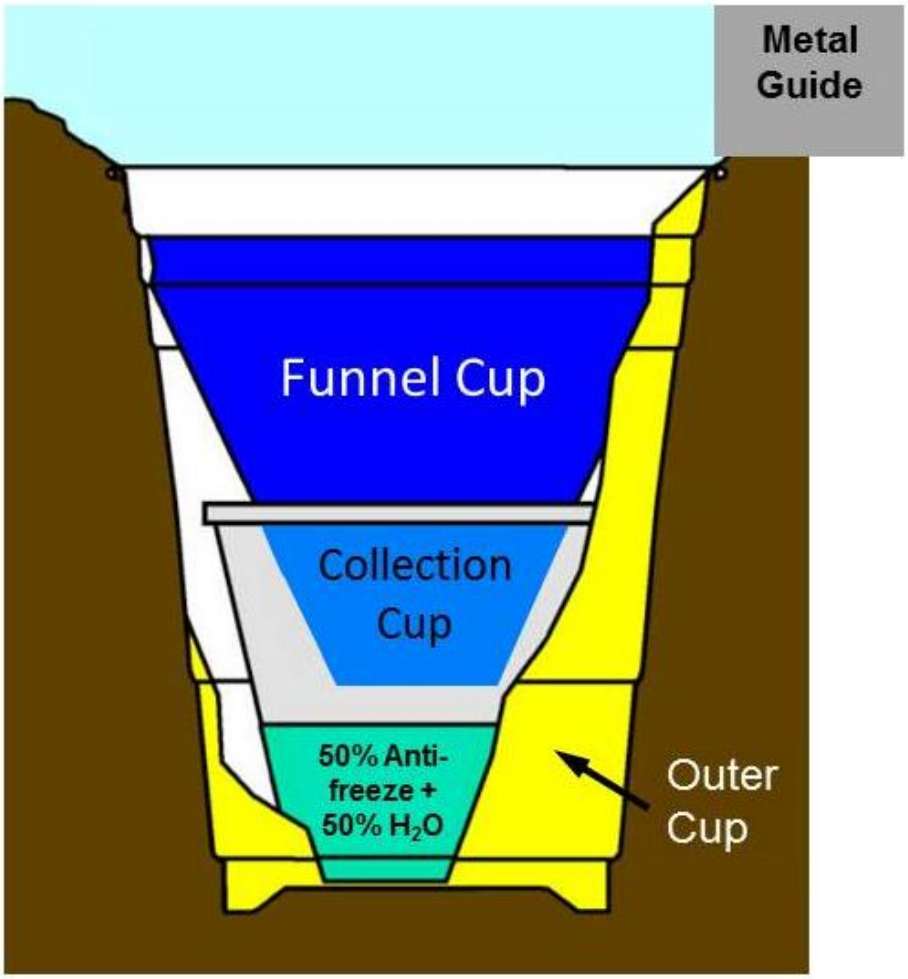
This shows the interface of the alfalfa fields with the sorghum plots.

Figure 7

Silt fencing was installed on three sides of each plot to minimize dispersal between plots.

Figure 8

A diagram of a pitfall trap.



2011, Adapted from Turfgrass Entomology Reference Charts, Pitfall Trap Diagram, University of Nebraska – Lincoln, SL Donelson

Figure 9

This is a trap unit consisting of two pitfall traps and a metal guide.

Figure 10

This diagram illustrates the placement and distances trap units were placed from the crop interface in each sorghum plot.

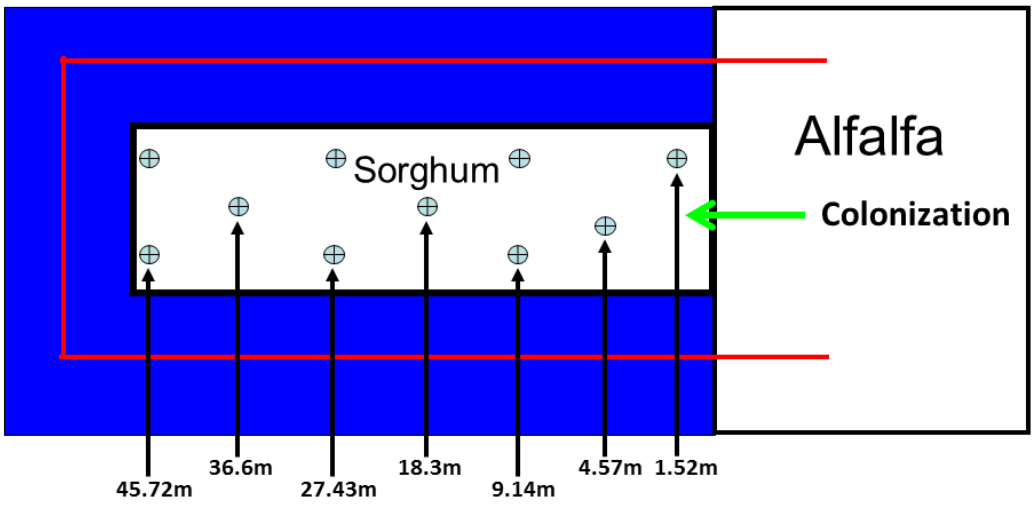
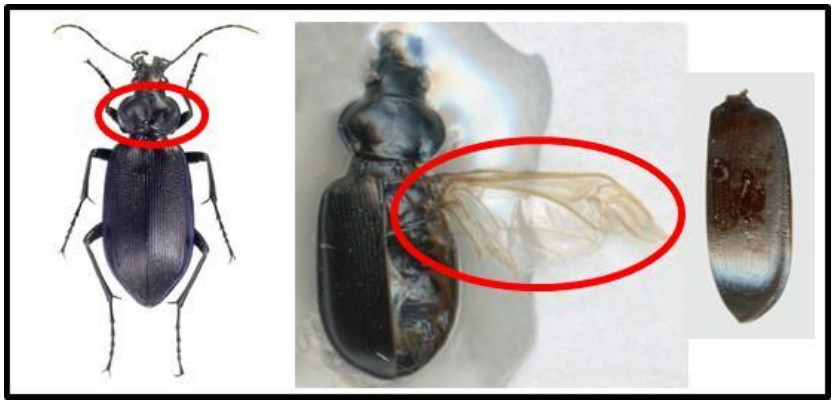
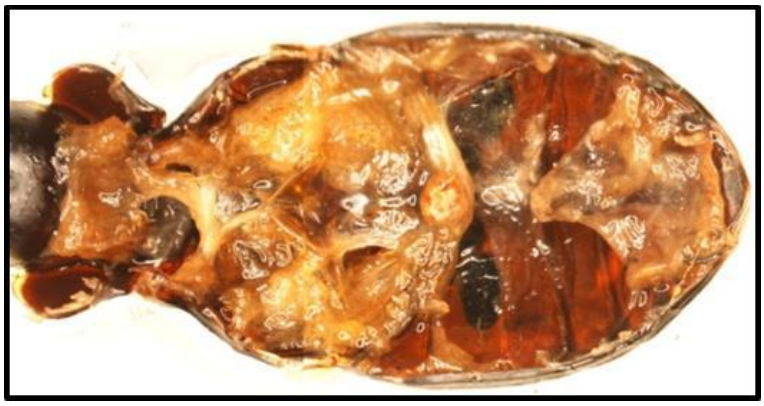


Figure 11

Tissues selected for the P sub-sample (A); tissues selected for the R sub-sample (B).

A. 

B. 

CHAPTER IV

RESULTS

Weather Conditions during 2006 and 2007

On August 22, 2006 the U. S. Drought Monitor designated the south central portion of Oklahoma including the Chickasha area as a D3 Drought – Extreme (scale D0 - D4) with –ignificant regional agricultural and hydrological impacts (Fuchs 2006). In addition to the limited rainfall, this period experienced persistent hot, dry winds from the south-southeast. In contrast, record rains fell in 2007 resulting in flooding at the study site in all three blocks (Table 1). The research site received 71% of its annual rainfall from May through September for 2007. June had the greatest amount of rain. From June 14th to July 18th, 2007 field conditions prevented data collection in all Blocks. Block B was temporarily damaged by water standing in alfalfa and sorghum for four weeks.

Weather variables for Chickasha, Oklahoma during 2006 and 2007 were collected from the Oklahoma Mesonet Daily Data Retrieval database (Mesonet 2011). A correlation matrix was constructed comparing 2006 weather to 2007 weather. No significant correlation between years was found for daily temperature, wind speed, humidity, (Pearson Correlation = 0.173, 0.151, -0.05, respectively) or rainfall, daily or

monthly, (0.071 and 0.194). The extreme weather conditions in each year necessitated further analyses and evaluation to be conducted for each year separately.

Beetle counts and prey availability were impacted by the extreme drought conditions in 2006 and extremely wet conditions in 2007. During the drought of 2006, no aphid samples were collected in either alfalfa or sorghum. In contrast, aphids were collected in both crops in 2007. Analysis by Pearson's correlation coefficient indicated a significant linear relationship in 2006 between total beetle counts and cumulative monthly rainfall ($r(22) = 0.481$, $p = 0.017$) and average humidity ($r(22) = 0.535$, $p = 0.007$). These correlations were positive in both cases. This is expected in drought conditions since carabids are susceptible to desiccation. For 2007, Pearson's correlation coefficient analysis revealed a significant linear relationship between total beetle counts and cumulative annual rainfall ($r(21) = 0.770$, $p \leq 0.000$). A significant negative linear relationship was found between the daily maximum humidity and total beetles counts in Block B ($r(21) = -0.550$, $p = 0.007$). This negative relationship was observed for Block A and Block C although it was not significant.

These extreme weather conditions may explain the differences in the activity-density (species' abundance and relative activity, A-D) of beetles at the genera level between years. The A-D for *Calosoma* (χ^2 (1, n = 326) = 197.902, $p < 0.000$), *Cratacanthus* (χ^2 (1, n = 336) = 114.333, $p < 0.000$), *Cyclotrachelus* (χ^2 (1, n = 124) = 41.806, $p < 0.000$), *Scarites* (χ^2 (1, n = 201) = 25.080, $p < 0.000$), and *Tetracha* (χ^2 (1, n = 229) = 10.485, $p = 0.001$) were significantly different between years. During 2006, *Calosoma* beetles were virtually absent in traps until September after temperatures had moderated. This is contrary to their normal behavior in central Oklahoma during June

when these beetles are usually found in large aggregations in crop fields. In the wet conditions of 2007, *Calosoma* beetles were trapped in all months with the highest peak in June and a second smaller peak in August. Data showed the opposite effect on the genus *Cratacanthus* which had its highest overall A-D during the drought. *Cratacanthus* experienced peak A-D in June with A-D dropping as temperatures increased over the growing season. In 2007, *Cratacanthus* experienced a 75% drop in A-D compared to 2006. A small peak occurred in A-D in June for *Cratacanthus*; however, as the flood water persisted from mid-June through mid-July A-D decreased to near zero in September. This genus is a strong burrower and may have been impacted by the prolonged wet, saturated soil conditions on the study site.

Colonization Results in 2006

A total of seven sampling dates were completed in 2006 (n = 1,057 beetles) and 2007 (n = 6,719). There were 15 and 19 genera identified in 2006 and 2007, respectively, with a total of 21 genera (Table 2).

In 2006, trap rates dropped substantially over time; there was a drop in the total number of carabids trapped after Day 2 by 18%, again on Day 5 by 51%, and on Day 7 by another 46% (Fig. 12, Top). The four most abundant genera, *Anisodactylus* (n = 255), *Cratacanthus* (n = 349), *Harpalus* (n = 148), *Scarites* (n = 114) accounted for 82% of total trap traps (Table 2). Three brachypterous (BR) genera, *Abacidus*, *Cyclotrachelus*, and *Pasimachus* along with two macropterous (MA) genera are not known to fly. *Calosoma* and *Tetracha* were trapped in very low numbers representing 0.5% of the total traps in 2006.

In 2006, wing morphology did not influence trap-catch distance. The colonization trend for the four most abundant genera, *Anisodactylus* (n = 254), *Cratacanthus* (n = 349), *Harpalus* (n = 148), and *Scarites* (n = 114), in NT and CT was for trap counts to be greater between 1.52m to 9.14m. After this range, numbers of individual beetles gradually dropped at increasing distance from the alfalfa-sorghum interface. This negative Pearson correlation was significant in Block A ($r = -0.165$, $p = 0.009$, $n = 206$) and Block B ($r = -0.175$, $p = 0.011$, $n = 173$). There were five genera that were only trapped in CT at very low numbers, *Abacidus* (n = 2), *Calosoma* (n = 2), *Chlaenius* (n = 4), *Stenolophus* (n = 4), and *Tetracha* (n = 9).

Traps placed at distances of 1.52m, 4.57m, 9.14m, 18.3m, 27.43m, 36.6m, and 45.72m were able to resolve small-scale movement over time. Data revealed that in 2006, six carabid genera, *Anisodactylus* (MA), *Clivina* (MA), *Cratacanthus* (DI), *Harpalus* (MA), *Poecilus* (MA), and *Scarites* (MA), were trapped at the greatest distance (45.72m) from the sorghum-alfalfa interface on Day 1 of evaluation. The genus *Abacidus* (BR) was trapped at 1.52m on Day 1 and on Day 4 at 9.14m (Fig. 13). Carabids from the genus *Cicindela* (MA) were trapped on Day 1 at 36.6m, Day 2 at 27.43m and on Day3 at 45.72m. The genus *Chlaenius* (MA) was trapped at 1.52m from the sorghum-alfalfa interface on Day 1, at 9.14m on Day 2, and at 27.43m on Day 7 (Fig. 14). *Stenolophus* species (MA) were trapped on Day 2 at 18.3, Day 5 at 27.43m. Carabids from the genus *Calosoma* (MA, not known to fly) were first trapped on Day 4 at 9.14m and again on Day 5 at 27.43m (Fig. 15). The genus *Tetracha* (MA) was trapped on Day 3 at 9.14m, Day 5 at 18.3m and then at 45.72m on Day 6 (Fig. 16).

Colonization Results in 2007

For 2007, analysis revealed a significant difference between wing morphology and distance trapped ($F = 16.6$, $df = 2$, $p \leq 0.0001$, $n = 2636$). A Tukey's multiple comparisons revealed that trap counts associated with MA wing morphology was significantly different from either BR or DI.

There was a gradual increase in trap counts from Day 1 to 2 by 29% and then from Day 2 to 3 by 36%. Trap rates peaked on Day 3 with a 31% decline by Day 7 (Fig. 12, Bottom). Excluding *Stenolophus* (MA, n = 4,080; due to its swarming behavior), *Anisodactylus* (MA, n = 341), *Clivina* (MA, n = 514), *Harpalus* (MA, n = 763), and *Scarites* (MA, n = 249), were the four most abundant genera and accounted for 71% of the total traps. The following genera, *Chlaenius* (MA, n = 8), *Discoderus* (MA, n = 2), *Lebia* (MA, n = 1), and *Pasimachus* (BR, n = 7) were trapped at very low numbers accounting for 0.06% of the total traps. *Abacidus* (BR) was not trapped in NT5 in any block. The genera *Geopinus* (MA) and *Poecilus* (MA) were only trapped in CT. Small scale colonization over time by genera was difficult to detect in 2007; eight genera trapped at 45.72m from the crop interface on Day 1. Three more genera were at 45.72m by Day 3 and five more by Day 5 excluding *Discoderus*, *Lebia*, and *Stenolophus* (Fig. 17 and Fig. 18 respectively). There was a significant negative Pearson correlation between the number of beetles trapped and the distance from the crop interface in Block B ($r = -0.168$, $p \leq 0.0001$, $n = 454$) and Block C ($r = -0.121$, $p \leq 0.0001$, $n = 819$).

Tillage Treatment Effects 2006

In 2006, there were no significant differences among treatments for total counts per plot ($F = 2.40$, $df = 2$, $p = 0.092$, $n = 432$). A one-way ANOVA indicated significant differences for trap counts among Blocks A, B, and C ($F = 6.46$, $df = 2$, $p = 0.002$, $n = 432$). Further analysis with Tukey's multiple comparisons between blocks revealed that the mean for Block B ($\bar{\alpha} = 5.00$, $SD = 8.11$, $p \leq 0.001$, $n = 144$) was significantly lower than Block C ($\bar{\alpha} = 9.00$, $SD = 9.20$, $p \leq 0.001$, $n = 144$) but not significantly lower than Block A ($\bar{\alpha} = 7.10$, $SD = 8.86$, $p = 0.086$, $n = 144$) (Table 3).

A one-way ANOVA revealed that three genera appeared to exhibit significant habitat preferences based on tillage treatments. *Cyclotrachelus* selected CT ($F=7.6$, $df = 2$, $p \leq 0.001$, $n = 168$) over NT or alfalfa, *Poecilus* had a preference for alfalfa ($F = 3.122$, $df = 2$, $p = 0.047$, $n = 136$) over CT or NT, and Scarites selected CT ($F = 4.411$, $df = 2$, $p = 0.025$, $n = 214$) over NT or alfalfa.

Tillage Treatment Effects 2007

In 2007, there were significant differences among all treatments for total counts per plot ($F = 12.92$, $df = 2$, $p \leq 0.000$, $n = 322$). Results from a Tukey's multiple comparison indicated that the mean trap count for alfalfa ($\bar{\alpha} = 14.50$, $SD = 11.60$, $p \leq 0.0001$, $n = 322$) was significantly greater than NT ($\bar{\alpha} = 5.20$, $SD = 6.27$, $n = 96$) and CT ($\bar{\alpha} = 7.00$, $SD = 8.17$, $n = 96$).

Trap count analysis from 2007 (one-way ANOVA) indicated there was significant differences between Blocks A, B, and C ($F = 14.40$, $df = 2$, $p \leq 0.0001$, $n = 322$). Tukey's multiple comparison showed the mean for Block B ($\bar{\alpha} = 5.00$, $SD = 5.64$, $p \leq 0.0001$, $n =$

322) was significantly lower than both Block A (M = 11.21, SD = 12.80, n = 106) and Block C (M = 11.11, SD = 7.88, n = 106) (Table 4).

A one-way ANOVA indicated that two genera appeared to exhibit a habitat preference. *Calosoma* selected alfalfa ($F = 40.22$, $df = 2$, $p \leq 0.000$, $n = 250$) over NT or CT while *Poecilus* selected CT ($F = 5.08$, $df = 2$, $p = 0.008$, $n = 118$) over NT or alfalfa (in contrast to 2006).

Trap Counts and Tillage: 2006-2007

There were a total of 6,563 carabid beetles trapped for both years from the following genera; *Calosoma*, *Cicindela*, *Cratacanthus*, *Cyclotrachelus*, *Pasimachus*, *Poecilus*, *Scarites*, and *Tetracha*. In 2006, 2,961 beetles were trapped with 13% of the beetles trapped in NT treatment plots, 67% in CT treatment plots, and 20% in adjacent alfalfa fields. In 2007, 3,602 carabid beetles were trapped with 27% of the beetles trapped in NT treatment plots, 39% in CT treatment plots, 28% in the adjacent alfalfa, and 6% in the fallow section. Trap counts, excluding *Stenolophus*, were dominated by *Cratacanthus* in 2006 (45%) and *Calosoma* in 2007 (34%).

Results from a t-test indicated there were no significant differences for total counts of carabids between years. The mean trap counts for each habitat type were CT ($\bar{\alpha} = 7.0$), NT ($\bar{\alpha} = 5.2$), and alfalfa ($\bar{\alpha} = 8.4$). There were significant differences in total trap counts between years for the following genera: *Calosoma*, *Cratacanthus*, *Cyclotrachelus*, and *Scarites* (Table 5). The overall mean number of beetles per trap by treatment by block indicated Block B had fewer beetles trapped than Block A or Block C in both years (Table 3 and Table 4).

Tillage Treatment Effects in No-till Plots and Fallow Sections

There was a significant difference in trap counts between 2006 NT1 and 2007 NT1 ($t = -3.76$, $df = 116$, $p \leq 0.0001$, $n = 118$). The NT1 treatment plots in 2007 ($n = 525$) had higher numbers of carabid beetles trapped compared to NT1 treatment plots in 2006 ($n = 374$). Additional analysis revealed significant differences in trap counts within three genera: *Calosoma, Cyclotrachelus,* and *Scarites,* possibly indicative of weather related impacts (Table 6).

Results of a t-test for NT1 (2-years old) and NT5 (1-year old) in Block A and Block C in 2007 revealed that there were significant differences in trap counts between these treatments ($t = 2.76$, $df = 113$, $p = 0.007$, $n = 115$). During the 2007 growing season, there were 28% more carabids trapped in NT1 ($n = 525$) than in NT5 ($n = 449$). No significant preference for NT1 or NT5 was found within genera.

Carabid counts between CT and Fallow in Plot 4 of all blocks for all genera were examined by t-test. Results of this t-test indicated there were significant differences between total counts for these two treatments ($t = 2.01$, $df = 136$, $p = 0.047$, $n = 138$). Further analysis by t-test and ANOVA were done to determine if genera exhibited a preference within treatment plot. Neither test found any significant preference for either treatment by any of the eight genera.

Isotopically Discrete Habitats using SCIRs

Data revealed that each crop had distinctly different isotope ratios. Field-collected alfalfa (-22.5 to -35‰) and sorghum (-9 to -18.5‰) plant samples had SCIRs within their

expected isotope range as described by O'Leary (1988) (Fig. 19). The mean for alfalfa was -29.11‰ (±0.12, n = 38) and sorghum had a mean of -13.00‰ (±0.08, n = 70).

Field-collected cowpea and pea aphids (known collectively as alfalfa aphids had SCIRs (n = 17, $\bar{\alpha}$ = -28.30‰, ±0.50) that reflected the SCIRs range of their host-plant alfalfa (-22.6 to -35‰) (Fig. 20). Field-collected corn leaf aphids had SCIRs (n = 23, $\bar{\alpha}$ = -11.70‰, ±0.11) that reflected feeding on their host-plant sorghum (-9 to -18.5‰) (Fig. 20). There were six corn leaf aphid samples that were excluded from the analysis due to processing contamination. Alfalfa aphids were enriched -0.82‰ compared to their host-plant alfalfa. Corn leaf aphids were enriched by -1.07‰ compared to sorghum plants. These values are consistent with previous results for similar systems indicating differences of ±0.5 – 1.3‰ between consumers and their dietary intake (DeNiro and Epstein 1978, Teeri and Schoeller 1979, Boutton et al. 1983, Wada et al. 1987, Ostrom and Fry 1993, Prasifka et al. 2004, Gratton and Forbes 2006) (Table 7). Plant and aphid ratios were consistent within and between years.

Laboratory grown alfalfa (n = 14, $\bar{\alpha}$ = -32.11‰, ± 0.30‰) and sorghum (n = 14, $\bar{\alpha}$ = -14.20‰, ± 0.20‰) had SCIRs within the expected range for each plant type, C_3 or C_4 (O'Leary 1988) (Fig. 21). Laboratory alfalfa aphids had SCIRs (n= 14, $\bar{\alpha}$ = -30.70‰, ± 0.27‰) corresponding to their host plant and were enriched by -1.44‰ (Fig. 22). Corn leaf aphids cultured in the laboratory had SCIRs (n = 11, $\bar{\alpha}$ = -14.00‰, ± 0.53‰) reflecting feeding on sorghum and were enriched by -0.21‰ (Fig. 22). The laboratory grown alfalfa was more depleted than field alfalfa by -3.00‰. Laboratory grown sorghum was more depleted than field sorghum by -1.20‰. This trend continued for

laboratory-reared alfalfa aphids and sorghum aphids which were more depleted than field-collected aphids by -2.40‰ and -2.30‰ respectively.

Field Carabid Dispersal Patterns using SCIRs

For 2006, dispersal of 699 target carabids were estimated based on their P and R sub-sample SCIRs and trap data (Table 8). Data indicate that 350 carabids moved from alfalfa to sorghum (Fig. 23) and 32 moved from sorghum to alfalfa during the study. These SCIRs data revealed that 129 carabids stayed in alfalfa and 56 carabids stayed in sorghum. Isotope data indicate that four beetles moved from sorghum to alfalfa, however; these four beetles were trapped in sorghum. Dispersal patterns for 128 carabids remain undetermined due to mixed isotope valves.

For 2007, dispersal for 856 target carabids has been analyzed based on their P and R sub-sample SCIRs and trap data (Table 9). The data indicate that 357 carabids moved from alfalfa to sorghum (Fig. 24) and 10 moved from sorghum to alfalfa. SCIRs data indicated that 293 carabids stayed in alfalfa and 15 carabids stayed in sorghum. There were four carabids that moved from sorghum to alfalfa based on SCIRs; however, they were trapped in sorghum. For 123 carabids, dispersal patterns remain undetermined due to mixed isotope valves.

Mass Balance Equation Calculations used to Clarify Dispersal Patterns

A mass balance equation was successfully utilized to quantify the proportional contribution of two food sources, alfalfa and sorghum, to the food web base of carabid beetles initially categorized as undetermined (See Equation 3.2). In order to determine dispersal for each beetle this equation was calculated for each P and R sub-sample

resulting in the proportional contribution of each source to the past dietary history and recent dietary intake. The mean value for all field alfalfa (-29.11‰) and sorghum (-13.00‰) samples were used to calculate the contribution of each source to the food web base (Haines 1976, Fry et al. 1978). These estimated contributions from alfalfa and sorghum to the food web base allowed dispersal patterns to be traced for beetles categorized as "undetermined" by the movement formula (Rector 2011b). Using 2006 and 2007 results, in addition to trap data, greater dispersal resolution for 175 carabids was estimated; however, dispersal for 76 carabids remains undetermined (Table 10 and Table 11, respectively). Overall, the mass balance equation increased dispersal pattern resolution by 65% in 2006 and 75% in 2007. In addition, it was determined that 36% and 55% of these beetles remained in residency in alfalfa long enough to assimilate the carbon isotope compositions of the prey feeding on alfalfa. This indicates resources in alfalfa were being utilized for extended periods of time over the entire growing season.

Data from this study indicate that movement from sorghum into alfalfa was minimal over both years (Table 8 and Table 9). However, further examination of the carabids categorized as "dispersal undetermined" revealed additional information about cyclic movement between habitats (Table 10 and Table 11). For example, there were six carabids with their P sub-sample in the sorghum category and the R sub-sample in the mixed category; however, they were trapped in alfalfa. These data indicate movement from sorghum into alfalfa. Additionally, 71 carabids had their P sub-sample in the mixed category and the R sub-sample in the alfalfa category; however they were trapped in sorghum. This indicates a recent move from alfalfa into sorghum.

Stable Carbon Isotope Ratios in Fallow Sections

In 2007, the southern half (15.24m x 22.86m) of treatment Plot CT4 was left fallow. This placement created an isolated patch surrounded on three sides by barren ground and one side by sorghum. All three sections were covered by weeds and grasses within 12 months (Table 12). Weed and grass samples were combined for each section before processing. The mean plant SCIRs for each section within a block were as follows: Block A, -13.67‰ (±0.250‰), Block B -13.83‰ (±0.14‰), and Block C -20.66‰ (±0.06‰). Data indicate a total of 54 carabids were trapped in the fallow section. Dispersal patterns for 50 out of 54 carabids trapped in the fallow section were determined (Table 13). Data indicate that 41 carabids moved into this section from alfalfa, three moved in from sorghum, and five moved into fallow from a mixed habitat. Analysis indicated that one beetle traveled from sorghum to alfalfa based on SCIRs; however, it was trapped in the fallow section. A mass balance equation was used to determine the dispersal for six beetles trapped in fallow that were initially categorized as undetermined. Two of the six were reclassified from undetermined to "sorghum to fallow" movement; however, four still remain unresolved.

The genus *Scarites* had the highest A-D in the fallow section which may have been due to its burrowing behavior. This genus remains motionless in burrows during daylight hours; consequently, dense vegetation in the fallow areas provided soil temperature modification for this genus.

Baseline Laboratory Isotope Study

The purpose of this feeding study was to estimate isotopic turnover rates between the P and R sub-sample tissues under controlled conditions. Data from this study revealed

that carabid tissues did not exhibit isotopic changes within seven to eight days of feeding. The duration of future feeding trials needs to be extended up to 60 days or more.

Diet Switching using SCIRs

In 2006, SCIR data indicate there were six carabids from two genera, *Cratacanthus* and *Pasimachus*, with complete diet switching (Table 14). One of these beetles appeared to switch from alfalfa to sorghum as indicated by a P-value of -28.42‰ and an R-value of -17.07‰. The other five carabids likely switched from sorghum to alfalfa as indicated by P-values in the -9 to -18.5‰ range and R-values in the range of -22.6 to -35.00‰. The overall range of enrichment or depletion for ($\Delta\delta^{13}C$) all samples was -5.57 to -11.35‰. In addition to these six carabids there were 40 beetles with one value in the mixed range (-18.6 to -22.5‰) and the other value in either the alfalfa or sorghum range. Two beetles in this group had alfalfa P-values and mixed R-values yet they were trapped in sorghum. Nine carabids had P-values in the sorghum range, mixed R-values, and they were trapped in alfalfa. Another seven beetles had mixed P-values and R-values in alfalfa where they were trapped. Twenty-two carabids had mixed P-values and alfalfa R-values; however they were trapped in sorghum. These 40 carabids were from the following genera: *Calosoma*, *Cicindela*, *Cratacanthus*, *Cyclotrachelus*, *Pasimachus*, *Scarites*, and *Tetracha* (Table 15). Beetles from the genus, *Poecilus* did not reveal diet switching of any kind.

Results for 2007 indicate seven beetles in the genera *Calosoma*, *Scarites*, and *Tetracha* had SCIRs consistent with a complete diet switch from sorghum to alfalfa (Table 16). The change ($\Delta\delta^{13}C$) for these beetles ranged from -7.08 to -13.40‰. Seventy-two carabids had one isotope ratio in the mixed diet range and the other one in either the

alfalfa or sorghum range (Table 17). Overall, the change ($\Delta\delta^{13}C$) for these 72 beetles ranged from -1.29 to -9.53‰. Five of the 72 carabids had P-values in sorghum and R-values in the mixed range; however, they were trapped in alfalfa. Another 18 beetles had mixed P-values, alfalfa R-values, and were trapped in alfalfa. Fifty-one beetles were trapped in sorghum with mixed P-values and R-values in the alfalfa range. Similar to 2006, seven genera, *Calosoma*, *Cicindela*, *Cratacanthus*, *Cyclotrachelus*, *Pasimachus*, *Scarites*, and *Tetracha* were included in the 72 carabids described above. No diet switching was evident in any *Poecilus* beetles.

Natal Origins

Carabid elytra, pronotal exoskeleton, and wings are virtually metabolically inactive after the adult emerges from pupation (Tallamy and Pesek 1996, Gratton and Forbes 2006). These tissues are known to retain carbon isotope compositions of dietary intake of the larval stage (Schallhart et al. 2009). Analysis of 2006 P sub-sample SCIR data determined that 479 carabid adults had natal origins in alfalfa (Fig. 25). There were 92 carabid adults with natal origins in sorghum. Origins for 128 beetles remain undetermined from 2006. In 2007, 691 carabid adults had natal origins in alfalfa, whereas, 31 had origins in sorghum (Fig. 26). There were 134 carabids with undetermined origins from 2007. A significant difference was indicated between beetles with natal origins in alfalfa and those with natal origins in sorghum in both years (Kruskal-Wallis test = 2006, $p = 0.014$ and 2007, $p \leq 0.000$).

Table 1

Monthly rainfall for Chickasha, Oklahoma during the sorghum growing season in 2006 and 2007, including the 30-year average.

Year	May	June	July	August	September	Period Total	Yearly Total Rain
2006	2.2	1.67	1.3	5.87	2.89	13.93	**27.14**
2007	8.24	**15.74**	4.99	5.83	2.07	36.87	**52.06**
30-year Average	5.24	4.11	2.11	2.73	3.6	17.79	**33.99**

(Mesonet 2011) Mesonet Climatological Data, Oklahoma Climatological Survey, 2010
Agweather Mesonet, University of Oklahoma, 2003-2011

Table 2

These are the 21 genera trapped during the seven-day colonization study in 2006 and 2007. (BR – brachypterous, DI – dimorphic-wing, MA – macropterous)

		2006	2007	
Genus	**Wing Type**	**Total Counts**	**Total Counts**	**Total**
Abacidus	BR	2	26	**28**
Anisodactylus	MA	254	341	**595**
Calosoma	MA	2	219	**221**
Chlaenius	MA	4	8	**12**
Cicindela	MA	41	87	**128**
Clivina	MA	67	514	**581**
Colliuris	MA	0	34	**34**
Cratacanthus	DI	349	73	**422**
Cyclotrachelus	BR	30	86	**116**
Discoderus	MA	0	2	**2**
Euryderus	MA	1	0	**1**
Galerita	MA	0	51	**51**
Geopinus	MA	0	11	**11**
Harpalus	MA	148	763	**911**
Lebia	MA	0	1	**1**
Microlestes	DI	0	136	**136**
Pasimachus	BR	10	7	**17**
Poecilus	MA	22	31	**53**
Scarites	MA	114	249	**363**
Stenolophus	MA	4	4,080	**4084**
Tetracha	MA	9	0	**9**
Total		**1057**	**6,719**	**7776**

Table 3

The mean number of beetles per trap by treatment by block for 2006.

Treatment	Block A	Block B	Block C	Total
Alfalfa	1.50	2.07	1.48	**1.68**
CT2	1.07	0.63	1.17	**0.96**
CT3	1.24	0.91	1.66	**1.27**
CT4	0.98	0.43	1.69	**1.04**
CT5	1.53	0.61	1.83	**1.32**
NT1	1.01	0.60	0.99	**0.87**
Total*	**1.21**[ab]	**0.84**[a]	**1.47**[b]	**1.17**

*mean across Block totals followed by the same letter are not significantly different (Tukey's multiple comparison, p = 0.01)

Table 4

The mean number of beetles per trap by treatment by block in 2007.

Treatment	Block A	Block B	Block C	Total
Alfalfa	3.68	1.94	3.06	**2.89**
CT2	1.42	0.62	1.55	**1.20**
CT3	1.45	0.51	1.99	**1.32**
CT4	2.20	1.06	1.90	**1.72**
FA	1.37	0.65	1.36	**1.13**
NT1	2.14	0.00	1.67	**1.90**
NT5	1.27	0.51	1.48	**1.09**
Total*	**1.91**[a]	**0.85**[b]	**1.86**[a]	**1.58**

*mean across Block totals followed by the same letter are not significantly different (Tukey's multiple comparison, p = 0.01)

Table 5

These genera had significant changes in their total counts between 2006 and 2007.

Genus	t	df	p	n	2006 Total Counts	2007 Total Counts
Calosoma	-5.75	33	0.000	47	142	1199
Cratacanthus	2.571	45	0.014	47	1317	584
Cyclotrachelus	-3.43	24	0.002	47	71	353
Scarites	-2.95	45	0.005	47	272	493

Table 6

These three genera had significant differences in their trap counts between 2006 and 2007 treatment Plot NT1.

Genus	t	df	p	n	2006 Total Counts	2007 Total Counts
Calosoma	-1.58	36	0.045	38	11	93
Cyclotrachelus	-2.80	32	0.009	34	6	91
Scarites	-2.44	30	0.019	39	22	61

Table 7

Trophic level shifts (mean $\Delta\delta^{13}C$) from crops to host-specific aphids as indicated by stable carbon isotope ratios.

Sample	n	$\delta^{13}C$ ±SD	$\Delta\delta^{13}C$
Alfalfa	38	-29.1 ±0.74	
Alfalfa Aphids	18	-28.5 ±2.17	-0.6
Sorghum	70	-12.8 ±0.70	
Corn leaf Aphids	23	-11.7 ±0.53	1.1

Table 8

Carabid movement within and among habitats based on isotope ratios for 2006.

Genera	Alfalfa to Sorghum	Sorghum to Alfalfa	Stayed in Alfalfa	Stayed in Sorghum	Return to Sorghum	Undeter-mined	Grand Total
Calosoma	17	0	16	0	0	3	**36**
Cicindela	53	1	15	0	0	41	**110**
Cratacanthus	146	23	23	42	1	31	**266**
Cyclotrachelus	14	0	5	2	0	5	**26**
Pasimachus	2	6	1	9	3	15	**36**
Poecilus	7	0	10	0	0	2	**19**
Scarites	45	0	11	0	0	9	**65**
Tetracha	66	2	48	3	0	22	**141**
Grand Total	**350**	**32**	**129**	**56**	**4**	**128**	**699**

Table 9

Carabid movement within and among habitats based on isotope ratios for 2007.

Genera	Alfalfa to Sorghum	Sorghum to Alfalfa	Stayed in Alfalfa	Stayed in Sorghum	Return to Sorghum	Undeter-mined	Fallow	Grand Total
Calosoma	94	4	172	1	0	12	9	**292**
Cicindela	52	0	31	0	0	26	7	**116**
Cratacanthus	28	3	8	6	0	19	6	**70**
Cyclotrachelus	62	0	17	2	0	13	4	**98**
Pasimachus	13	1	5	1	0	16	0	**36**
Poecilus	9	0	5	1	0	2	0	**17**
Scarites	65	1	26	4	2	17	21	**136**
Tetracha	34	1	29	0	2	18	7	**91**
Grand Total	**357**	**10**	**293**	**15**	**4**	**123**	**54**	**856**

Table 10

Resolution of movement for carabids previously categorized as having undetermined dispersal in 2006.

Genera	Sorghum to Alfalfa	Stayed in Sorghum	SOR→AL →SOR	Mixed to Sorghum	Mixed→AL →SOR	Mixed to Alfalfa	Undeter-mined	Grand Total
Calosoma	1	0	1	0	1	0	0	**3**
Cicindela	3	5	1	0	11	4	17	**41**
Cratacanthus	3	2	0	1	8	4	13	**31**
Cyclotrachelus	0	0	0	0	3	1	1	**5**
Pasimachus	1	0	0	0	8	4	2	**15**
Poecilus	0	0	0	0	1	0	1	**2**
Scarites	0	1	0	0	4	0	4	**9**
Tetracha	1	2	0	0	10	2	7	**22**
Grand Total	**9**	**10**	**2**	**1**	**46**	**15**	**45**	**128**

Table 11

Resolution of movement for the carabids previously categorized as having undetermined dispersal in 2007.

Genera	Sorghum to Alfalfa	Stayed in Sorghum	SOR→AL →SOR	Mixed to Sorghum	Mixed→AL →SOR	Mixed to Alfalfa	Undeter-mined	Grand Total
Calosoma	1	0	0	0	7	4	0	**12**
Cicindela	2	2	0	0	13	1	8	**26**
Cratacanthus	1	6	0	1	4	0	7	**19**
Cyclotrachelus	0	1	0	0	9	2	1	**13**
Pasimachus	1	0	1	0	6	5	3	**16**
Poecilus	0	0	0	0	1	0	1	**2**
Scarites	1	0	0	0	8	2	6	**17**
Tetracha	1	0	0	0	8	4	5	**18**
Grand Total	**7**	**9**	**1**	**1**	**56**	**18**	**31**	**123**

Table 12

Weed and grass inventory for all Fallow sections.

Block A Fallow Plot 4	C_3 or C_4	Block B Fallow Plot 4	C_3 or C_4	Block C Fallow Plot 4	C_3 or C_4
Crab grass	C_4	Clover	C_3	Bermuda	C_4
Foxtail	C_4	Common Sunflowers	C_3	Clover	C_3
Johnson grass	C_4	Crab grass	C_4	Common Sunflowers	C_3
Kochia	C_4	Curly Dock	C_3	Crab grass	C_4
Mare's Tail	C_4	Foxtail	C_4	Crested Wheat grass	C_3
Pigweed	C_4	Henbit	C_3	Curly Dock	C_3
Red Spangletop grass	C_4	Johnson grass	C_4	Downy Broam	C_3
Smartweed	C_4	Kochia	C_4	Foxtail	C_4
Sunflowers	C_3	Little Blue Stem	C_4	Johnson grass	C_4
		Pennsy. Smartweed	C_3	Kochia	C_4
		Pigweed	C_3	Mare's Tail	C_4
		Pokeweed	C_3	Pennsy. Smartweed	C_3
		Red Spangletop grass	C_3	Pigweed	C_4
		Stargrass	C_4	Pokeweed	C_3
		Tumble Pigweed	C_4	Stargrass	C_4
		Windmillgrass	C_4	Thistle	C_4
				Windmillgrass	C_4
% C_3 or C_4	**11% / 89%**		**50% / 50%**		**41% / 59%**

Table 13

Fallow section movement determined by SCIRs and a mass balance equation (3.2) for all treatment Plots 4South in 2007.

Genera	Alfalfa to Fallow	Sorghum to Fallow	Mixed→AL→ FA	SO→AL→ FA	Undeter-mined	Grand Total
Calosoma	9	0	0	0	0	**9**
Cicindela	5	0	0	0	2	**7**
Cratacanthus	2	3	0	0	1	**6**
Cyclotrachelus	3	0	1	0	0	**4**
Pasimachus	0	0	0	0	0	**0**
Poecilus	0	0	0	0	0	**0**
Scarites	17	0	2	1	1	**21**
Tetracha	5	0	2	0	0	**7**
Grand Total	**41**	**3**	**5**	**1**	**4**	**54**

Table 14
Stable carbon isotope ratios reveal complete diet switching for two genera in 2006.

2006	Trap	Sorghum to Alfalfa		Alfalfa to Sorghum	
Genus	**Number**	**P-Value**	**R-Value**	**P-Value**	**R-Value**
Cratacanthus	C4			-28.42	-17.07
	A17	-16.74	-26.50		
	AA6	-15.20	-23.04		
Pasimachus	C3	-18.59	-27.76		
	C26	-17.94	-23.51		
	B17	-17.28	-25.04		
Mean		**-17.15 ±0.60**	**-25.20 ±0.90**		

Table 15

Diet switching in carabids indicated by a stable carbon isotopic ratio of a mixed diet in 2006.

2006		Mixed to Alfalfa		Sorghum to Mixed		Alfalfa to Mixed	
Genus	**Trap**	**P-Value**	**R-Value**	**P-Value**	**R-Value**	**P-Value**	**R-Value**
Calosoma	C45	-20.97	-25.36				
Cicindela	A23	-21.75	-23.04				
	A25	-22.36	-24.08				
	A47	-22.06	-24.21				
	B5	-21.15	-23.79				
	C17					-24.39	-22.18
	A16	-22.12	-24.09				
	AA9	-22.32	-26.56				
Cratacanthus	CA10	-22.32	-24.94				
	AA10			-14.78	-18.95		
	CA10			-13.91	-20.67		
	AA10			-14.78	-18.95		
	CA9			-17.15	-21.29		
	CA6			-17.01	-21.08		
	AA1			-17.02	-20.66		
	AA9			-17.10	-20.52		
	C16					-23.06	-22.40
Cyclotrachelus	A17	-20.89	-23.09				
	B17	-22.32	-24.87				
	CA6	-21.51	-25.02				

Pasimachus	C15	-22.32	-25.18				
	A13	-21.77	-24.50				
	BA1	-21.77	-25.40				
	C17	-20.52	-26.32				
	C36	-21.92	-25.76				
	CA6	-20.44	-24.71				
	C17	-21.49	-26.13				
	CA6			-15.76	-22.17		
	CA10			-14.34	-21.02		
Scarites	C13	-21.37	-24.76				
	A33	-21.35	-23.11				
	C15	-22.10	-25.49				
	C36	-20.87	-26.67				
Tetracha	A13	-22.15	-24.38				
	B47	-21.39	-24.24				
	C27	-21.01	-23.33				
	A47	-22.14	-24.17				
	BA1	-22.28	-24.54				
	C3	-21.70	-26.05				
	BA1	-21.57	-24.65				
Mean		**-21.65 ±0.11**	**-24.77 ±0.20**	**-16.00 ±0.44**	**-20.60 ±0.40**	**-23.73 ±0.70**	**-22.29 ±0.11**

Table 16

Stable carbon isotope ratios reveal complete diet switching for three genera in 2007.

2007	Trap	Sorghum to Alfalfa		Alfalfa to Sorghum	
Genus	**Number**	**P-Value**	**R-Value**	**P-Value**	**R-Value**
Calosoma	AA2	-17.90	-26.46		
	BA2	-18.14	-25.51		
Scarites	C43	-17.54	-24.62		
	B6	-13.17	-26.57		
	B33	-17.20	-28.06		
Tetracha	A26	-15.76	-24.48		
	A46	-17.29	-26.25		
Mean		**-17.00 ±0.66**	**-26.00 ±0.50**		

Table 17

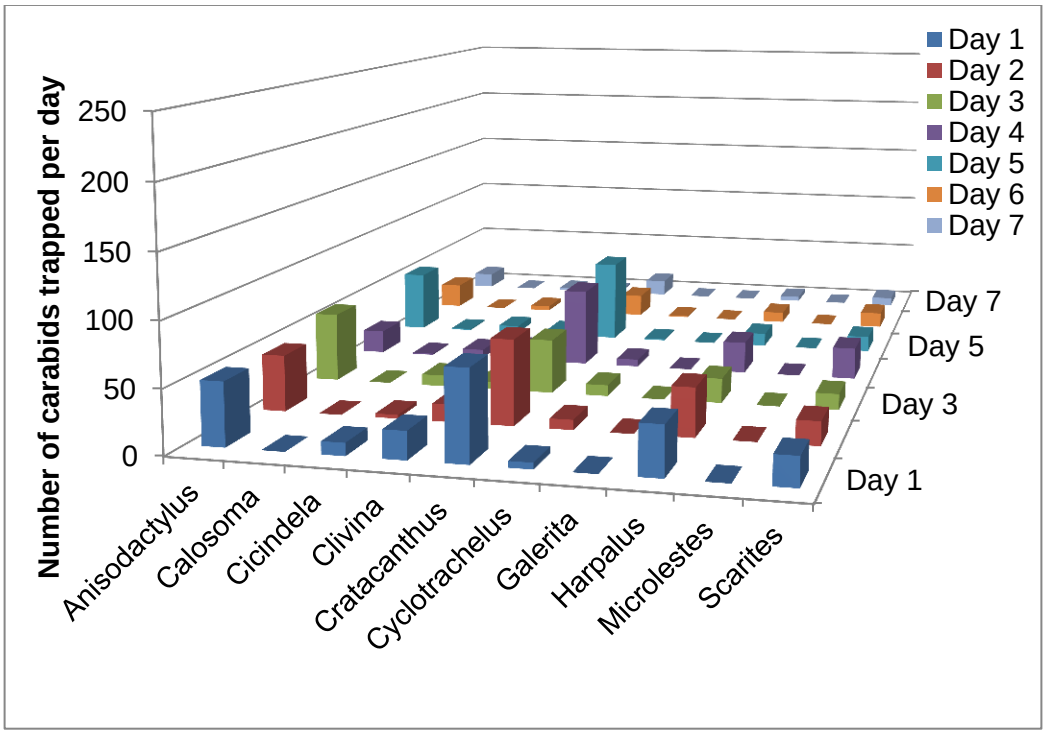
Diet switching in carabids indicated by a stable carbon isotopic ratio of a mixed diet in 2007.

2007		Mixed to Alfalfa		Sorghum to Mixed	
Genus	**Trap**	**P-Value**	**R-Value**	**P-Value**	**R-Value**
Calosoma	CA6	-19.25	-29.08		
	AA2	-19.62	-27.03		
	AA10			-16.89	-21.58
	BA9			-17.57	-20.66
	CA10	-20.32	-27.11		
	A4	-20.90	-26.70		
	A3	-21.98	-25.23		
	A43	-20.90	-26.70		
	AA6	-21.42	-27.24		
	C25	-21.40	-25.89		
	AA10	-21.07	-25.76		
	C6	-19.74	-23.86		
	C27	-21.80	-25.18		
Cicindela	A5	-20.92	-23.18		
	A6	-20.35	-23.05		
	A43	-22.46	-25.20		
	A27	-20.97	-23.73		
	A25	-20.11	-23.36		
	C37	-21.26	-24.09		
Cratacanthus	C13	-20.31	-24.83		
	C25	-20.47	-27.48		
	C6	-19.55	-23.19		
	C23	-22.33	-24.61		
Cyclotrachelus	A5	-20.20	-25.13		
	A33	-22.32	-28.88		
	C5	-22.32	-24.92		
	C6	-22.42	-24.58		
	CA10	-21.95	-25.48		
	C43	-22.09	-27.88		
	C45	-20.42	-23.86		
	A6	-20.44	-23.77		
	AA6	-21.98	-25.68		
	A6	-21.96	-24.59		
	B5	-22.48	-25.60		
	C23	-21.39	-23.41		
Pasimachus	BA6	-20.58	-30.11		
	CA9	-21.64	-27.40		

	C3	-21.20	-27.56		
	B5	-18.84	-24.48		
	C37	-22.31	-25.76		
	B17	-21.82	-25.22		
	BA1	-20.16	-23.78		
	C25	-21.75	-25.42		
	CA10			-17.16	-20.37
	CA2	-19.11	-26.71		
	A46	-21.39	-24.41		
	AA9	-20.68	-24.87		
	B43	-22.27	-24.92		
	CA2	-20.03	-24.79		
Scarites	C36	-19.95	-25.91		
	C23	-21.71	-25.81		
	C27	-20.59	-24.03		
	C35	-19.35	-24.15		
	C25	-22.39	-25.95		
	A23	-21.38	-25.81		
	B16	-22.29	-23.58		
	B36	-20.10	-24.02		
	BA1	-19.37	-27.69		
	BA6	-22.23	-24.74		
	BA10	-20.11	-25.63		
Tetracha	A33	-21.93	-25.29		
	A35	-21.83	-24.78		
	C26	-20.39	-23.84		
	A45	-21.62	-24.85		
	A25	-19.70	-24.37		
	CA9	-22.17	-24.58		
	A27	-22.43	-25.88		
	BA10	-21.96	-24.67		
	C27	-22.38	-26.21		
	A47	-22.21	-24.56		
	C7	-22.42	-24.99		
	C17	-21.13	-25.59		
Mean		**-21.14 ±0.12**	**-25.34 ±0.18**	**-17.32 ±0.15**	**-21.00 ±0.25**

Figure 12

Colonization pattern for selected genera in 2006 (Top) and 2007 (Bottom).



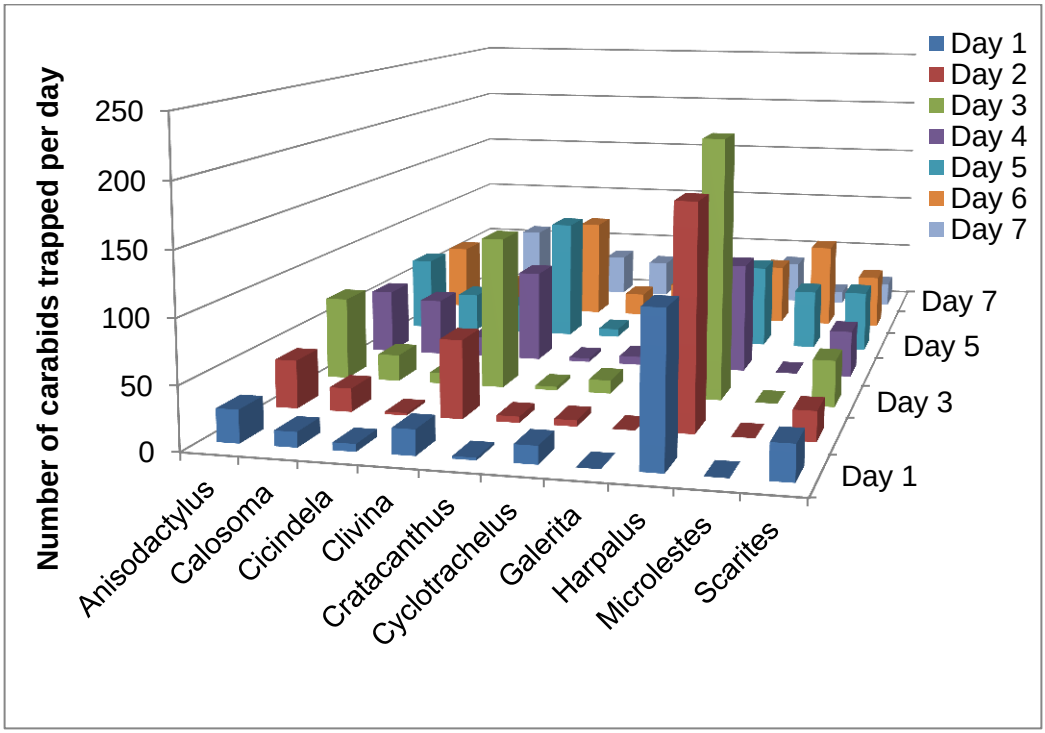


Figure 13

Carabids in the genus *Abacidus* were trapped at the following colonization distances in 2006.

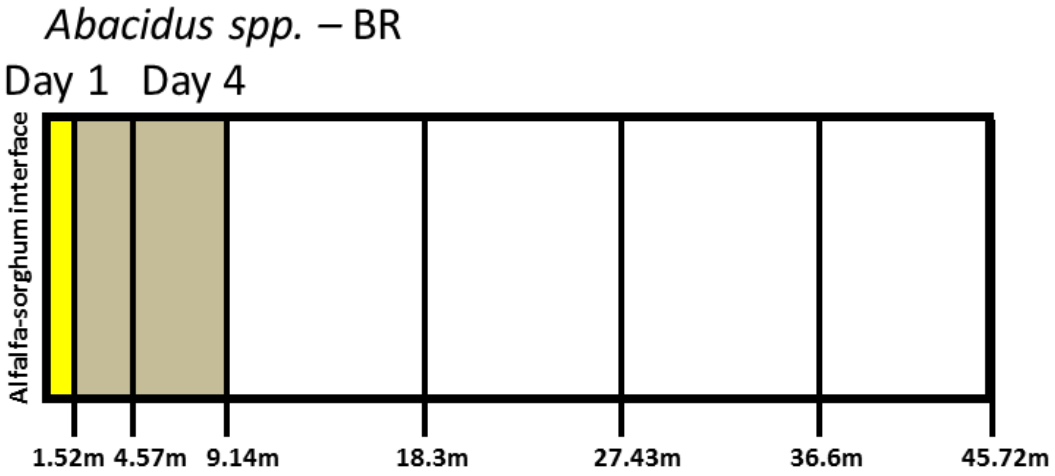


Figure 14

Carabids in the genus *Chlaenius* were trapped at the following colonization distances in 2006.

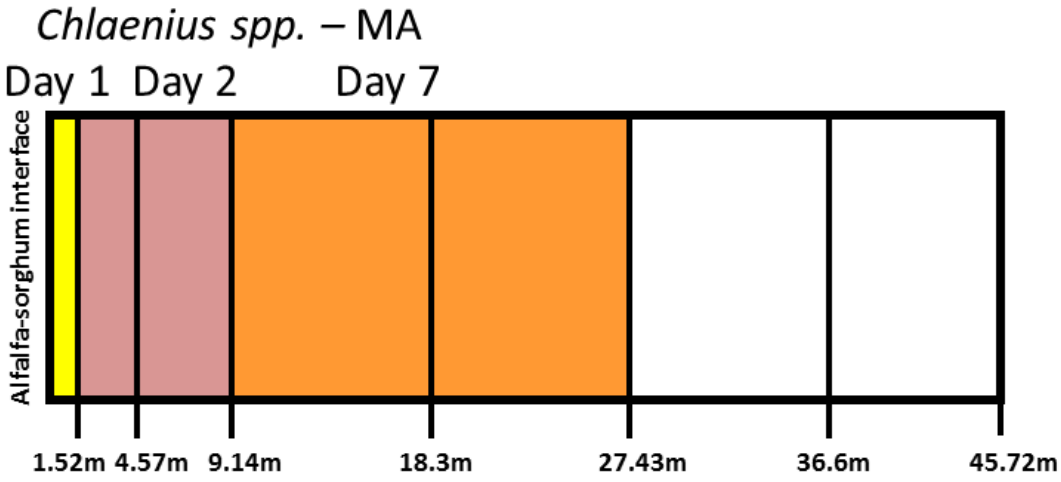


Figure 15
Carabids in the genus *Calosoma* were trapped at the following colonization distances in 2006.

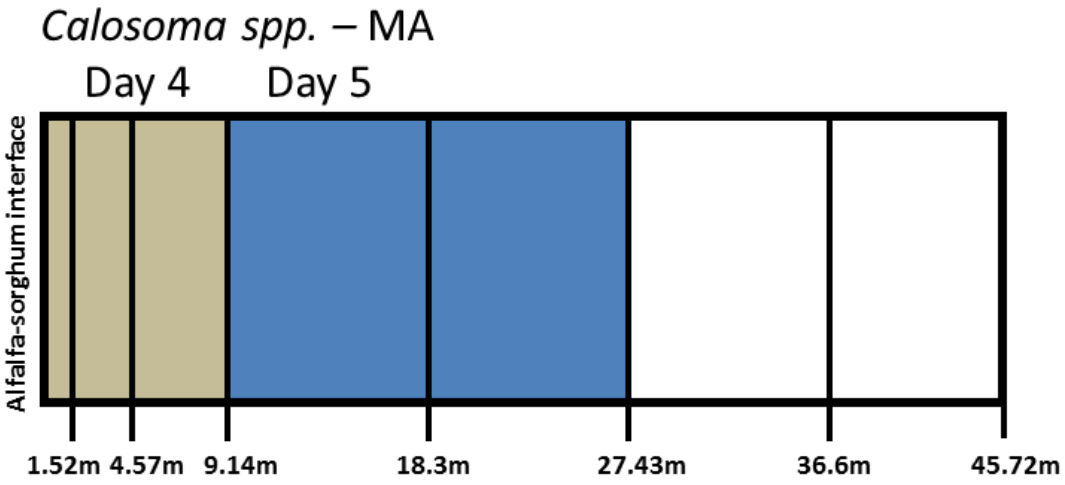


Figure 16
Carabids in the genus *Tetracha* were trapped at the following colonization distances in 2006.

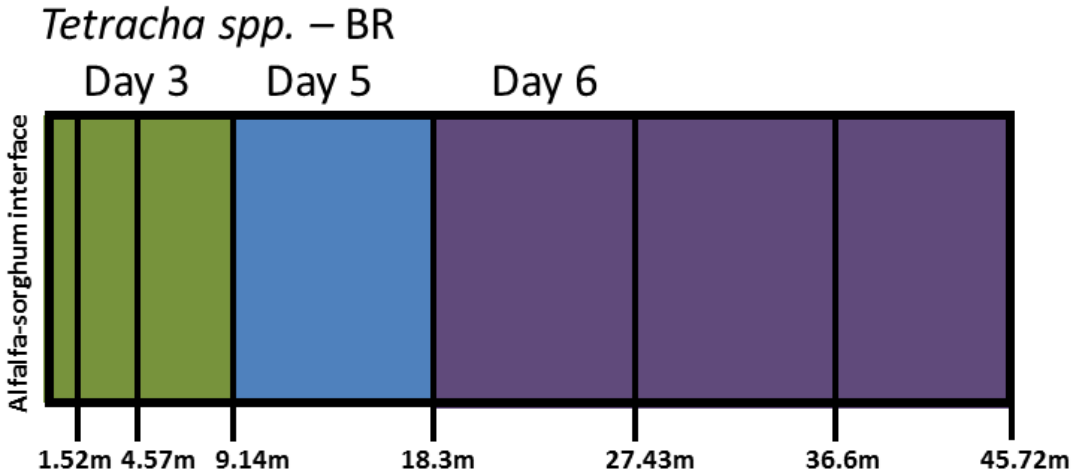


Figure 17
Carabids in the following three genera were trapped at the following colonization distances in 2007.

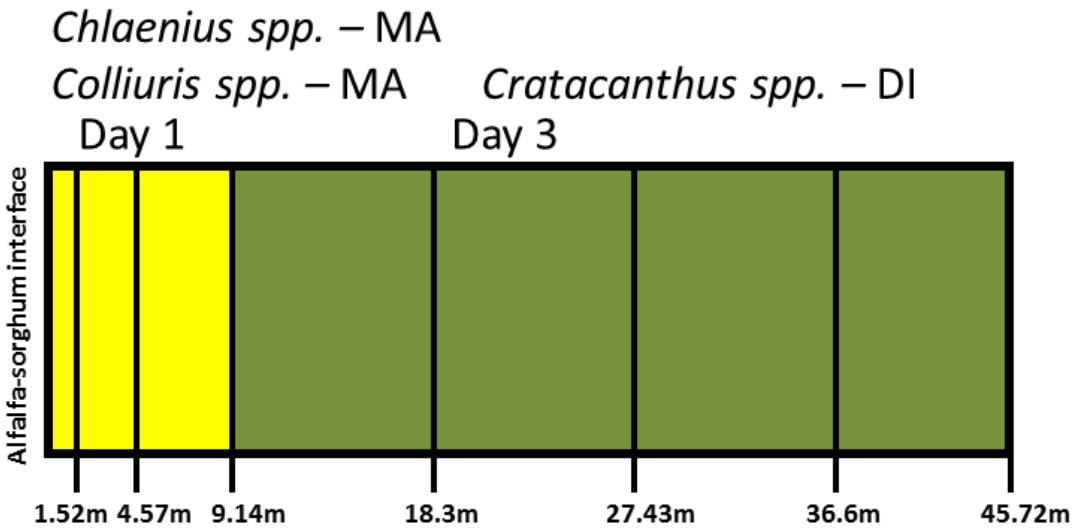


Figure 18
Carabids in the following five genera were trapped at the following colonization distances in 2007.

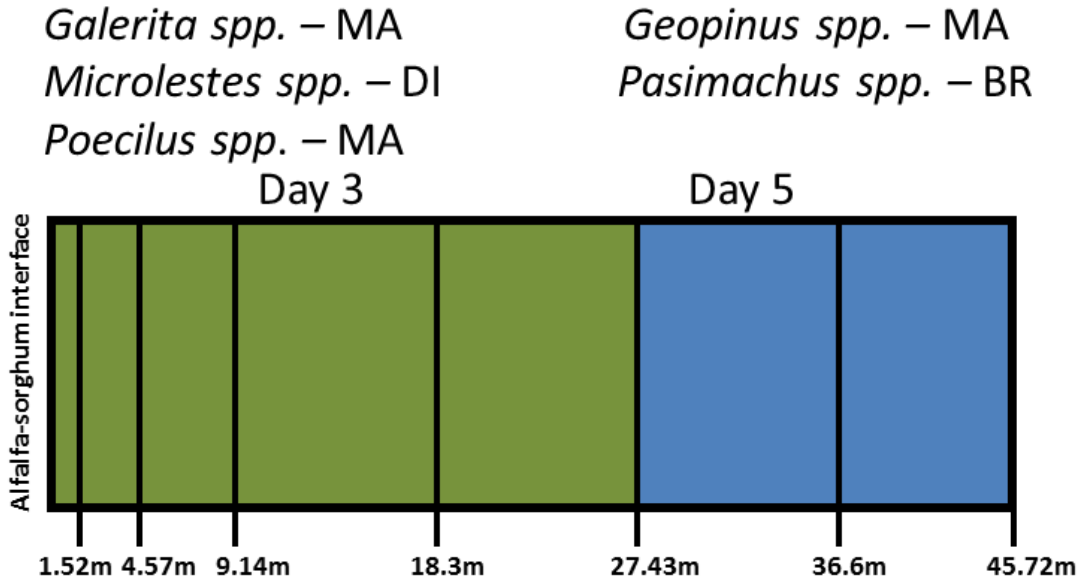


Figure 19
Stable carbon isotope frequencies for field alfalfa and sorghum samples (both years combined).

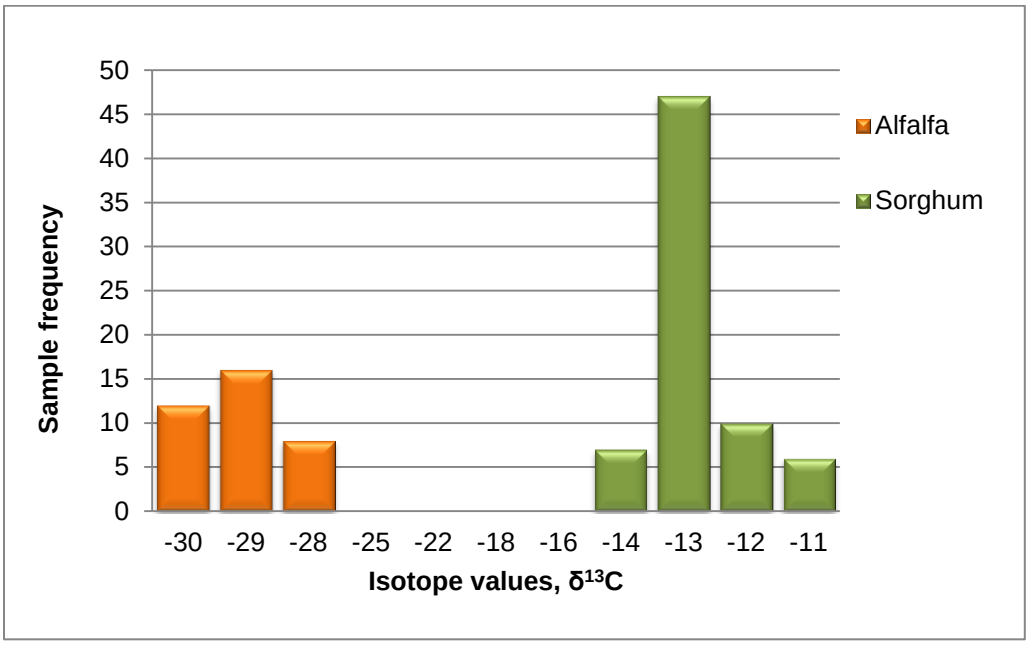


Figure 20
Stable carbon isotope frequencies for field alfalfa and sorghum aphids (both years combined).

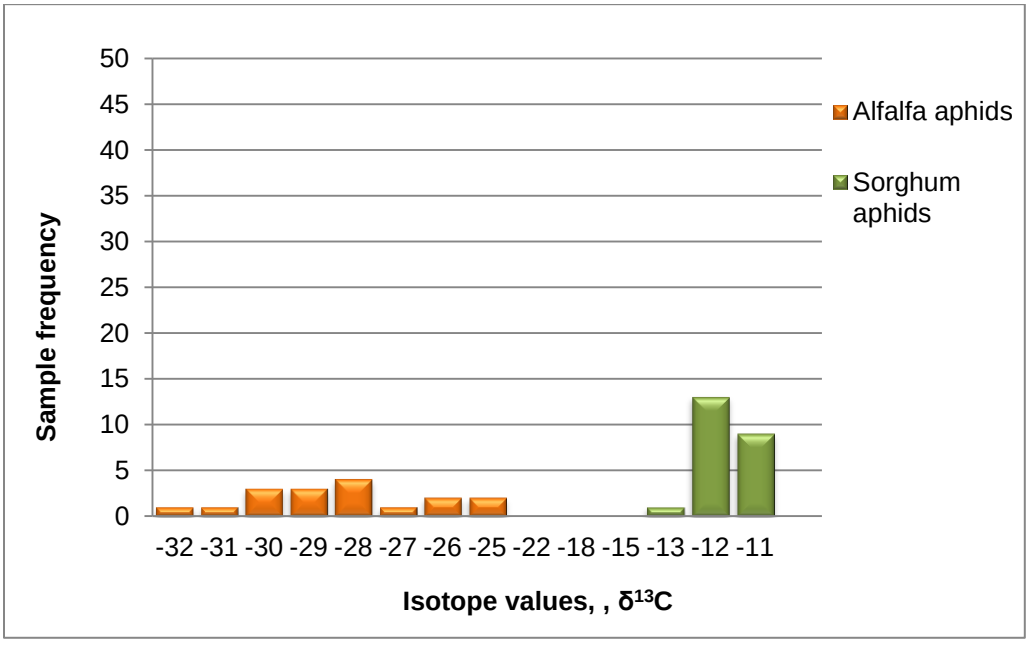


Figure 21

Stable carbon isotope frequencies for laboratory grown alfalfa and sorghum samples (both years combined).

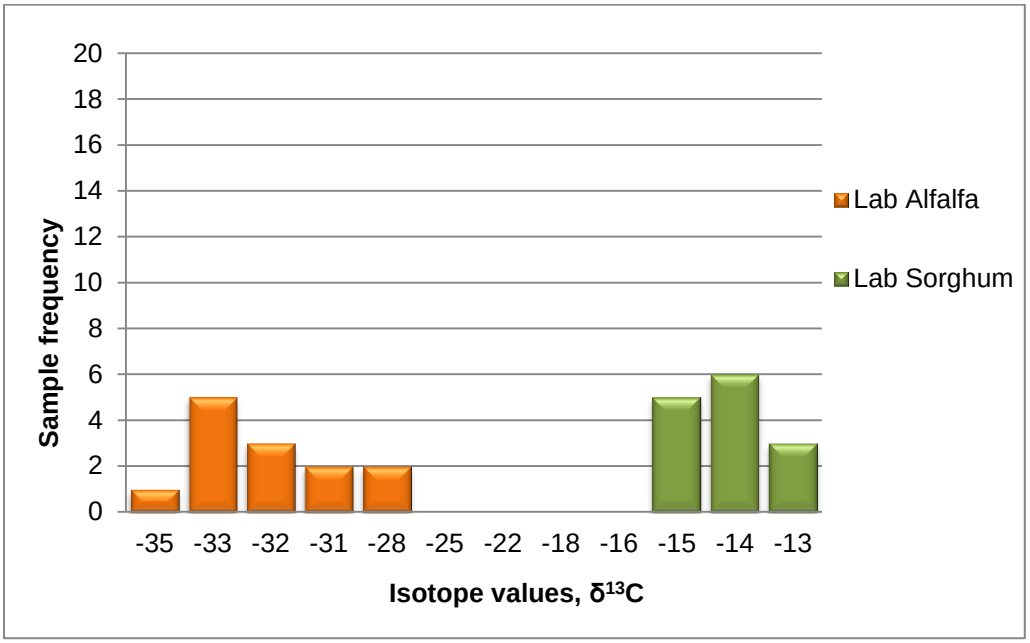


Figure 22

Stable carbon isotope frequencies for laboratory-reared alfalfa and sorghum aphids samples (both years combined).

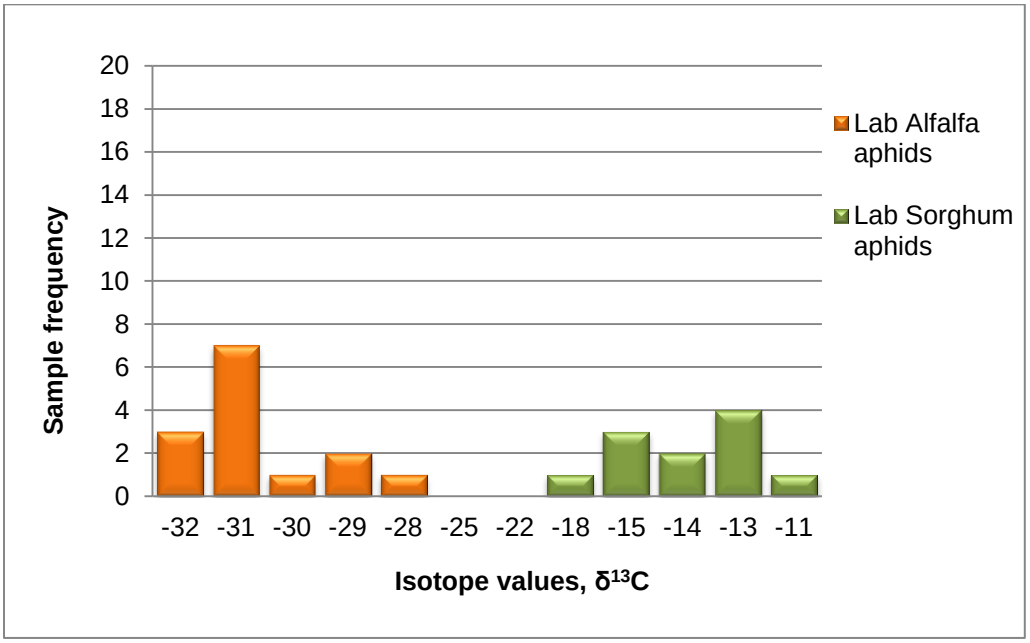


Figure 23
Carabid movement from alfalfa into sorghum in 2006.

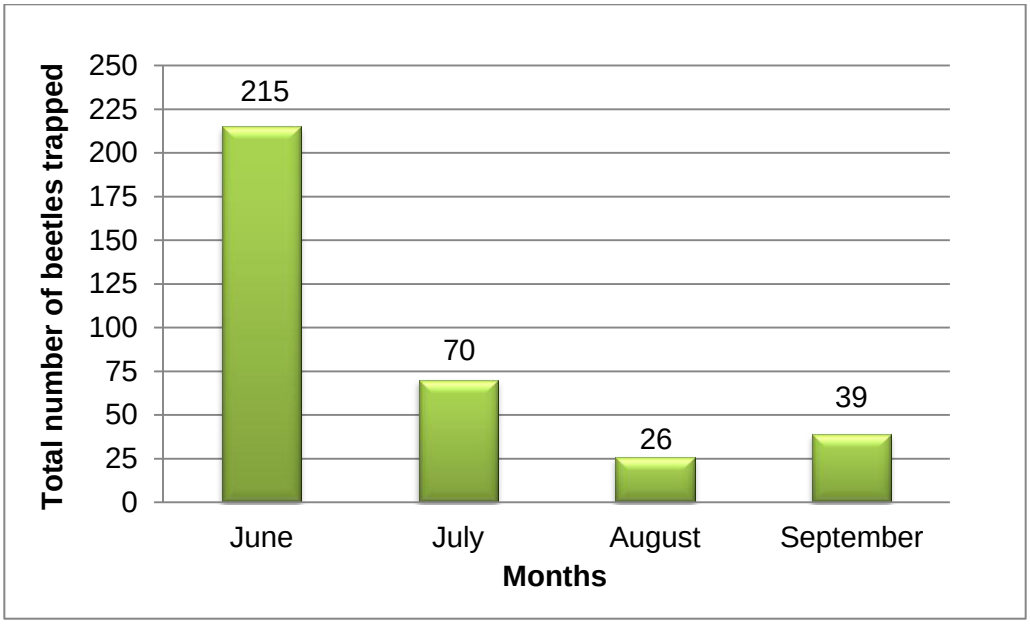


Figure 24
Carabid movement from alfalfa into sorghum in 2007.

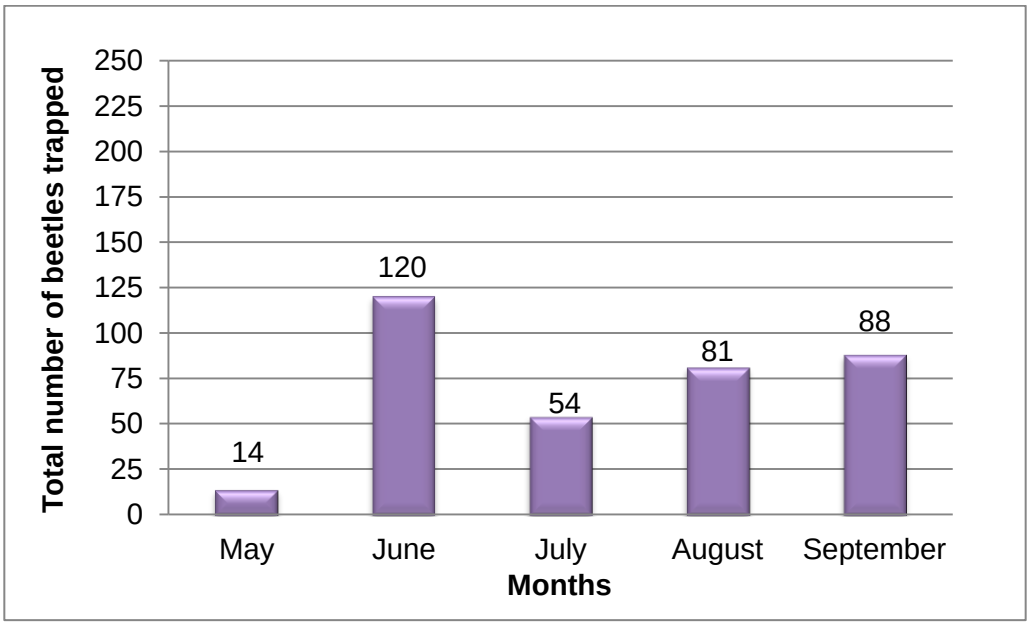


Figure 25
Natal origins based on the P sub-sample values were assigned in each genus for 2006.

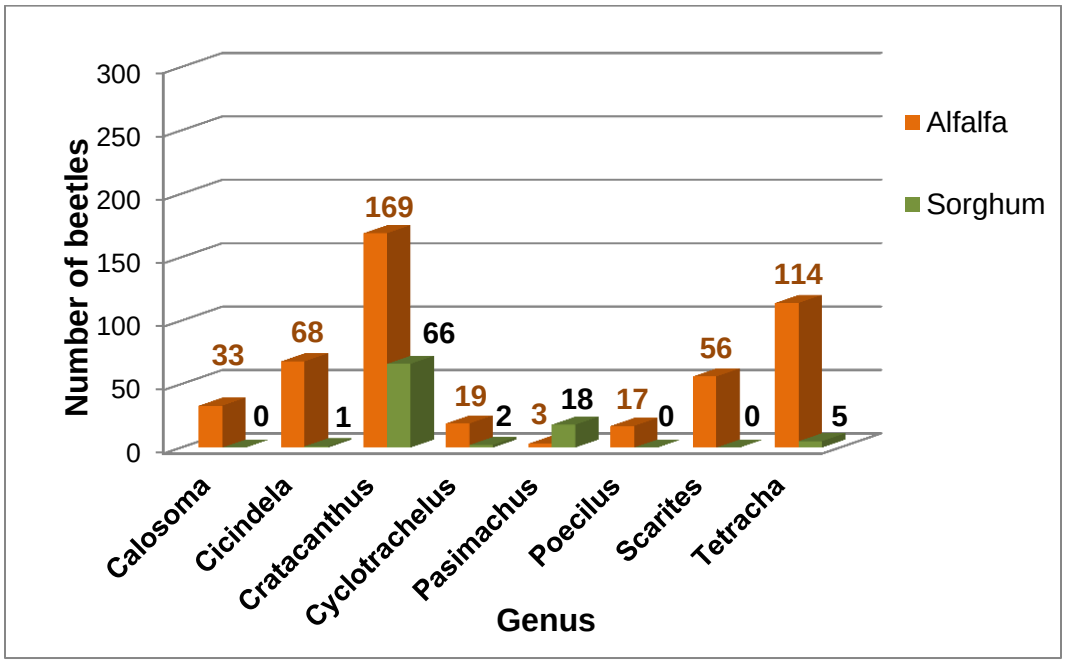
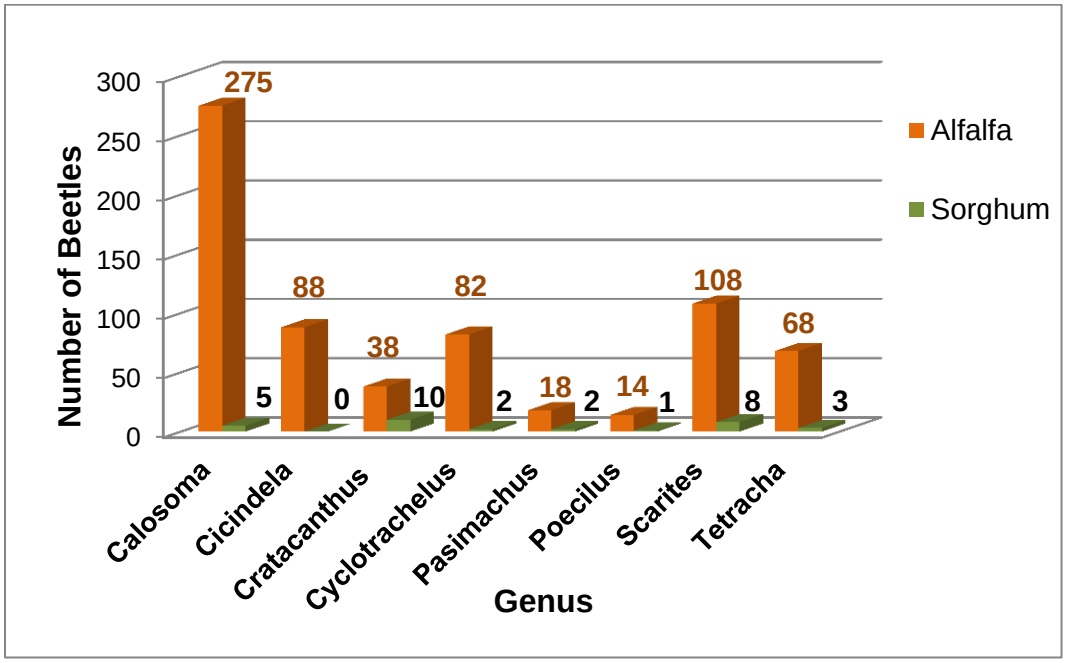


Figure 26
Natal origins based on the P sub-sample values were assigned in each genus for 2007.



CHAPTER V

DISCUSSION

Colonization and Tillage Effects

This colonization study revealed that there were four genera that accounted for 82% (2006) and 71% (2007) of total trap catches. Annual agricultural fields are generally in an early succession stage and therefore it is typical to have a few dominant species represent ~80% of the total carabid community (Esau and Peters 1975, Thiele 1977, Dritschilo and Wanner 1980). In 2007, unusually high trap catches of *Stenolophus* species were due to swarming or dispersal flights which are common in spring for this genus (Larochelle and Lariviere 2003).

In 2006, wing morphology did not correspond to carabid colonization of sorghum. There are three possible explanations for this outcome. First, the plot size may have been too small relative to dispersal capabilities of prevalent carabids in this study regardless of wing type (Wallin and Ekbom 1988). The genera trapped at the maximum distance on Day 1were *Anisodactylus*, *Clivina*, *Harpalus*, *Poecilus*, and *Scarites* all of which are macropterous and known to be frequent flyers in this region. In addition, *Cratacanthus* was trapped at the maximum distance on Day 1 and was the most abundant

wing-dimorphic species with winged individuals commonly known to fly. In 2006, *Pasimachus* and *Cyclotrachelus*, both BR species, were trapped at the maximum distance on Day 2. Best et al (1981) found the maximum linear walking distance covered by *Poecilus chalcites* (Say) was 91m per day, for *Scarites substriatus* Haldeman it was 65m per day and for *Harpalus pennsylvanicus* was 25m per day based on observations or re-trap data. Whether these genera walk and/or fly, covering this distance 24-hours after traps were opened (3-7 total days – see below) is highly possible. Second, the effect of wing morphology for DI (15%) and BR (4%) types may have been masked due to the larger proportion of MA beetles (81%) trapped in both years; any effect of wing morphology on limiting the ability of BR and DI beetles to disperse over distances would not have been evident. Third, in 2006 there was a delay of seven days between planting sorghum and opening pitfall traps due to installation problems. Beetles of all wing types were trapped at the maximum distance within one to two days after trapping began suggesting that many of these carabids had already entered sorghum treatment plots. This may be indicated by a peak in trap catches within the first three days. In comparison, in 2007 the delay between planting and opening traps was three days. Trap catches increased up to day three and then declined to day seven. This may indicate planting and trap installation operations kept carabids from colonizing before traps were opened. It is clear however, data from both years indicate that dispersal from overwintering sites in a refuge habitat into crops can happen quickly due to the high mobility of carabids (Purvis and Fadl 1996).

It is likely that the treatment plot sizes were too small to actually reflect the impact of wing morphology on dispersal. In addition, the delay in opening traps in 2006

likely allowed carabids of all wing types to colonize prior to trapping, muting any impact wing morphology might have on dispersal. In 2007, wing morphology had a statistically significant impact on colonization. This was driven by the disproportional number of MA carabids trapped compared to BR and DI carabids. Some factors contributing to this high percentage of MA beetles were: 1) the genus *Clivina* had an 87% increase in numbers caught compared to 2006 and is known to swarm in the spring, 2) *Harpalus* had an 81% increase in numbers caught compared to 2006, 3) *Calosoma* had a 99% increase compared to 2006, and 4) better moisture and lower temperatures in 2007.

In the present study, there was a negative correlation between the mean number of individuals per trap and distance from the alfalfa-sorghum interface in both years in two out of three blocks. Den Boer (1970) found similar results in a study conducted over eight years in reclaimed polders (reclaimed land from the ocean). He found that there was a similar negative correlation between the mean number of individuals trapped per year in the heath of Kralo in the Netherlands and the distance from deciduous woods. Coombes and Sotherton (1986) studied dispersal of carabids from field edges into cereal crops. They determined that the greater numbers of individuals were trapped closer to edges and as distance from the edge increased the trap numbers decreased.

Results of the present study found that NT and CT treatments had no impact on total carabid activity-density (A-D) per trap. These results are similar to Tonhasca (1993) who found no significant tillage effect on the total number of individuals; however, there were significant effects at the species level. There are inconsistent results from previous studies regarding the impact of tillage practices on carabids. For example, studies on carabids have found A-D higher in NT than CT (Brust et al. 1985, House and Parmelee

1985, Stinner and House 1990, Weiss et al. 1990, Andersen 1999, Holland and Reynolds 2003) while others found carabid A-D was lower in NT (Barney and Pass 1986, Cárcamo 1995) and still others have found no difference between CT and NT (Tyler and Ellis 1979).

Results from this study revealed that there were treatment effects at the genera level in both years. The genus *Cyclotrachelus* was more abundant in CT treatments in the first year of this study. Conversely, Tonhasca (1993) found that *Cyclotrachelus sodalis* (LeConte) was more abundant in NT treatments in a study of monoculture and strip-intercropping plots under NT and CT in Ohio. Esau and Peters (1975) found the same species to be more abundant in fence rows. During 2007, *Cyclotrachelus* species did not respond significantly to any treatment in this study.

In 2006, the genus *Poecilus* was more abundant in alfalfa in contrast to 2007, when captures were greatest in CT. The selection of alfalfa may have been in response to drought conditions and low prey availability in CT. Selecting CT in 2007 is in agreement with results from Tonhasca (1993) who found *Poecilus chalcites* more abundant in CT. Tonhasca (1993) indicated that this species was observed entering cracks and holes in the bare soil of CT treatments. In 2006, *Scarites* species were more abundant in CT which is in accordance with findings by Esau and Peters (1975) and Tonhasca (1993). Esau and Peters (1975) also found that *Scarites quadriceps* Chaudoir were more abundant in corn fields and Tonhasca (1993) found *Scarites substriatus* were more common in CT treatments. During 2007, *Scarites* species did not respond significantly to any treatment.

In the study conducted by Tonhasca (1993), weather conditions in Ohio were very dry the first year followed by above normal rainfall the second year; conditions similar to this study. Tonhasca (1993) suggested the difference in rainfall between years could have been one reason there were such differences between trap catches for *C. sodalis* and *P. chalcites*. The extreme weather conditions in 2006 and 2007 for Oklahoma could be the reason for habitat selection differences between years for *Cyclotrachelus, Poecilus,* and *Scarites*.

The genus *Calosoma* selected alfalfa over NT or CT in 2007; however, in 2006 this species had no significant habitat preference. *Calosoma* is prevalent in alfalfa fields in the SGP. During its breeding season, *Calosoma affine* Chaudoir has been observed in large numbers in June and early July in alfalfa (personal observations, SL Donelson). This genus was trapped in very low numbers throughout in 2006; again, most likely in response to the drought.

It was surprising that there was a difference between total counts for CT and Fallow and yet no habitat preference by genera in treatment Plot 4 of all blocks. The differences between NT1 treatment plots were due to increased trap catches in 2007, most likely another indication of the extreme change in weather conditions between years. There appeared to be an age effect shown between the two-year old NT1 (higher trap counts) plots and the one-year old NT5 plots (Fig. 27). Two-year old plots have more organic material built up on the soil surface providing increased moderation of environmental factors and greater microhabitat stability.

The utilization of ground level barriers have been successfully used to control carabid dispersal (Edwards et al. 1979, Chiverton 1987, Holland et al. 1996, Menalled et al. 1999a). Silt fencing was installed at the beginning of the study and remained in place for the duration of the study with the exception of a one-time replacement of heavily damaged material after year one. This material was highly susceptible to wind damage, sun deterioration, and flood damage. The use of ground level barriers around plots to reduce movement of carabids between plots was not effective for *Calosoma* and likely not for *Tetracha* beetles. Observations of individual *Calosoma* beetles climbing up and over the silt fencing indicated that these beetles could easily move between treatment plots.

Conventionally-tilled environments experience catastrophic disturbance destabilizing the physical habitat and resources. These conditions take longer periods of time to recover. Once stabilized, the resources available in CT are less numerous and highly dispersed; this increases the time carabids spend foraging over greater distances especially for very hungry beetles (Wallin 1991, Frampton et al. 1995). An increase in foraging activity increases the opportunities for carabids to be trapped which could explain the overall higher average number of beetles per trap in CT. Best et al. (1981) found that the three carabid species in their study dispersed more than the average rate of a few meters per day as defined by Thiele (1977) which they attributed to the openness or lack of weeds in the agricultural land in the study.

No-till habitats have a more stable initial environment, provide immediate resources and prey despite planting activity. Over time this habitat more consistently provides resources allowing carabids to forage more efficiently thereby decreasing their

A-D. Because carabids are foraging less, the likelihood they will be trapped decreases, providing one explanation for the low average number of carabids caught per trap in NT. In addition, NT habitats have more ground cover which is known to slow carabid foraging thereby decreasing the opportunities to be trapped. The amount of vegetation surrounding a trap in the fallow section could have been an impediment to a beetle's ability to reach a trap thereby decreasing the chance of trapping that carabid. However, vegetation around the trap units in the fallow section was continually cleared away or flattened to reduce this impediment.

Carabids colonized an annual crop, sorghum, from a semi-permanent refuge habitat, alfalfa, over a short time interval and very early in crop development. Alfalfa provided carabids with the necessary resources to survive when the ephemeral resources within annual crops deteriorate. The most effective biological control impact from carabids is early in the growing season when pest populations are still at low densities. These beetles have high search capabilities and are known to locate low density prey aggregations within crops and consume large quantities of pests (Sunderland and Vickerman 1980, Lövei and Sunderland 1996).

Highly mobile Carabidae are able to escape agricultural disturbances relatively quickly provided there is a refuge habitat nearby. Many carabids common to farms may be adapted to disturbance regimes and some may even be enhanced by these practices (Thiele 1977, Lövei and Sunderland 1996). Carabids are abundant and persistent in agroecosystems, regardless of disturbances, mainly due to their reproductive plasticity and flexible behavioral and environmental requirements (Thiele 1977, Makarov 1994, Fadl and Purvis 1998, Holland 2002). Carabid assemblages are relatively consistent with

a composition of generalists that are non-habitat specific with long reproductive cycles. These life history characteristics provide farming systems with long-term biological control services from many carabid species relative to other natural enemies with shorter life-spans. The downside to long lives is that various life stages of carabids are highly dependent on the availability of multiple habitats. Alfalfa supplies carabids with alternative prey, a variety of microhabitats which in return provide oviposition sites where newly emerged larvae can survive away from farming operations and the requisite overwintering sites for adults and larvae. Utilizing alfalfa as a semi-permanent refuge habitat keeps crop land in production while enhancing local carabid beetle populations.

Stable Carbon Isotope Movement

This study represents the first application of SCIRs to determine individual carabid beetle dispersal between a semi-permanent refuge habitat (alfalfa) and an annual crop (sorghum). The clear differences between field alfalfa (C_3) and sorghum (C_4) isotope ratios in this study met the requirement of using isotopically discrete habitats to elucidate dispersal of carabids among and between habitats as set forth in Prasifka et al. (2004). Isotope ratios from the selected P and R sub-sample tissues have shown a high degree of resolution for determining movement of individual beetles. Resolution was enhanced when trap data were considered in conjunction with SCIRs and when a mass balance equation was employed. Trap data supports the dietary information reflected in SCIRs. These data verified that stable carbon isotope data is a reliable technique for characterizing complex food webs and reconstructing dispersal patterns of individual carabid beetles within a diverse agroecosystem.

Results revealed the greatest overall carabid dispersal was from alfalfa to sorghum in both years. The peak dispersal from alfalfa to sorghum for *Cicindela*, *Cratacanthus*, *Cyclotrachelus*, *Poecilus*, and *Scarites* occurred in June of both years. This trend showed that semi-permanent alfalfa was being used as a refuge during soil preparation (tillage) and planting of sorghum in May. Following this initial peak in dispersal, data revealed continuous dispersal from alfalfa into sorghum over the entire growing season which is similar to results found by Prasifka and Heinz (2004). Their study detected an initial period of rapid dispersal of *H. convergens* into cotton (C_3) from sorghum or corn followed by five to six weeks of sustained dispersal from the C_4 crops into cotton.

Baseline Laboratory Isotope Study

The purpose of this feeding study was to estimate isotopic turnover rates between the P and R sub-sample tissues under controlled conditions. The expected outcome for the P sub-sample's SCIRs was to remain unchanged throughout the trial and the R sub-sample's SCIRs were predicted to shift towards the new diet isotope compositions over time. This turnover rate is the time it take tissues to completely exchange the isotope composition from a previous food source to that of a new isotopically different food source. This rate establishes a time frame that allows us to determine how much time passed since the diet switch. This information could be used to determine the length of residency within a habitat or how recently a beetle moved into a new habitat based on diet switching.

In general, carabids are not cultured in the laboratory due to their relatively long reproductive cycles, up to two years for some beetle species. This necessitated live-

trapping carabids from the Oklahoma State University Agronomy Research Station. Collecting started in mid-May and continued through early-September in both years. Only five of the eight study genera, *Calosoma*, *Cicindela*, *Cratacanthus*, *Poecilus*, and *Scarites* were trapped in sufficient numbers to conduct baseline study in both years. No *Cyclotrachelus*, *Pasimachus*, or *Tetracha* were trapped by any method employed; Consumption of the aphids during the lab study was evident; however, SCIR data indicated no turnover during the short experimental time-frame. Feeding intervals and the duration of this study were extrapolated from diet switching studies for ladybeetles, *Hippodamia convergens* Guerin (Prasifka et al. 2004), *Harmonia axyridis* (Pallas), *Hippodamia variegate* (Goeze), and *Coccinella septempunctata* (L.) (Ostrom et al. 1997, Gratton and Forbes 2006). Ostrom et al. (1997) found a 75% or greater shift in $\delta^{13}C$ and $\delta^{15}N$ during a diet switching study on *H. variegate*, fed on sorghum aphids and switched to pork liver, occurred within six and 21 days, respectively. If isotope turnover rates are known a priori it is possible to go back in time and space to estimate when and where the diet switch took place (Podlesak et al. 2005). Without these baseline turnover rates it is not possible to estimate length of residency in either alfalfa or sorghum. Though it is not possible at this time to determine how long field-caught carabids were in a particular habitat before their tissues assimilated the new isotope ratios; it is clear that for some beetles a change in habitat included a change in diet.

Diet Switching Between Alfalfa and Sorghum

This study documented carabid beetle diet switching between alfalfa and sorghum prey resources based on distinct differences among the SCIRs of these two sources. Utilizing isotopically discrete habitats maximized the period during which diet switching

could be detected in various carabid tissues. Therefore, greater differences were observed in the SCIRs of the P and R sub-sample reducing the effect of fractionation between tissues, diet mixing or non-equilibrium states among tissues. The metabolically inactive tissues, such as elytra, preserved past dietary histories. Conversely, metabolically active carabid tissues, such as flight muscles, reflect recent dietary intake. Gratton and Forbes (2006) found similar results by giving ladybeetles two different diet treatments over two weeks. Each *Harmonia axyridis* beetle sample was dissected into six different tissue samples; elytra, hind wings, legs, cuticular integument, flight muscles, and reproductive and fatty tissues for stable carbon isotope processing. These researchers determined that beetles collected just prior to the diet switch had tissues that were not isotopically different; however, after the switch from a soybean diet to a corn diet, tissues changed toward the new diet. In addition, they found isotope turnover rates were different for different tissues. For example, they determined that reproductive and fatty tissues assimilated the new isotope ratios faster than legs and hind wings.

There are three possible hypotheses first applied to ladybeetles that may explain why the number of carabid beetles showing complete diet switching was lower than expected (Krauter et al. 2001, Prasifka et al. 2004). First, constant beetle dispersal from alfalfa with depleted $\delta^{13}C$ values could dilute the expected enrichment with a diet switch from alfalfa aphids to sorghum aphids (Prasifka et al. 2004). This dilution effect would be from the higher number of new arrivals in sorghum that were trapped at higher frequencies when compared to sorghum residents. Secondly, diet switching may have been reduced due to very low prey availability in sorghum as a result of extreme weather conditions. Carabids may have not been feeding or were feeding at a low rate in sorghum

which could cause SCIRs to remain consistent with alfalfa. The application of this hypothesis can be clarified through DNA analysis of gut contents in future research. Finally, if carabids were moving between alfalfa and sorghum at the same rate and feeding in both habitats SCIRs may remain stable (Krauter et al. 2001). However, dispersal data indicate the majority of carabid movement was from alfalfa into sorghum over the entire growing season. Though some cyclic movement was taking place, data indicated that it was likely at low levels. Stable carbon isotope ratios did not increase or become more enriched over time in either year. In addition, aphid populations that were present decreased as the season continued and crop phenology changed. This last explanation does not fit with the data or field conditions as expected since carabids are polyphagous and feed on many different prey. Based on data from this study, the first hypothesis describing a dilution effect from higher trap frequency of new arrivals is the most likely explanation for the low number of carabids with complete diet switching.

Carabid Natal Origins and Larval Habitat Utilization

This study demonstrated that natal origins can be determined from carbon isotopic compositions transferred to adults from larval dietary intake. Subsequently, larval habitat use can be inferred from this data and movement of adult carabids away from their natal origins could be tracked. In this study, alfalfa appears to be the natal habitat for most individuals collected, and this semi-permanent crop is clearly a source for carabids in the agricultural landscape. Tallamy and Pesek (1996) found similar evidence in that larval luperine rootworms (Family: Chrysomelidae) pasted on their isotope compositions to the adult beetle. These researchers found that adult spotted cucumber beetles, *Diabrotica undecimpunctata howardii* Barber, elytra (-9.94 ±0.10‰) retained the isotopic

composition of its larva which fed only as a larva on corn roots (-9.63 ±0.17‰). Schallhart et al. (2009) found that the elytra of the adult click beetle, *Agriotes obscurus* (L.), contained the enriched isotopic composition of maize-fed larvae, whereas the adults of wheat-fed larvae reflected the depleted composition of wheat. This study was able to track adult male *A. obscurus* from a C_4 habitat to a nearby C_3 habitat based on isotope data from adult elytra.

A primary goal of insect ecology is to determine life histories and elucidate species' distribution patterns. The current study has utilized multiple techniques to accomplish this goal for carabid beetles in agroecosystems of the SGP. In this study it has been possible to determine the dispersal patterns and habitat utilization for individual carabid beetles. For example, carabid beetle #67 was a flightless (BR) female and appears to have been an egg and larva in alfalfa based on the isotope ratio of the P sub-sample tissues. This beetle moved into sorghum Plot NT5 and was trapped at 18.3m on Day 1of the colonization study. Beetle #67 selected treatment Plot NT5 which was one-year old no-till with sorghum stubble from the previous year under conventional-tillage. Based on the R sub-sample isotope ratio diet switching from prey in alfalfa to prey in sorghum was indicated. Data from these studies assist in determining what habitats carabids are utilizing for feeding, oviposition, larval development, and overwintering. Knowing what habitats are necessary for carabids to complete their life cycles could contribute to the information needed by IPM practitioners and producers' who make decisions to protect or enhance refuge habitats. By conserving these refuge areas, producers can potentially increase the biological control services provided by carabid beetles in diverse agricultural landscapes over multiple seasons in multiple crops.

CHAPTER VI

SUMMARY

In the Southern Great Plains, biological control of agricultural pests is common in annual cropping systems. Natural enemy assemblages have a regulating effect on pest populations which can maintain these densities below economic threshold levels. Carabidae constitute a major part of agricultural fauna and are an important part of natural enemy assemblages in agroecosystems (Fox and MacLellan 1956, Rivard 1964, Whitcomb and Bell 1964, Rivard 1965, 1966, Frank 1971, Kirk 1971, Esau and Peters 1975, Kendall 2003). Modern farming operations can threaten carabids in two major ways. First, monocultures and conventional-tillage dominate farming practices in the prairies of North America. These systems are characterized by vast acres of a single crop often resulting in increased fragmentation and isolation of suitable habitats necessary for carabid beetles to complete their life cycles. The second threat comes from the over-use of broad-spectrum insecticide, compulsory for pest management in monoculture systems, which reduce carabid efficacy as biological control agents (Los and Allen 1983, Marino and Landis 1996, Menalled et al. 1999a). Conservation of carabid beetles in agroecosystems is dependent on knowing their habitat requirements, understanding their

dispersal powers, and life cycles. However, carabid biology within diverse agricultural systems of the Southern Great Plains is not well studied. This research evaluated the impact of tillage on carabid biology, elucidated carabid dispersal powers in diversified agricultural system, clarified habitat and prey resources used by carabid beetles, and investigated natal origins.

This 2-year study has quantified carabid colonization of an annual crop (sorghum) from a semi-permanent habitat (alfalfa) as it related to wing morphology and disturbance (tillage). Colonization occurred quickly and carabids trapped were typical of agricultural systems in this region. Based on the experimental design, small scale colonization was measureable for some carabid genera, but the impact of wing morphology on the ability of a particular genus to colonize sorghum was undetectable in 2006. In 2007, colonization appeared to be dependent upon wing morphology; however, this effect may have been from over-representation of one morphological type.

No-till and conventional-tillage sorghum treatments were part of the experimental design, and there were no significant differences in total pitfall trap counts between no-till and conventional-tillage plots within years. Tillage effects, however, were detectable at the genus level in this study. Weather conditions may have had a direct effect on habitat selection or the lack of a preference by carabids in both years. Three habitats, no-till sorghum, conventionally-tilled sorghum or stands of alfalfa, were present in both years and alfalfa had the highest mean number of beetles trapped by date by plot in 2007. Based on an increased number of carabids trapped, two consecutive years of no-till sorghum appeared to provide a habitat that conserves carabids in diversified systems.

In this study, the clear differences between field alfalfa (C_3) and sorghum (C_4) isotope ratios met the requirement of using isotopically discrete habitats to elucidate dispersal of carabids among and between habitats as set forth in Prasifka and Heinz (2004). As expected, C_3 and C_4 plant stable carbon isotope compositions were reflected in host-specific aphids feeding on each crop. This study provided evidence that carabids were moving within and among sorghum and alfalfa with some indication of cyclic colonization. Tissues selected for this study, metabolically inactive tissues (elytra, hind wings, and pronotal exoskeleton) and metabolically active carabid tissues (flight muscles, reproductive tissues, and soft organs) provided appropriate temporal and spatial resolution for individual beetles. Isotope data revealed that alfalfa was a source of carabids to rapidly colonize sorghum and then continuously provided new colonizers over the growing season.

The utilization of a mass balance equation which estimates the proportional contribution from alfalfa and sorghum to the food web base of carabids increased resolution of dispersal patterns in both years. Additionally, dispersal and diet switching resolution where clarified when stable carbon isotope ratios are coupled with trap data. Carabid beetle diet switching was detected between alfalfa and sorghum prey resources based on distinct differences among the stable carbon isotope ratios of these two discrete ^{13}C habitats. Utilizing isotopically discrete habitats maximized the period during which diet switching could be detected in P (Past = slow/no tissue turnover) and R (Recent = Fast tissue turnover) sub-sample carabid tissues. Metabolically inactive tissues (P) retained past dietary information while metabolically active tissues (R) reflected recent dietary intake. Greater differences were observed in the stable carbon isotope ratios of the

P and R sub-sample tissues reducing the effect of fractionation between tissues, diet mixing or non-equilibrium states among tissues.

This study has demonstrated that natal origins can be determined from carbon isotopic compositions transferred to carabid adults from larval dietary intake. Subsequently, larval habitat and resource utilization has been inferred from this data and movement of adult carabids away from their natal origins was tracked. Natal origins indicated that alfalfa provided carabids with alternate prey, oviposition sites, overwintering habitat, and refuge from farming operations.

By understanding the environmental requirements of carabids, their conservation in diversified agricultural habitats may be enhanced. Researchers and producers have quantitative evidence that habitat diversity matters to carabid survival in the Southern Great Plains. Additionally, confirmation that carabid beetles utilize resources in both alfalfa and sorghum over the growing season has been provided. Alfalfa supplies carabids with alternative prey and a variety of microhabitats for oviposition sites where emerged larvae can survive with minimal disturbance. Utilizing alfalfa as a semi-permanent refuge habitat for natural enemies maintains crop land in production while enhancing local carabid beetle populations. Knowing what habitats are necessary for carabids to complete their life cycle contributes to the information needed by IPM practitioners and producers' who make decisions to protect or enhance refuge habitats. By conserving semi-permanent (alfalfa), producers can potentially increase the biological control services provided by carabid beetles in diverse agricultural landscapes over multiple seasons.

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APPPENDIX A

Stable carbon isotope values for the P and R sub-sample tissues in 2006.

DATE	TRAP #	PLOT	GENUS	SEX	WING	P-Sample $\delta^{13}C$	R-Sample $\delta^{13}C$
6/9/2006	A 6	NT1	Cratacanthus	M	Ma	-22.25	-22.30
6/9/2006	A 17	CT2	Cyclotrachelus	F	Br	-20.89	-23.09
6/9/2006	A 46	CT5	Cratacanthus	F	Ma	-14.12	-14.12
6/9/2006	A 47	CT5	Cicindela	M	Ma	-22.23	-22.84
6/9/2006	B 3	NT1	Cicindela	M	Ma	-25.70	-25.94
6/9/2006	B 7	NT1	Scarites	U	Ma	-23.53	-25.04
6/9/2006	B 13	CT2	Cratacanthus	F	Ma	-26.82	-29.03
6/9/2006	B 33	CT4	Scarites	U	Ma	-26.80	-26.71
6/9/2006	B 37	CT4	Scarites	M	Ma	-28.06	-28.05
6/9/2006	B 45	CT5	Scarites	M	Ma	-26.25	-26.58
6/9/2006	B 47	CT5	Scarites	M	Ma	-26.89	-27.08
6/9/2006	BA 1	AL	Cicindela	M	Ma	-24.05	-24.86
6/9/2006	BA 6	AL	Cratacanthus	F	Br	-25.57	-26.27
6/9/2006	BA 6	AL	Poecilus	F	Ma	-25.60	-25.96
6/9/2006	BA 6	AL	Scarites	F	Ma	-25.26	-25.69
6/9/2006	BA 6	AL	Scarites	M	Ma	-27.41	-27.68
6/9/2006	C 7	NT1	Cratacanthus	F	Ma	-23.21	-24.12
6/9/2006	C 16	CT2	Cratacanthus	M	Ma	-25.82	-25.96
6/9/2006	C 25	CT3	Cratacanthus	F	Ma	-28.06	-26.89
6/9/2006	C 26	CT3	Scarites	F	Ma	-27.45	-27.54
6/9/2006	C 33	CT4	Scarites	U	Ma	-25.48	-25.79
6/9/2006	C 35	CT4	Scarites	M	Ma	-20.24	-20.54
6/9/2006	C 35	CT4	Cratacanthus	M	Ma	-27.30	-25.67
6/9/2006	C 43	CT5	Cyclotrachelus	F	Br	-24.38	-24.16
6/9/2006	C 45	CT5	Cratacanthus	M	Ma	-26.18	-28.39
6/9/2006	C 46	CT5	Cratacanthus	F	Br	-28.42	-17.07
6/9/2006	CA 6	AL	Cicindela	U	Ma	-24.23	-24.04
6/9/2006	CA 6	AL	Cratacanthus	F	Ma	-17.36	-15.91
6/10/2006	A 16	CT2	Scarites	F	Ma	-24.32	-25.42
6/10/2006	A 17	CT2	Cicindela	M	Ma	-23.85	-24.14

6/10/2006	A	17	CT2	Cratacanthus	M	Ma	-16.74	-26.50
6/10/2006	B	6	NT1	Pasimachus	F	Br	-26.29	-26.39
6/10/2006	B	25	CT3	Scarites	F	Ma	-26.35	-26.45
6/10/2006	B	47	CT5	Scarites	M	Ma	-25.79	-25.87
6/10/2006	BA	6	AL	Scarites	U	Ma	-25.48	-25.82
6/10/2006	BA	6	AL	Poecilus	M	Ma	-20.24	-20.22
6/10/2006	C	7	NT1	Cratacanthus	F	Ma	-27.54	-27.96
6/10/2006	C	16	CT2	Cratacanthus	F	Br	-26.35	-26.94
6/10/2006	C	17	CT2	Cratacanthus	F	Ma	-26.88	-27.34
6/10/2006	C	26	CT3	Cyclotrachelus	M	Br	-22.72	-21.96
6/10/2006	C	27	CT3	Cratacanthus	F	Ma	-28.13	-28.41
6/10/2006	C	33	CT4	Scarites	M	Ma	-27.60	-26.44
6/10/2006	C	35	CT4	Cratacanthus	F	Br	-27.35	-28.44
6/10/2006	C	36	CT4	Cratacanthus	M	Br	-26.39	-26.54
6/10/2006	C	43	CT5	Cratacanthus	M	Ma	-26.22	-26.53
6/10/2006	C	46	CT5	Cratacanthus	M	Ma	-26.55	-26.62
6/11/2006	A	3	NT1	Cratacanthus	F	Ma	-26.62	-27.17
6/11/2006	A	17	CT2	Cicindela	F	Ma	-23.71	-23.90
6/11/2006	A	17	CT2	Cratacanthus	M	Ma	-24.75	-24.96
6/11/2006	A	25	CT3	Cicindela	M	Ma	-23.83	-24.76
6/11/2006	A	26	CT3	Poecilus	F	Ma	-24.99	-25.46
6/11/2006	A	33	CT4	Cyclotrachelus	F	Br	-22.07	-22.92
6/11/2006	A	36	CT4	Cratacanthus	M	Ma	-26.66	-27.63
6/11/2006	A	37	CT4	Cyclotrachelus	F	Br	-25.61	-26.07
6/11/2006	A	45	CT5	Scarites	F	Ma	-22.55	-23.74
6/11/2006	A	47	CT5	Scarites	F	Ma	-23.48	-25.69
6/11/2006	B	15	CT2	Poecilus	F	Ma	-26.47	-26.65
6/11/2006	B	27	CT3	Scarites	M	Ma	-25.71	-26.65
6/11/2006	BA	2	AL	Pasimachus	M	Br	-23.98	-25.75
6/11/2006	BA	6	AL	Poecilus	F	Ma	-24.81	-25.59
6/11/2006	C	7	NT1	Cratacanthus	M	UK	-26.08	-26.39
6/11/2006	C	15	CT2	Scarites	M	Ma	-20.39	-21.40
6/11/2006	C	26	CT3	Cratacanthus	F	UK	-25.94	-26.92
6/11/2006	C	27	CT3	Cratacanthus	M	Br	-26.91	-27.15
6/11/2006	C	27	CT3	Scarites	F	Ma	-24.87	-26.94
6/11/2006	C	33	CT4	Cyclotrachelus	M	Br	-24.08	-24.69
6/11/2006	C	35	CT4	Cratacanthus	F	Ma	-27.59	-28.57
6/11/2006	C	43	CT5	Cratacanthus	M	UK	-25.81	-28.14
6/11/2006	CA	2	AL	Cratacanthus	F	Ma	-14.45	-16.37
6/11/2006	CA	2	AL	Cyclotrachelus	M	Br	-24.29	-25.62
6/12/2006	A	15	CT2	Scarites	M	Ma	-24.64	-27.15

6/12/2006	A	16	CT2	Cratacanthus	F	Ma	-26.11	-26.18
6/12/2006	A	16	CT2	Cyclotrachelus	M	Br	-23.80	-24.88
6/12/2006	A	16	CT2	Scarites	M	Ma	-24.93	-22.62
6/12/2006	A	17	CT2	Cratacanthus	M	Ma	-16.10	-17.43
6/12/2006	A	17	CT2	Cicindela	M	Ma	-24.68	-25.53
6/12/2006	A	17	CT2	Calosoma	M	Ma	-29.19	-30.28
6/12/2006	A	37	CT4	Cratacanthus	M	Ma	-15.87	-18.61
6/12/2006	A	47	CT5	Scarites	F	Ma	-25.91	-27.30
6/12/2006	B	6	NT1	Cratacanthus	F	Ma	-27.46	-27.34
6/12/2006	B	13	CT2	Cratacanthus	F	Ma	-23.84	-23.96
6/12/2006	B	17	CT2	Cratacanthus	M	Ma	-25.56	-25.45
6/12/2006	B	17	CT2	Scarites	F	Ma	-23.38	-24.57
6/12/2006	BA	6	AL	Poecilus	F	Ma	-25.39	-25.83
6/12/2006	C	7	NT1	Cratacanthus	F	Ma	-17.58	-18.31
6/12/2006	C	13	CT2	Cratacanthus	M	Br	-26.94	-27.34
6/12/2006	C	13	CT2	Scarites	M	Ma	-21.37	-24.76
6/12/2006	C	17	CT2	Cyclotrachelus	M	Br	-24.28	-24.93
6/12/2006	C	26	CT3	Scarites	M	Ma	-25.42	-27.38
6/12/2006	C	27	CT3	Cratacanthus	M	Ma	-23.97	-24.71
6/12/2006	C	35	CT4	Cratacanthus	F	Ma	-27.51	-27.95
6/12/2006	C	45	CT5	Cratacanthus	M	Br	-25.71	-25.30
6/12/2006	C	45	CT5	Scarites	F	Ma	-26.18	-25.34
6/13/2006	A	16	CT2	Cratacanthus	M	Ma	-26.91	-25.99
6/13/2006	A	43	CT5	Cratacanthus	M	Ma	-22.32	-22.81
6/13/2006	A	45	CT5	Cyclotrachelus	F	Br	-26.25	-27.36
6/13/2006	BA	6	AL	Poecilus	F	Ma	-24.92	-25.09
6/13/2006	C	7	NT1	Cratacanthus	F	Ma	-24.97	-24.37
6/13/2006	C	17	CT2	Cratacanthus	M	Ma	-26.03	-26.61
6/13/2006	C	25	CT3	Cratacanthus	F	Ma	-27.61	-27.49
6/13/2006	C	26	CT3	Scarites	F	Ma	-19.00	-22.35
6/13/2006	C	33	CT4	Cratacanthus	F	Br	-26.75	-27.16
6/13/2006	C	37	CT4	Cratacanthus	F	Ma	-27.25	-26.26
6/13/2006	C	43	CT5	Cratacanthus	F	Ma	-15.89	-16.00
6/13/2006	C	45	CT5	Cratacanthus	F	Ma	-27.16	-27.66
6/13/2006	C	46	CT5	Cratacanthus	F	Ma	-26.36	-25.96
6/13/2006	C	47	CT5	Cratacanthus	F	Ma	-27.67	-28.06
6/14/2006	A	3	NT1	Poecilus	F	Ma	-23.38	-22.49
6/14/2006	A	15	CT2	Scarites	F	Ma	-26.06	-27.47
6/14/2006	A	33	CT4	Scarites	M	Ma	-21.35	-23.11
6/14/2006	A	45	CT5	Cicindela	F	Ma	-19.73	-21.77

6/14/2006	A	47	CT5	Tetracha	F	Ma	-23.67	-25.00
6/14/2006	B	26	CT3	Scarites	M	Ma	-26.90	-27.81
6/14/2006	BA	1	AL	Cicindela	M	Ma	-27.38	-27.06
6/14/2006	BA	9	AL	Scarites	F	Ma	-25.56	-26.32
6/14/2006	C	7	NT1	Cratacanthus	M	Ma	-23.57	-24.65
6/14/2006	C	16	CT2	Cratacanthus	M	Br	-19.97	-21.30
6/14/2006	C	17	CT2	Cratacanthus	M	Ma	-15.38	-14.66
6/14/2006	C	25	CT3	Cratacanthus	M	Ma	-25.68	-25.63
6/14/2006	C	27	CT3	Cratacanthus	F	Ma	-27.14	-26.26
6/14/2006	C	46	CT5	Cratacanthus	F	Ma	-27.23	-27.75
6/15/2006	A	6	NT1	Cratacanthus	F	Ma	-24.65	-24.87
6/15/2006	B	17	CT2	Cratacanthus	F	Ma	-25.85	-25.33
6/15/2006	C	7	NT1	Cratacanthus	F	Ma	-27.22	-27.02
6/15/2006	C	15	CT2	Scarites	F	Ma	-22.10	-25.49
6/15/2006	C	15	CT2	Cicindela	F	Ma	-23.92	-24.30
6/15/2006	C	26	CT3	Scarites	F	Ma	-24.85	-25.40
6/15/2006	C	27	CT3	Cratacanthus	M	Br	-27.23	-27.89
6/15/2006	C	27	CT3	Scarites	M	Ma	-25.39	-25.15
6/15/2006	C	46	CT5	Cratacanthus	F	Ma	-28.13	-27.66
6/15/2006	C	47	CT5	Cratacanthus	M	Ma	-27.22	-27.79
6/15/2006	C	47	CT5	Scarites	M	Ma	-26.54	-26.58
6/23/2006	A	3	NT1	Tetracha	F	Ma	-25.96	-26.19
6/23/2006	A	5	NT1	Tetracha	M	Ma	-25.17	-25.89
6/23/2006	A	5	NT1	Cyclotrachelus	M	Br	-25.34	-26.93
6/23/2006	A	5	NT1	Cicindela	M	Ma	-22.10	-23.67
6/23/2006	A	5	NT1	Scarites	M	Ma	-24.61	-25.02
6/23/2006	A	6	NT1	Scarites	F	Ma	-24.32	-25.91
6/23/2006	A	7	NT1	Tetracha	M	Ma	-25.23	-28.13
6/23/2006	A	13	CT2	Tetracha	F	Ma	-22.15	-24.38
6/23/2006	A	15	CT2	Cicindela	F	Ma	-28.01	-25.07
6/23/2006	A	15	CT2	Tetracha	M	Ma	-23.91	-25.65
6/23/2006	A	16	CT2	Cratacanthus	F	Ma	-16.18	-15.59
6/23/2006	A	16	CT2	Scarites	F	Ma	-23.40	-24.41
6/23/2006	A	17	CT2	Cratacanthus	M	Br	-18.69	-19.64
6/23/2006	A	17	CT2	Tetracha	M	Ma	-24.74	-25.55
6/23/2006	A	23	CT3	Cicindela	M	Ma	-21.75	-23.04
6/23/2006	A	23	CT3	Tetracha	F	Ma	-22.03	-23.70
6/23/2006	A	25	CT3	Cicindela	M	Ma	-22.36	-24.08
6/23/2006	A	25	CT3	Tetracha	M	Ma	-16.89	-20.10
6/23/2006	A	27	CT3	Cratacanthus	F	Ma	-25.73	-26.81
6/23/2006	A	27	CT3	Cicindela	F	Ma	-25.35	-24.77

6/23/2006	A	33	CT4	Tetracha	F	Ma	-28.03	-25.70
6/23/2006	A	35	CT4	Scarites	M	Ma	-26.39	-28.79
6/23/2006	A	36	CT4	Tetracha	M	Ma	-25.53	-26.69
6/23/2006	A	37	CT4	Tetracha	M	Ma	-25.43	-26.65
6/23/2006	A	43	CT5	Cyclotrachelus	F	Br	-25.07	-25.57
6/23/2006	A	43	CT5	Tetracha	F	Ma	-25.09	-28.00
6/23/2006	A	45	CT5	Cratacanthus	F	Ma	-17.62	-19.36
6/23/2006	A	45	CT5	Tetracha	M	Ma	-24.48	-26.94
6/23/2006	A	46	CT5	Scarites	F	Ma	-24.80	-24.30
6/23/2006	A	46	CT5	Tetracha	M	Ma	-24.49	-26.02
6/23/2006	A	47	CT5	Cratacanthus	M	Ma	-18.33	-18.68
6/23/2006	A	47	CT5	Cicindela	M	Ma	-22.06	-24.21
6/23/2006	A	47	CT5	Tetracha	M	Ma	-19.60	-22.24
6/23/2006	AA	1	AL	Scarites	F	Ma	-25.90	-27.77
6/23/2006	AA	2	AL	Cicindela	F	Ma	-23.06	-24.50
6/23/2006	AA	2	AL	Tetracha	F	Ma	-24.12	-25.69
6/23/2006	AA	6	AL	Tetracha	M	Ma	-25.91	-26.24
6/23/2006	B	3	NT1	Cicindela	F	Ma	-20.18	-21.89
6/23/2006	B	5	NT1	Cratacanthus	M	Br	-20.76	-22.73
6/23/2006	B	5	NT1	Cicindela	F	Ma	-21.15	-23.79
6/23/2006	B	6	NT1	Cratacanthus	M	Ma	-29.04	-27.04
6/23/2006	B	7	NT1	Cratacanthus	F	Ma	-26.20	-26.92
6/23/2006	B	13	CT2	Cratacanthus	F	Ma	-26.05	-26.86
6/23/2006	B	16	CT2	Cratacanthus	F	Ma	-14.55	-16.23
6/23/2006	B	17	CT2	Cyclotrachelus	M	Br	-22.32	-24.87
6/23/2006	B	17	CT2	Cratacanthus	F	Ma	-19.63	-20.35
6/23/2006	B	23	CT3	Scarites	M	Ma	-26.24	-27.76
6/23/2006	B	43	CT5	Scarites	M	Ma	-26.42	-29.44
6/23/2006	B	43	CT5	Tetracha	F	Ma	-19.08	-21.17
6/23/2006	B	43	CT5	Cratacanthus	F	Ma	-24.57	-24.97
6/23/2006	B	46	CT5	Tetracha	F	Ma	-26.73	-27.62
6/23/2006	B	46	CT5	Cratacanthus	M	Ma	-26.85	-26.26
6/23/2006	B	47	CT5	Tetracha	F	Ma	-21.39	-24.24
6/23/2006	BA	1	AL	Tetracha	M	Ma	-23.90	-25.75
6/23/2006	BA	1	AL	Tetracha	F	Ma	-27.54	-29.22
6/23/2006	BA	2	AL	Cratacanthus	M	Ma	-23.30	-26.85
6/23/2006	BA	6	AL	Scarites	F	Ma	-26.35	-26.36
6/23/2006	BA	6	AL	Poecilus	F	Ma	-26.45	-27.03
6/23/2006	BA	9	AL	Cratacanthus	F	Ma	-18.45	-20.04
6/23/2006	BA	9	AL	Tetracha	F	Ma	-25.38	-25.38
6/23/2006	BA	9	AL	Scarites	F	Ma	-20.31	-21.64

6/23/2006	BA	9	AL	Tetracha	F	Ma	-18.43	-18.31
6/23/2006	BA	10	AL	Tetracha	M	Ma	-26.98	-27.41
6/23/2006	C	5	NT1	Cratacanthus	M	Ma	-25.20	-26.22
6/23/2006	C	5	NT1	Tetracha	M	Ma	-23.64	-25.38
6/23/2006	C	6	NT1	Cratacanthus	F	Br	-27.69	-29.04
6/23/2006	C	7	NT1	Pasimachus	F	Br	-22.05	-27.74
6/23/2006	C	7	NT1	Cratacanthus	F	Ma	-26.53	-27.97
6/23/2006	C	13	CT2	Cratacanthus	F	Br	-27.81	-27.72
6/23/2006	C	15	CT2	Cratacanthus	F	Ma	-27.04	-27.27
6/23/2006	C	16	CT2	Cratacanthus	M	Ma	-23.06	-22.40
6/23/2006	C	17	CT2	Cratacanthus	M	Br	-17.06	-18.68
6/23/2006	C	17	CT2	Tetracha	F	Ma	-26.51	-27.58
6/23/2006	C	17	CT2	Cicindela	F	Ma	-24.74	-26.11
6/23/2006	C	23	CT3	Pasimachus	M	Br	-15.76	-21.84
6/23/2006	C	23	CT3	Tetracha	F	Ma	-26.07	-27.31
6/23/2006	C	25	CT3	Scarites	F	Ma	-28.52	-27.85
6/23/2006	C	25	CT3	Cratacanthus	F	Ma	-16.12	-17.59
6/23/2006	C	26	CT3	Tetracha	F	Ma	-26.10	-27.26
6/23/2006	C	26	CT3	Cratacanthus	F	Ma	-19.04	-19.35
6/23/2006	C	27	CT3	Scarites	M	Ma	-26.31	-28.21
6/23/2006	C	27	CT3	Tetracha	M	Ma	-21.01	-23.33
6/23/2006	C	27	CT3	Cratacanthus	F	Br	-26.08	-26.47
6/23/2006	C	33	CT4	Cratacanthus	F	Br	-27.28	-28.47
6/23/2006	C	36	CT4	Tetracha	F	Ma	-25.50	-26.45
6/23/2006	C	36	CT4	Cratacanthus	M	Ma	-26.82	-28.65
6/23/2006	C	37	CT4	Tetracha	F	Ma	-29.08	-26.54
6/23/2006	C	37	CT4	Cratacanthus	F	Ma	-20.04	-21.47
6/23/2006	C	43	CT5	Cratacanthus	M	Ma	-19.09	-20.10
6/23/2006	C	43	CT5	Cicindela	F	Ma	-20.41	-22.81
6/23/2006	C	45	CT5	Cratacanthus	M	Ma	-28.81	-28.77
6/23/2006	C	46	CT5	Tetracha	M	Ma	-25.26	-26.33
6/23/2006	C	46	CT5	Cratacanthus	F	Ma	-25.08	-26.37
6/23/2006	C	47	CT5	Cratacanthus	F	Ma	-24.84	-25.16
6/23/2006	C	47	CT5	Tetracha	F	Ma	-26.87	-27.68
6/23/2006	CA	6	AL	Tetracha	M	Ma	-25.16	-26.42
6/23/2006	CA	6	AL	Cicindela	M	Ma	-26.57	-24.40
6/23/2006	CA	6	AL	Tetracha	F	Ma	-25.73	-25.79
6/23/2006	CA	6	AL	Pasimachus	F	Br	-15.76	-22.17
6/23/2006	CA	6	AL	Cyclotrachelus	M	Br	-23.85	-24.00
6/23/2006	CA	6	AL	Scarites	F	Ma	-25.28	-26.95
6/23/2006	CA	6	AL	Cratacanthus	M	Ma	-22.14	-22.27

6/23/2006	CA	9	AL	Cratacanthus	M	Ma	-18.52	-20.86
6/23/2006	CA	9	AL	Cyclotrachelus	M	Br	-24.24	-26.75
6/23/2006	CA	10	AL	Cratacanthus	M	Ma	-16.04	-17.91
6/23/2006	CA	10	AL	Tetracha	F	Ma	-25.57	-27.99
6/23/2006	CA	10	AL	Cicindela	F	Ma	-23.91	-25.02
6/25/2006	A	3	NT1	Cicindela	M	Ma	-21.06	-22.90
6/25/2006	A	5	NT1	Tetracha	F	Ma	-22.18	-23.04
6/25/2006	A	7	NT1	Cicindela	F	Ma	-31.10	-27.59
6/25/2006	A	15	CT2	Cratacanthus	M	Ma	-15.78	-17.94
6/25/2006	A	15	CT2	Cicindela	M	Ma	-21.24	-22.34
6/25/2006	A	16	CT2	Cratacanthus	F	Ma	-26.43	-27.45
6/25/2006	A	16	CT2	Tetracha	F	Ma	-25.47	-26.24
6/25/2006	A	17	CT2	Cicindela	F	Ma	-25.38	-25.52
6/25/2006	A	23	CT3	Cicindela	F	Ma	-22.57	-22.74
6/25/2006	A	26	CT3	Cicindela	M	Ma	-27.60	-25.65
6/25/2006	A	26	CT3	Cratacanthus	F	Ma	-25.34	-25.31
6/25/2006	A	27	CT3	Cratacanthus	M	Ma	-26.38	-25.45
6/25/2006	A	35	CT4	Cicindela	F	Ma	-19.83	-21.26
6/25/2006	A	36	CT4	Tetracha	M	Ma	-26.02	-26.82
6/25/2006	A	43	CT5	Tetracha	F	Ma	-23.78	-23.93
6/25/2006	A	45	CT5	Cratacanthus	F	Ma	-25.41	-25.98
6/25/2006	A	45	CT5	Cicindela	M	Ma	-25.69	-25.10
6/25/2006	A	46	CT5	Tetracha	M	Ma	-26.16	-26.97
6/25/2006	A	47	CT5	Cratacanthus	F	Ma	-17.83	-20.13
6/25/2006	A	47	CT5	Tetracha	F	Ma	-22.14	-24.17
6/25/2006	AA	1	AL	Tetracha	M	Ma	-25.14	-25.28
6/25/2006	AA	2	AL	Tetracha	F	Ma	-25.25	-25.62
6/25/2006	AA	6	AL	Tetracha	M	Ma	-20.91	-21.92
6/25/2006	AA	9	AL	Cicindela	M	Ma	-18.95	-20.24
6/25/2006	B	16	CT2	Cratacanthus	F	Ma	-25.58	-25.99
6/25/2006	B	17	CT2	Cratacanthus	F	Ma	-15.81	-17.35
6/25/2006	B	26	CT3	Tetracha	F	Ma	-24.62	-25.06
6/25/2006	B	27	CT3	Cratacanthus	M	Ma	-16.32	-17.87
6/25/2006	B	35	CT4	Scarites	M	Ma	-26.91	-29.38
6/25/2006	B	35	CT4	Cratacanthus	M	Ma	-26.14	-26.55
6/25/2006	B	43	CT5	Cratacanthus	M	Ma	-20.54	-21.12
6/25/2006	B	45	CT5	Scarites	F	Ma	-26.25	-27.36
6/25/2006	B	46	CT5	Tetracha	F	Ma	-26.46	-27.71
6/25/2006	BA	1	AL	Cicindela	M	Ma	-24.85	-25.80
6/25/2006	BA	1	AL	Tetracha	F	Ma	-22.28	-24.54
6/25/2006	BA	2	AL	Cratacanthus	M	Ma	-25.90	-26.85

6/25/2006	BA	6	AL	Tetracha	M	Ma	-26.24	-27.19
6/25/2006	BA	6	AL	Cratacanthus	M	Ma	-25.49	-27.48
6/25/2006	BA	6	AL	Poecilus	F	Ma	-26.80	-27.64
6/25/2006	BA	9	AL	Tetracha	F	Ma	-24.90	-27.44
6/25/2006	BA	9	AL	Cratacanthus	M	Ma	-24.39	-24.85
6/25/2006	BA	10	AL	Tetracha	M	Ma	-27.57	-27.53
6/25/2006	C	7	NT1	Cratacanthus	F	Br	-23.72	-25.73
6/25/2006	C	15	CT2	Pasimachus	F	Br	-22.32	-25.18
6/25/2006	C	15	CT2	Tetracha	F	Ma	-24.15	-25.45
6/25/2006	C	15	CT2	Cratacanthus	F	Ma	-14.34	-16.23
6/25/2006	C	16	CT2	Cratacanthus	M	Br	-27.64	-28.79
6/25/2006	C	25	CT3	Cratacanthus	F	Ma	-14.25	-20.34
6/25/2006	C	26	CT3	Cratacanthus	M	Ma	-25.34	-26.04
6/25/2006	C	28	CT3	Cratacanthus	M	Ma	-24.55	-25.30
6/25/2006	C	33	CT4	Tetracha	F	Ma	-23.39	-25.09
6/25/2006	C	36	CT4	Cratacanthus	M	Ma	-26.22	-26.83
6/25/2006	C	37	CT4	Tetracha	F	Ma	-22.01	-23.03
6/25/2006	C	37	CT4	Cratacanthus	F	Ma	-24.83	-26.16
6/25/2006	C	43	CT5	Cratacanthus	F	Ma	-26.30	-26.44
6/25/2006	C	45	CT5	Cratacanthus	F	Ma	-16.19	-16.32
6/25/2006	C	46	CT5	Tetracha	F	Ma	-26.48	-27.38
6/25/2006	C	46	CT5	Cratacanthus	F	Ma	-26.08	-27.37
6/25/2006	C	47	CT5	Cratacanthus	F	Ma	-17.47	-20.13
6/25/2006	CA	1	AL	Pasimachus	M	Br	-22.27	-24.27
6/25/2006	CA	6	AL	Scarites	F	Ma	-26.53	-26.95
6/25/2006	CA	6	AL	Cratacanthus	M	Ma	-14.67	-16.46
6/27/2006	A	7	NT1	Scarites	M	Ma	-23.55	-23.22
6/27/2006	A	13	CT2	Cicindela	M	Ma	-19.28	-18.92
6/27/2006	A	16	CT2	Cicindela	M	Ma	-23.13	-23.15
6/27/2006	A	23	CT3	Tetracha	M	Ma	-27.58	-28.43
6/27/2006	A	25	CT3	Tetracha	M	Ma	-25.42	-26.87
6/27/2006	A	25	CT3	Cicindela	M	Ma	-25.31	-25.28
6/27/2006	A	26	CT3	Cratacanthus	F	Ma	-14.41	-16.50
6/27/2006	A	27	CT3	Cyclotrachelus	F	Br	-18.28	-19.90
6/27/2006	A	37	CT4	Cratacanthus	F	Ma	-23.94	-24.75
6/27/2006	A	43	CT5	Tetracha	M	Ma	-20.77	-22.46
6/27/2006	A	43	CT5	Cratacanthus	F	Ma	-24.17	-26.90
6/27/2006	A	45	CT5	Tetracha	F	Ma	-23.49	-25.43
6/27/2006	A	46	CT5	Cicindela	F	Ma	-25.23	-25.95
6/27/2006	AA	9	AL	Tetracha	M	Ma	-26.58	-26.57
6/27/2006	AA	10	AL	Tetracha	M	Ma	-23.46	-24.21
6/27/2006	AA	10	AL	Cratacanthus	M	Ma	-24.79	-20.68

6/27/2006	B	26	CT3	Cratacanthus	M	Ma	-26.63	-26.22
6/27/2006	C	7	NT1	Cratacanthus	F	Ma	-27.11	-28.49
6/27/2006	C	15	CT2	Cratacanthus	M	Ma	-26.24	-27.21
6/27/2006	C	16	CT2	Cratacanthus	M	Ma	-27.85	-27.37
6/27/2006	C	26	CT3	Cratacanthus	F	Ma	-20.40	-18.12
6/27/2006	C	27	CT3	Scarites	F	Ma	-26.11	-26.63
6/27/2006	C	36	CT4	Cratacanthus	M	Ma	-25.73	-27.69
6/27/2006	C	37	CT4	Cratacanthus	F	Ma	-15.87	-16.81
6/27/2006	C	45	CT5	Cratacanthus	F	Ma	-24.01	-24.15
6/27/2006	C	47	CT5	Cyclotrachelus	M	Br	-24.23	-24.47
6/27/2006	C	47	CT5	Cratacanthus	M	Ma	-25.26	-25.12
6/27/2006	CA	2	AL	Cratacanthus	F	Ma	-25.54	-25.87
6/27/2006	CA	6	AL	Cratacanthus	F	Ma	-21.79	-22.40
6/27/2006	CA	6	AL	Tetracha	M	Ma	-28.92	-27.47
6/29/2006	A	5	NT1	Cicindela	M	Ma	-25.14	-27.11
6/29/2006	A	7	NT1	Cratacanthus	M	Ma	-30.21	-34.75
6/29/2006	A	13	CT2	Pasimachus	M	Br	-21.77	-24.50
6/29/2006	A	17	CT2	Cicindela	F	Ma	-18.97	-21.99
6/29/2006	A	23	CT3	Cratacanthus	F	Ma	-26.47	-26.59
6/29/2006	A	25	CT3	Cratacanthus	F	Ma	-26.20	-27.05
6/29/2006	A	25	CT3	Cicindela	M	Ma	-22.15	-21.60
6/29/2006	A	26	CT3	Cratacanthus	F	Ma	-23.76	-24.70
6/29/2006	A	26	CT3	Cicindela	M	Ma	-24.36	-24.33
6/29/2006	A	27	CT3	Cicindela	M	Ma	-27.72	-31.81
6/29/2006	A	33	CT4	Cratacanthus	M	Ma	-25.67	-26.36
6/29/2006	A	35	CT4	Cratacanthus	M	Ma	-13.94	-15.07
6/29/2006	A	36	CT4	Cicindela	M	Ma	-22.68	-23.69
6/29/2006	A	43	CT5	Cicindela	M	Ma	-22.18	-22.97
6/29/2006	A	45	CT5	Tetracha	M	Ma	-23.90	-24.37
6/29/2006	A	46	CT5	Cratacanthus	M	Ma	-24.33	-25.43
6/29/2006	A	47	CT5	Tetracha	M	Ma	-26.99	-27.16
6/29/2006	B	15	CT2	Cratacanthus	F	Ma	-25.27	-24.29
6/29/2006	B	23	CT3	Cratacanthus	M	Ma	-22.67	-23.77
6/29/2006	B	37	CT4	Scarites	M	Ma	-21.29	-21.40
6/29/2006	B	45	CT5	Tetracha	F	Ma	-23.56	-25.45
6/29/2006	BA	6	AL	Scarites	M	Ma	-26.51	-25.86
6/29/2006	BA	9	AL	Tetracha	F	Ma	-26.73	-26.64
6/29/2006	C	17	CT2	Cicindela	F	Ma	-24.39	-22.18
6/29/2006	C	27	CT3	Cyclotrachelus	F	Br	-23.28	-25.39
6/29/2006	C	37	CT4	Cratacanthus	F	Ma	-26.34	-26.70
6/29/2006	C	43	CT5	Cratacanthus	F	Ma	-22.72	-24.40
6/29/2006	CA	6	AL	Tetracha	M	Ma	-24.62	-25.28
7/1/2006	A	7	NT1	Cicindela	M	Ma	-23.96	-24.10

7/1/2006	A	13	CT2	Tetracha	F	Ma	-23.45	-24.37
7/1/2006	A	13	CT2	Cicindela	M	Ma	-22.57	-22.48
7/1/2006	A	17	CT2	Cratacanthus	M	Ma	-19.76	-19.64
7/1/2006	A	23	CT3	Cratacanthus	F	Ma	-25.53	-26.69
7/1/2006	A	33	CT4	Tetracha	M	Ma	-25.44	-25.60
7/1/2006	A	33	CT4	Cratacanthus	F	Ma	-25.86	-25.59
7/1/2006	A	36	CT4	Cratacanthus	F	Ma	-18.58	-19.28
7/1/2006	A	45	CT5	Cratacanthus	F	Ma	-24.51	-25.59
7/1/2006	AA	6	AL	Cratacanthus	M	Ma	-15.29	-15.61
7/1/2006	B	16	CT2	Tetracha	M	Ma	-26.40	-26.30
7/1/2006	BA	9	AL	Tetracha	M	Ma	-26.59	-27.10
7/1/2006	C	5	NT1	Cratacanthus	M	Ma	-14.29	-14.75
7/1/2006	C	15	CT2	Tetracha	F	Ma	-26.51	-26.89
7/1/2006	C	15	CT2	Cratacanthus	F	Ma	-22.69	-23.79
7/1/2006	C	17	CT2	Pasimachus	F	Br	-22.33	-23.06
7/1/2006	CA	2	AL	Pasimachus	F	Br	-18.41	-20.75
7/1/2006	CA	9	AL	Cratacanthus	F	Br	-17.15	-21.29
7/14/2006	A	3	NT1	Cicindela	M	Ma	-25.08	-25.05
7/14/2006	A	3	NT1	Tetracha	F	Ma	-18.26	-18.93
7/14/2006	A	6	NT1	Tetracha	M	Ma	-21.28	-20.83
7/14/2006	A	6	NT1	Cicindela	M	Ma	-25.36	-24.89
7/14/2006	A	7	NT1	Cicindela	M	Ma	-23.61	-23.50
7/14/2006	A	13	CT2	Cicindela	M	Ma	-22.88	-23.51
7/14/2006	A	15	CT2	Cicindela	M	Ma	-21.78	-21.65
7/14/2006	A	16	CT2	Cicindela	M	Ma	-22.12	-24.09
7/14/2006	A	23	CT3	Cicindela	M	Ma	-22.79	-25.55
7/14/2006	A	25	CT3	Cicindela	M	Ma	-23.10	-24.62
7/14/2006	A	25	CT3	Cratacanthus	F	Br	-15.28	-18.20
7/14/2006	A	26	CT3	Cicindela	M	Ma	-28.17	-23.00
7/14/2006	A	26	CT3	Cratacanthus	F	Ma	-25.50	-26.74
7/14/2006	A	27	CT3	Cratacanthus	F	Ma	-26.01	-26.44
7/14/2006	A	33	CT4	Cicindela	M	Ma	-24.45	-30.30
7/14/2006	A	35	CT4	Scarites	M	Ma	-26.07	-25.52
7/14/2006	A	35	CT4	Cicindela	M	Ma	-24.13	-24.63
7/14/2006	A	35	CT4	Cratacanthus	F	Ma	-23.34	-24.50
7/14/2006	A	36	CT4	Cicindela	F	Ma	-23.62	-24.80
7/14/2006	A	37	CT4	Cicindela	M	Ma	-23.65	-25.33
7/14/2006	A	37	CT4	Tetracha	F	Ma	-25.28	-26.39
7/14/2006	A	43	CT5	Tetracha	F	Ma	-24.62	-25.18
7/14/2006	A	43	CT5	Cratacanthus	F	Ma	-16.86	-18.49

7/14/2006	A	45	CT5	Cicindela	M	Ma	-25.53	-26.50
7/14/2006	A	45	CT5	Tetracha	M	Ma	-23.99	-24.87
7/14/2006	A	45	CT5	Cratacanthus	F	Ma	-23.45	-24.59
7/14/2006	A	46	CT5	Cratacanthus	F	Ma	-24.97	-25.30
7/14/2006	A	46	CT5	Cicindela	M	Ma	-23.46	-24.20
7/14/2006	A	46	CT5	Tetracha	M	Ma	-21.53	-23.72
7/14/2006	A	47	CT5	Tetracha	F	Ma	-27.26	-27.05
7/14/2006	A	47	CT5	Cicindela	M	Ma	-22.52	-22.48
7/14/2006	AA	1	AL	Scarites	F	Ma	-25.76	-26.39
7/14/2006	AA	1	AL	Cratacanthus	F	Ma	-17.02	-20.66
7/14/2006	AA	2	AL	Cicindela	M	Ma	-20.20	-21.90
7/14/2006	AA	6	AL	Tetracha	M	Ma	-24.08	-26.30
7/14/2006	AA	6	AL	Cratacanthus	F	Ma	-25.49	-27.58
7/14/2006	AA	9	AL	Tetracha	M	Ma	-25.66	-27.92
7/14/2006	AA	9	AL	Cratacanthus	F	Ma	-17.10	-20.52
7/14/2006	AA	10	AL	Tetracha	M	Ma	-21.28	-22.86
7/14/2006	AA	10	AL	Cratacanthus	F	Ma	-14.78	-18.95
7/14/2006	B	7	NT1	Tetracha	M	Ma	-25.07	-25.55
7/14/2006	B	13	CT2	Cratacanthus	F	Ma	-26.39	-27.47
7/14/2006	B	15	CT2	Tetracha	F	Ma	-26.62	-28.10
7/14/2006	B	23	CT3	Tetracha	M	Ma	-23.87	-24.14
7/14/2006	B	35	CT4	Scarites	F	Ma	-27.28	-28.87
7/14/2006	B	35	CT4	Tetracha	F	Ma	-25.91	-25.73
7/14/2006	B	37	CT4	Poecilus	M	Ma	-23.83	-26.46
7/14/2006	B	37	CT4	Tetracha	M	Ma	-26.02	-27.66
7/14/2006	BA	1	AL	Pasimachus	M	Br	-21.77	-25.40
7/14/2006	BA	1	AL	Tetracha	M	Ma	-27.17	-27.61
7/14/2006	BA	1	AL	Cratacanthus	F	Ma	-13.72	-15.74
7/14/2006	BA	2	AL	Tetracha	F	Ma	-24.24	-26.56
7/14/2006	BA	2	AL	Tetracha	M	Ma	-25.64	-26.12
7/14/2006	BA	6	AL	Cyclotrachelus	F	Br	-23.84	-26.39
7/14/2006	BA	6	AL	Scarites	M	Ma	-26.66	-27.62
7/14/2006	BA	6	AL	Poecilus	F	Ma	-23.29	-26.14
7/14/2006	BA	9	AL	Tetracha	M	Ma	-26.01	-26.85
7/14/2006	C	16	CT2	Cicindela	M	Ma	-23.67	-23.52
7/14/2006	C	17	CT2	Pasimachus	U	Br	-20.52	-26.32
7/14/2006	C	23	CT3	Cratacanthus	F	Br	-24.65	-25.92
7/14/2006	C	35	CT4	Poecilus	F	Ma	-25.43	-26.07
7/14/2006	C	36	CT4	Tetracha	M	Ma	-26.83	-30.53
7/14/2006	C	36	CT4	Pasimachus	M	Br	-21.92	-25.76
7/14/2006	C	37	CT4	Tetracha	M	Ma	-25.41	-25.85

7/14/2006	C	37	CT4	Cratacanthus	F	Ma	-25.26	-26.03
7/14/2006	C	43	CT5	Cicindela	M	Ma	-25.22	-26.32
7/14/2006	C	47	CT5	Cratacanthus	M	Ma	-16.63	-19.60
7/14/2006	C	47	CT5	Tetracha	F	Ma	-25.83	-26.82
7/14/2006	CA	1	AL	Cratacanthus	F	Ma	-19.63	-21.44
7/14/2006	CA	2	AL	Pasimachus	F	Br	-15.89	-17.62
7/14/2006	CA	2	AL	Cratacanthus	F	Ma	-26.37	-26.01
7/14/2006	CA	6	AL	Pasimachus	M	Br	-20.44	-24.71
7/14/2006	CA	6	AL	Tetracha	M	Ma	-24.24	-27.44
7/14/2006	CA	6	AL	Cratacanthus	F	Ma	-25.78	-27.08
7/14/2006	CA	6	AL	Cicindela	M	Ma	-24.81	-26.71
7/14/2006	CA	9	AL	Cratacanthus	F	Ma	-15.26	-18.08
7/14/2006	CA	10	AL	Cratacanthus	M	Ma	-22.32	-24.94
7/14/2006	CA	10	AL	Tetracha	F	Ma	-25.53	-27.10
7/21/2006	A	16	CT2	Cyclotrachelus	F	Br	-18.13	-20.62
7/21/2006	A	17	CT2	Cicindela	M	Ma	-23.30	-25.09
7/21/2006	A	23	CT3	Cratacanthus	F	Ma	-28.46	-28.78
7/21/2006	A	25	CT3	Cicindela	F	Ma	-24.48	-24.60
7/21/2006	A	26	CT3	Scarites	M	Ma	-22.80	-26.10
7/21/2006	A	26	CT3	Cicindela	M	Ma	-24.88	-23.14
7/21/2006	A	26	CT3	Cratacanthus	F	Ma	-24.78	-25.87
7/21/2006	A	37	CT4	Tetracha	M	Ma	-27.09	-27.06
7/21/2006	A	43	CT5	Scarites	M	Ma	-23.87	-28.32
7/21/2006	AA	1	AL	Cratacanthus	M	Ma	-26.54	-26.13
7/21/2006	AA	6	AL	Cratacanthus	M	Br	-13.78	-14.32
7/21/2006	AA	9	AL	Cratacanthus	M	Ma	-14.73	-17.09
7/21/2006	AA	10	AL	Cratacanthus	F	Ma	-20.39	-22.11
7/21/2006	B	16	CT2	Tetracha	F	Ma	-24.14	-26.39
7/21/2006	B	37	CT4	Tetracha	M	Ma	-26.87	-25.43
7/21/2006	C	3	NT1	Pasimachus	M	Br	-18.59	-27.76
7/21/2006	C	3	NT1	Tetracha	F	Ma	-21.70	-26.05
7/21/2006	C	15	CT2	Tetracha	M	Ma	-24.18	-24.74
7/21/2006	C	35	CT4	Cratacanthus	F	Ma	-26.60	-26.41
7/21/2006	C	36	CT4	Scarites	F	Ma	-20.87	-26.67
7/21/2006	C	36	CT4	Cratacanthus	M	Ma	-22.19	-23.79
7/21/2006	C	47	CT5	Cratacanthus	M	Br	-27.50	-27.96
7/21/2006	CA	2	AL	Cratacanthus	F	Ma	-19.64	-21.16
7/21/2006	CA	9	AL	Cratacanthus	M	Br	-19.18	-19.90
7/21/2006	CA	10	AL	Cratacanthus	F	Ma	-19.18	-22.47
7/28/2006	A	15	CT2	Tetracha	F	Ma	-15.89	-20.10
7/28/2006	A	15	CT2	Poecilus	U	Ma	-25.28	-24.96

7/28/2006	A	17	CT2	Cratacanthus	F	Ma	-25.14	-25.26
7/28/2006	A	26	CT3	Cicindela	M	Ma	-24.14	-24.43
7/28/2006	A	46	CT5	Tetracha	F	Ma	-21.15	-23.15
7/28/2006	AA	1	AL	Cicindela	M	Ma	-25.33	-27.04
7/28/2006	AA	1	AL	Cratacanthus	F	Ma	-17.01	-17.90
7/28/2006	AA	6	AL	Cratacanthus	F	Br	-22.85	-23.63
7/28/2006	AA	10	AL	Cratacanthus	M	Ma	-16.11	-15.56
7/28/2006	BA	9	AL	Tetracha	M	Ma	-24.53	-25.46
7/28/2006	C	3	NT1	Tetracha	F	Ma	-25.67	-27.16
7/28/2006	C	23	CT3	Cratacanthus	M	Ma	-13.72	-15.01
7/28/2006	C	25	CT3	Cratacanthus	F	Ma	-23.57	-24.37
7/28/2006	C	46	CT5	Tetracha	M	Ma	-27.12	-27.13
7/28/2006	C	47	CT5	Cratacanthus	F	Ma	-26.58	-27.41
7/28/2006	CA	1	AL	Cratacanthus	F	Ma	-25.28	-25.51
7/28/2006	CA	6	AL	Cratacanthus	F	Br	-20.69	-22.79
8/4/2006	A	7	NT1	Cicindela	F	Ma	-24.46	-24.84
8/4/2006	A	7	NT1	Cratacanthus	F	Ma	-16.12	-18.69
8/4/2006	A	25	CT3	Cicindela	F	Ma	-23.34	-22.79
8/4/2006	A	26	CT3	Cicindela	M	Ma	-23.60	-22.10
8/4/2006	A	36	CT4	Cratacanthus	M	Ma	-16.91	-19.51
8/4/2006	A	46	CT5	Cicindela	M	Ma	-19.28	-21.00
8/4/2006	AA	1	AL	Cicindela	M	Ma	-24.43	-24.70
8/4/2006	AA	2	AL	Cicindela	F	Ma	-20.18	-20.11
8/4/2006	AA	10	AL	Cratacanthus	M	Ma	-12.65	-13.47
8/4/2006	B	7	NT1	Calosoma	M	Ma	-18.70	-22.83
8/4/2006	CA	6	AL	Cratacanthus	M	Ma	-26.24	-26.25
8/11/2006	A	7	NT1	Cratacanthus	M	Ma	-21.87	-23.84
8/11/2006	A	7	NT1	Scarites	F	Ma	-22.77	-24.52
8/11/2006	A	13	CT2	Cicindela	M	Ma	-21.50	-20.49
8/11/2006	A	15	CT2	Cicindela	F	Ma	-20.42	-23.43
8/11/2006	A	16	CT2	Cratacanthus	F	Ma	-14.82	-17.67
8/11/2006	A	16	CT2	Cicindela	F	Ma	-24.76	-24.40
8/11/2006	A	17	CT2	Cratacanthus	F	Ma	-15.97	-22.05
8/11/2006	A	23	CT3	Cratacanthus	F	Ma	-23.38	-23.27
8/11/2006	A	26	CT3	Cratacanthus	M	Ma	-21.55	-23.42
8/11/2006	A	27	CT3	Cratacanthus	M	Ma	-15.07	-15.56
8/11/2006	A	37	CT4	Cratacanthus	M	Ma	-22.69	-24.42
8/11/2006	A	45	CT5	Cicindela	M	Ma	-23.86	-23.23
8/11/2006	A	46	CT5	Cratacanthus	F	Ma	-13.99	-14.58
8/11/2006	A	47	CT5	Cicindela	M	Ma	-22.02	-21.05
8/11/2006	A	47	CT5	Cratacanthus	M	Ma	-24.65	-24.11

8/11/2006	BA	6	AL	Tetracha	F	Ma	-25.81	-26.72
8/11/2006	C	6	NT1	Cratacanthus	F	Ma	-24.23	-24.23
8/11/2006	C	27	CT3	Cratacanthus	F	Br	-27.27	-27.57
8/11/2006	C	33	CT4	Cratacanthus	F	Br	-22.98	-24.44
8/11/2006	C	36	CT4	Cratacanthus	M	Ma	-25.73	-25.88
8/11/2006	CA	6	AL	Cratacanthus	F	Ma	-17.15	-18.17
8/11/2006	CA	9	AL	Cratacanthus	M	Ma	-23.34	-23.40
8/19/2006	A	23	CT3	Cicindela	F	Ma	-20.57	-23.00
8/19/2006	A	26	CT3	Cicindela	F	Ma	-21.17	-21.52
8/19/2006	A	35	CT4	Pasimachus	F	Br	-18.40	-18.45
8/19/2006	A	35	CT4	Cicindela	M	Ma	-20.13	-21.68
8/19/2006	A	37	CT4	Cratacanthus	M	Ma	-20.48	-20.88
8/19/2006	A	45	CT5	Cratacanthus	F	Ma	-17.80	-20.59
8/19/2006	A	47	CT5	Scarites	M	Ma	-25.49	-23.49
8/19/2006	AA	9	AL	Cratacanthus	F	Ma	-19.92	-20.39
8/19/2006	B	3	NT1	Pasimachus	U	Br	-20.51	-20.53
8/19/2006	B	15	CT2	Tetracha	M	Ma	-27.51	-28.67
8/19/2006	BA	2	AL	Cicindela	M	Ma	-26.56	-23.65
8/19/2006	C	26	CT3	Pasimachus	M	Br	-17.94	-23.51
8/19/2006	C	47	CT5	Cratacanthus	F	Br	-26.45	-27.50
8/25/2006	A	33	CT4	Cicindela	F	Ma	-19.78	-19.60
8/25/2006	AA	6	AL	Cicindela	M	Ma	-24.07	-25.33
8/25/2006	AA	9	AL	Cicindela	M	Ma	-25.19	-25.58
8/25/2006	AA	9	AL	Cratacanthus	F	Ma	-21.33	-23.81
8/25/2006	AA	10	AL	Cratacanthus	F	Br	-15.72	-16.59
8/25/2006	B	7	NT1	Tetracha	F	Ma	-23.04	-23.61
8/25/2006	B	17	CT2	Cratacanthus	M	Ma	-18.48	-17.89
8/25/2006	B	23	CT3	Pasimachus	F	Br	-15.12	-20.39
8/25/2006	B	26	CT3	Pasimachus	M	Br	-17.78	-20.78
8/25/2006	B	37	CT4	Cyclotrachelus	M	Br	-21.73	-22.84
8/25/2006	BA	1	AL	Tetracha	M	Ma	-21.57	-24.65
8/25/2006	BA	1	AL	Cicindela	M	Ma	-19.30	-20.73
8/25/2006	BA	1	AL	Cratacanthus	M	Ma	-24.69	-25.35
8/25/2006	BA	2	AL	Tetracha	F	Ma	-23.79	-24.28
8/25/2006	BA	2	AL	Tetracha	M	Ma	-25.71	-26.75
8/25/2006	BA	2	AL	Cratacanthus	F	Ma	-18.70	-21.26
8/25/2006	BA	6	AL	Tetracha	M	Ma	-27.38	-27.55
8/25/2006	BA	6	AL	Pasimachus	M	Br	-16.01	-18.18
8/25/2006	BA	6	AL	Poecilus	F	Ma	-25.87	-28.02
8/25/2006	BA	9	AL	Tetracha	F	Ma	-25.28	-26.08
8/25/2006	C	3	NT1	Cratacanthus	F	Ma	-25.60	-26.88
8/25/2006	C	7	NT1	Pasimachus	M	Br	-22.24	-23.15

8/25/2006	C	16	CT2	Cratacanthus	M	Ma	-26.59	-27.19
8/25/2006	C	23	CT3	Pasimachus	F	Br	-23.71	-24.61
8/25/2006	C	26	CT3	Pasimachus	M	Br	-19.96	-21.72
8/25/2006	C	27	CT3	Pasimachus	F	Br	-18.51	-21.15
8/25/2006	C	27	CT3	Tetracha	M	Ma	-26.14	-26.32
8/25/2006	C	33	CT4	Cratacanthus	M	Ma	-26.64	-28.08
8/25/2006	C	36	CT4	Tetracha	U	Ma	-21.86	-22.04
8/25/2006	C	37	CT4	Cratacanthus	F	Ma	-26.40	-26.68
8/25/2006	C	43	CT5	Pasimachus	M	Br	-15.56	-18.22
8/25/2006	C	43	CT5	Cratacanthus	F	Ma	-26.83	-28.25
8/25/2006	C	45	CT5	Cratacanthus	M	Ma	-15.35	-19.18
8/25/2006	C	46	CT5	Cratacanthus	M	Ma	-26.45	-28.21
8/25/2006	C	47	CT5	Cratacanthus	M	Ma	-27.28	-28.12
8/25/2006	CA	1	AL	Cratacanthus	M	Ma	-24.11	-25.44
8/25/2006	CA	2	AL	Cratacanthus	F	Ma	-22.63	-23.53
8/25/2006	CA	6	AL	Tetracha	M	Ma	-27.55	-27.95
8/25/2006	CA	6	AL	Cratacanthus	F	Ma	-20.40	-23.40
8/25/2006	CA	10	AL	Tetracha	M	Ma	-27.25	-27.78
8/25/2006	CA	10	AL	Cratacanthus	F	Ma	-25.51	-26.52
9/1/2006	A	7	NT1	Calosoma	M	Ma	-26.47	-27.19
9/1/2006	A	13	CT2	Cicindela	F	Ma	-23.72	-24.34
9/1/2006	A	16	CT2	Cratacanthus	M	Ma	-26.20	-26.12
9/1/2006	A	17	CT2	Cicindela	F	Ma	-20.75	-21.52
9/1/2006	A	25	CT3	Tetracha	F	Ma	-21.03	-21.85
9/1/2006	A	36	CT4	Cyclotrachelus	F	Br	-25.85	-25.38
9/1/2006	A	37	CT4	Calosoma	F	Ma	-28.11	-29.64
9/1/2006	AA	1	AL	Calosoma	M	Ma	-25.73	-27.13
9/1/2006	AA	1	AL	Cicindela	M	Ma	-18.87	-22.76
9/1/2006	AA	6	AL	Tetracha	F	Ma	-25.35	-26.84
9/1/2006	AA	6	AL	Cratacanthus	F	Ma	-15.20	-23.04
9/1/2006	AA	6	AL	Cicindela	F	Ma	-21.00	-23.03
9/1/2006	B	17	CT2	Pasimachus	M	Br	-17.28	-25.04
9/1/2006	B	23	CT3	Cyclotrachelus	U	Br	-23.08	-23.34
9/1/2006	B	27	CT3	Pasimachus	M	Br	-16.52	-20.30
9/1/2006	B	36	CT4	Poecilus	U	Ma	-23.37	-23.81
9/1/2006	B	37	CT4	Tetracha	F	Ma	-19.47	-20.12
9/1/2006	BA	1	AL	Cratacanthus	M	Ma	-20.05	-21.19
9/1/2006	BA	2	AL	Cratacanthus	F	Ma	-24.13	-26.38
9/1/2006	BA	6	AL	Tetracha	M	Ma	-26.47	-27.40
9/1/2006	BA	9	AL	Tetracha	M	Ma	-22.93	-24.13
9/1/2006	BA	10	AL	Tetracha	F	Ma	-18.33	-21.39
9/1/2006	BA	10	AL	Tetracha	M	Ma	-24.09	-26.37

9/1/2006	C	5	NT1	Cratacanthus	F	Ma	-22.97	-25.41
9/1/2006	C	6	NT1	Pasimachus	M	Br	-17.16	-21.60
9/1/2006	C	15	CT2	Cratacanthus	M	Ma	-27.28	-27.55
9/1/2006	C	26	CT3	Cratacanthus	M	Ma	-15.79	-17.38
9/1/2006	C	36	CT4	Cratacanthus	F	Ma	-24.96	-26.04
9/1/2006	C	37	CT4	Cyclotrachelus	F	Br	-24.50	-26.45
9/1/2006	C	46	CT5	Cratacanthus	F	Ma	-14.36	-19.64
9/1/2006	CA	1	AL	Pasimachus	M	Br	-22.13	-22.90
9/1/2006	CA	2	AL	Cratacanthus	F	Ma	-27.35	-28.13
9/1/2006	CA	6	AL	Tetracha	F	Ma	-24.11	-25.56
9/1/2006	CA	6	AL	Tetracha	F	Ma	-24.85	-23.97
9/1/2006	CA	9	AL	Cratacanthus	F	Ma	-25.23	-25.83
9/1/2006	CA	10	AL	Cratacanthus	F	Ma	-13.91	-20.67
9/8/2006	A	13	CT2	Calosoma	F	Ma	-29.72	-31.85
9/8/2006	A	15	CT2	Calosoma	F	Ma	-25.94	-31.56
9/8/2006	A	17	CT2	Calosoma	M	Ma	-24.97	-26.77
9/8/2006	A	26	CT3	Cicindela	M	Ma	-27.23	-25.38
9/8/2006	A	27	CT3	Calosoma	M	Ma	-27.22	-28.70
9/8/2006	A	27	CT3	Cicindela	F	Ma	-18.97	-21.67
9/8/2006	A	45	CT5	Calosoma	F	Ma	-26.36	-27.95
9/8/2006	AA	1	AL	Calosoma	M	Ma	-24.53	-28.03
9/8/2006	AA	2	AL	Cicindela	M	Ma	-21.06	-22.67
9/8/2006	AA	2	AL	Calosoma	F	Ma	-30.10	-30.41
9/8/2006	AA	6	AL	Cicindela	F	Ma	-16.79	-18.71
9/8/2006	AA	6	AL	Calosoma	M	Ma	-29.48	-30.02
9/8/2006	AA	9	AL	Calosoma	M	Ma	-25.95	-27.79
9/8/2006	AA	9	AL	Cicindela	M	Ma	-23.32	-25.28
9/8/2006	AA	10	AL	Calosoma	M	Ma	-27.73	-29.27
9/8/2006	B	5	NT1	Cratacanthus	M	Ma	-24.97	-25.53
9/8/2006	B	36	CT4	Cratacanthus	F	Ma	-17.12	-16.50
9/8/2006	B	37	CT4	Poecilus	U	Ma	-21.94	-22.95
9/8/2006	B	47	CT5	Pasimachus	F	Br	-14.28	-19.40
9/8/2006	BA	6	AL	Poecilus	M	Ma	-26.36	-26.80
9/8/2006	BA	6	AL	Calosoma	M	Ma	-28.07	-28.76
9/8/2006	BA	6	AL	Tetracha	M	Ma	-22.71	-25.19
9/8/2006	BA	9	AL	Tetracha	M	Ma	-24.54	-25.75
9/8/2006	BA	10	AL	Tetracha	U	Ma	-25.11	-26.11
9/8/2006	C	7	NT1	Cicindela	F	Ma	-22.62	-24.62
9/8/2006	C	13	CT2	Tetracha	F	Ma	-25.48	-26.25
9/8/2006	C	15	CT2	Cratacanthus	F	Ma	-17.41	-17.65
9/8/2006	C	17	CT2	Pasimachus	M	Br	-21.49	-26.13

9/8/2006	C	27	CT3	Cratacanthus	F	Ma	-26.48	-27.04
9/8/2006	C	37	CT4	Calosoma	M	Ma	-27.98	-28.59
9/8/2006	CA	1	AL	Cratacanthus	F	Ma	-25.58	-26.22
9/8/2006	CA	6	AL	Cyclotrachelus	M	Br	-21.51	-25.02
9/8/2006	CA	6	AL	Cratacanthus	F	Ma	-17.01	-21.08
9/8/2006	CA	6	AL	Tetracha	F	Ma	-26.83	-28.49
9/8/2006	CA	10	AL	Pasimachus	M	Br	-14.34	-21.02
9/8/2006	CA	10	AL	Tetracha	F	Ma	-24.81	-27.08
9/15/2006	A	6	NT1	Cicindela	F	Ma	-23.19	-22.41
9/15/2006	A	17	CT2	Cicindela	F	Ma	-21.34	-21.33
9/15/2006	A	26	CT3	Cicindela	U	Ma	-26.74	-26.29
9/15/2006	A	27	CT3	Cicindela	F	Ma	-19.18	-22.95
9/15/2006	A	27	CT3	Calosoma	F	Ma	-28.51	-28.49
9/15/2006	A	37	CT4	Cicindela	M	Ma	-21.94	-21.22
9/15/2006	A	46	CT5	Calosoma	F	Ma	-29.12	-29.24
9/15/2006	A	47	CT5	Cicindela	F	Ma	-22.39	-21.60
9/15/2006	AA	2	AL	Calosoma	M	Ma	-28.46	-28.28
9/15/2006	AA	6	AL	Cyclotrachelus	F	Br	-26.91	-27.24
9/15/2006	AA	6	AL	Calosoma	M	Ma	-27.51	-27.34
9/15/2006	AA	9	AL	Cicindela	M	Ma	-22.32	-26.56
9/15/2006	AA	9	AL	Calosoma	F	Ma	-28.56	-28.39
9/15/2006	AA	9	AL	Tetracha	M	Ma	-26.37	-28.91
9/15/2006	AA	10	AL	Calosoma	M	Ma	-29.00	-29.12
9/15/2006	AA	10	AL	Cicindela	M	Ma	-18.89	-18.57
9/15/2006	B	3	NT1	Cratacanthus	M	Br	-21.41	-23.68
9/15/2006	B	6	NT1	Cratacanthus	M	Ma	-26.84	-26.28
9/15/2006	B	15	CT2	Calosoma	F	Ma	-27.52	-27.66
9/15/2006	B	26	CT3	Cratacanthus	M	Ma	-23.78	-24.32
9/15/2006	B	37	CT4	Calosoma	F	Ma	-29.09	-30.27
9/15/2006	BA	2	AL	Cicindela	M	Ma	-23.62	-24.10
9/15/2006	BA	6	AL	Poecilus	M	Ma	-28.38	-28.40
9/15/2006	BA	6	AL	Calosoma	F	Ma	-30.18	-29.45
9/15/2006	BA	10	AL	Calosoma	M	Ma	-28.74	-28.91
9/15/2006	C	3	NT1	Cratacanthus	M	Br	-27.23	-28.42
9/15/2006	C	6	NT1	Calosoma	F	Ma	-29.29	-30.38
9/15/2006	C	15	CT2	Cratacanthus	M	Br	-25.86	-26.54
9/15/2006	C	26	CT3	Calosoma	F	Ma	-27.15	-30.11
9/15/2006	C	27	CT3	Calosoma	M	Ma	-29.66	-29.52
9/15/2006	C	27	CT3	Tetracha	F	Ma	-23.77	-26.85
9/15/2006	C	33	CT4	Tetracha	F	Ma	-24.97	-25.58
9/15/2006	C	35	CT4	Calosoma	F	Ma	-29.36	-29.91

9/15/2006	C	45	CT5	Calosoma	M	Ma	-20.97	-25.36
9/15/2006	C	47	CT5	Cratacanthus	M	Ma	-26.27	-26.26
9/15/2006	CA	2	AL	Calosoma	F	Ma	-21.09	-19.43
9/15/2006	CA	6	AL	Pasimachus	M	Br	-19.09	-19.01
9/15/2006	CA	6	AL	Tetracha	M	Ma	-21.32	-22.57
9/15/2006	CA	6	AL	Calosoma	M	Ma	-26.77	-27.33
9/15/2006	CA	9	AL	Calosoma	M	Ma	-25.50	-25.39
9/15/2006	CA	10	AL	Pasimachus	M	Br	-15.30	-16.36
9/15/2006	CA	10	AL	Calosoma	M	Ma	-28.26	-30.66

APPPENDIX B

Stable carbon isotope values for the P and R sub-sample tissues in 2007.

DATE	TRAP #	PLOT	GENUS	SEX	WING	P-Sample $\delta^{13}C$	R-Sample $\delta^{13}C$
5/30/2007	A 6	NT1	Cyclotrachelus	M	Br	-21.96	-24.59
5/30/2007	A 7	NT1	Scarites	F	Ma	-24.54	-26.42
5/30/2007	A 26	CT3	Cyclotrachelus	M	Br	-17.35	-19.88
5/30/2007	A 33	FA	Cyclotrachelus	F	Br	-27.94	-29.89
5/30/2007	AA 9	AL	Calosoma	M	Ma	-27.65	-30.69
5/30/2007	AA 9	AL	Scarites	M	Ma	-24.24	-27.10
5/30/2007	B 7	NT1	Cyclotrachelus	M	Br	-22.59	-24.34
5/30/2007	B 33	FA	Scarites	M	Ma	-25.81	-28.05
5/30/2007	B 45	NT5	Scarites	M	Ma	-27.35	-26.91
5/30/2007	B 46	NT5	Scarites	M	Ma	-24.15	-25.27
5/30/2007	BA 6	AL	Calosoma	M	Ma	-28.16	-31.33
5/30/2007	BA 9	AL	Calosoma	F	Ma	-29.54	-30.94
5/30/2007	BA 10	AL	Calosoma	M	Ma	-23.88	-28.52
5/30/2007	C 7	NT1	Scarites	M	Ma	-28.02	-28.10
5/30/2007	C 15	CT2	Cyclotrachelus	M	Br	-22.76	-24.91
5/30/2007	C 26	CT3	Scarites	F	Ma	-24.52	-24.68
5/30/2007	C 35	FA	Scarites	M	Ma	-25.43	-26.89
5/30/2007	C 36	CT4	Scarites	M	Ma	-18.50	-20.76
5/30/2007	C 37	CT4	Cratacanthus	F	Ma	-26.60	-26.23
5/30/2007	C 46	NT5	Cyclotrachelus	M	Br	-29.37	-29.05
5/30/2007	C 47	NT5	Cyclotrachelus	M	Br	-23.15	-26.85
5/30/2007	CA 2	AL	Cicindela	M	Ma	-20.93	-21.76
5/30/2007	CA 6	AL	Calosoma	M	Ma	-24.63	-29.14
5/30/2007	CA 10	AL	Cicindela	M	Ma	-21.81	-23.22
5/30/2007	CA 10	AL	Cyclotrachelus	M	Br	-21.95	-25.48
5/31/2007	AA 1	AL	Calosoma	F	Ma	-27.60	-31.18
5/31/2007	AA 2	AL	Calosoma	M	Ma	-26.08	-30.24
5/31/2007	AA 6	AL	Calosoma	M	Ma	-29.68	-31.38
5/31/2007	AA 9	AL	Calosoma	M	Ma	-28.93	-31.43

5/31/2007	B	5	NT1	Cicindela	M	Br	-19.92	-21.53
5/31/2007	B	33	FA	Scarites	M	Ma	-26.75	-28.75
5/31/2007	B	35	FA	Scarites	M	Ma	-26.44	-28.29
5/31/2007	BA	2	AL	Calosoma	F	Ma	-29.18	-30.75
5/31/2007	BA	2	AL	Cicindela	M	Ma	-21.47	-21.01
5/31/2007	BA	6	AL	Calosoma	M	Ma	-26.91	-32.08
5/31/2007	BA	6	AL	Pasimachus	F	Br	-20.58	-30.11
5/31/2007	BA	10	AL	Calosoma	M	Ma	-24.21	-28.02
5/31/2007	C	3	NT1	Scarites	M	Ma	-27.64	-28.69
5/31/2007	C	15	CT2	Scarites	M	Ma	-25.31	-28.22
5/31/2007	C	16	CT2	Scarites	M	Ma	-20.68	-22.06
5/31/2007	C	35	FA	Scarites	F	Ma	-25.92	-27.50
5/31/2007	C	36	CT4	Scarites	M	Ma	-19.95	-25.91
5/31/2007	C	37	CT4	Scarites	M	Ma	-23.16	-25.68
5/31/2007	C	47	NT5	Scarites	M	Ma	-23.31	-25.69
5/31/2007	CA	10	AL	Calosoma	M	Ma	-25.59	-29.17
5/31/2007	CA	10	AL	Scarites	M	Ma	-26.93	-28.23
6/1/2007	A	3	NT1	Cyclotrachelus	M	Br	-22.85	-27.24
6/1/2007	A	16	CT2	Calosoma	M	Ma	-27.07	-28.11
6/1/2007	A	35	FA	Cicindela	M	Ma	-23.86	-25.60
6/1/2007	AA	1	AL	Cyclotrachelus	M	Br	-26.36	-26.79
6/1/2007	AA	6	AL	Calosoma	M	Ma	-27.96	-29.52
6/1/2007	AA	9	AL	Calosoma	M	Ma	-27.62	-30.27
6/1/2007	B	17	CT2	Scarites	F	Ma	-24.70	-26.47
6/1/2007	B	33	FA	Scarites	M	Ma	-26.26	-28.86
6/1/2007	B	35	FA	Scarites	M	Ma	-27.48	-31.19
6/1/2007	B	46	NT5	Scarites	M	Ma	-27.54	-30.38
6/1/2007	B	47	NT5	Scarites	M	Ma	-27.34	-29.19
6/1/2007	BA	2	AL	Cicindela	M	Ma	-23.79	-24.32
6/1/2007	BA	6	AL	Calosoma	F	Ma	-27.91	-30.62
6/1/2007	BA	6	AL	Calosoma	M	Ma	-29.39	-31.08
6/1/2007	BA	9	AL	Calosoma	M	Ma	-28.84	-31.52
6/1/2007	BA	10	AL	Calosoma	M	Ma	-29.03	-30.61
6/1/2007	C	5	NT1	Scarites	F	Ma	-27.03	-27.63
6/1/2007	C	26	CT3	Cratacanthus	F	Ma	-25.77	-28.06
6/1/2007	C	27	CT3	Calosoma	M	Ma	-27.93	-31.65
6/1/2007	C	27	CT3	Pasimachus	M	Br	-24.82	-29.72
6/1/2007	C	33	FA	Scarites	M	Ma	-26.65	-27.86
6/1/2007	C	36	CT4	Scarites	M	Ma	-25.49	-26.85
6/1/2007	C	37	CT4	Scarites	F	Ma	-25.80	-26.73

6/1/2007	C	43	NT5	Scarites	M	Ma	-17.54	-24.62
6/1/2007	C	46	NT5	Cyclotrachelus	M	Br	-23.03	-29.08
6/1/2007	CA	2	AL	Calosoma	M	Ma	-27.00	-29.33
6/1/2007	CA	2	AL	Cicindela	F	Ma	-26.51	-27.97
6/1/2007	CA	6	AL	Calosoma	M	Ma	-27.85	-30.02
6/1/2007	CA	6	AL	Calosoma	F	Ma	-19.25	-29.08
6/4/2007	A	3	NT1	Calosoma	M	Ma	-26.97	-27.99
6/4/2007	A	3	NT1	Scarites	M	Ma	-23.85	-25.64
6/4/2007	A	5	NT1	Cyclotrachelus	F	Br	-20.20	-25.13
6/4/2007	A	26	CT3	Calosoma	F	Ma	-28.00	-28.10
6/4/2007	AA	1	AL	Calosoma	M	Ma	-28.06	-30.93
6/4/2007	AA	2	AL	Calosoma	M	Ma	-19.62	-27.03
6/4/2007	AA	6	AL	Calosoma	M	Ma	-24.91	-28.10
6/4/2007	AA	9	AL	Calosoma	M	Ma	-26.53	-32.74
6/4/2007	AA	10	AL	Calosoma	F	Ma	-27.52	-31.00
6/4/2007	C	6	NT1	Cyclotrachelus	F	Br	-23.71	-27.09
6/4/2007	C	6	NT1	Scarites	F	Ma	-25.93	-26.90
6/4/2007	C	13	CT2	Cratacanthus	F	Ma	-20.31	-24.83
6/4/2007	C	15	CT2	Cyclotrachelus	F	Br	-25.86	-29.19
6/4/2007	C	27	CT3	Scarites	M	Ma	-28.23	-29.01
6/4/2007	C	33	FA	Scarites	M	Ma	-28.29	-29.57
6/4/2007	C	36	CT4	Calosoma	M	Ma	-28.92	-29.20
6/4/2007	C	45	NT5	Calosoma	M	Ma	-29.12	-30.30
6/4/2007	C	47	NT5	Cicindela	M	Ma	-23.05	-23.77
6/4/2007	C	47	NT5	Scarites	M	Ma	-28.38	-29.39
6/4/2007	CA	1	AL	Scarites	F	Ma	-26.58	-26.71
6/4/2007	CA	2	AL	Calosoma	M	Ma	-29.17	-33.07
6/4/2007	CA	6	AL	Calosoma	M	Ma	-29.04	-31.44
6/4/2007	CA	6	AL	Cyclotrachelus	M	Br	-23.89	-24.24
6/4/2007	CA	9	AL	Pasimachus	F	Br	-21.64	-27.40
6/4/2007	CA	10	AL	Calosoma	M	Ma	-28.67	-32.20
6/4/2007	CA	10	AL	Cicindela	F	Ma	-27.30	-28.08
6/5/2007	A	5	NT1	Cicindela	F	Ma	-22.87	-24.65
6/5/2007	A	7	NT1	Calosoma	M	Ma	-25.68	-31.62
6/5/2007	A	7	NT1	Cyclotrachelus	F	Br	-26.38	-29.57
6/5/2007	A	27	CT3	Scarites	F	Ma	-24.75	-24.89
6/5/2007	A	35	FA	Cicindela	M	Ma	-24.75	-24.89
6/5/2007	AA	1	AL	Calosoma	M	Ma	-28.37	-31.06
6/5/2007	AA	2	AL	Calosoma	M	Ma	-26.97	-31.70
6/5/2007	AA	6	AL	Calosoma	M	Ma	-28.57	-30.89
6/5/2007	AA	6	AL	Cicindela	M	Ma	-20.38	-20.89

6/5/2007	AA	9	AL	Calosoma	M	Ma	-29.16	-31.14
6/5/2007	AA	10	AL	Calosoma	F	Ma	-16.89	-21.58
6/5/2007	B	6	NT1	Scarites	F	Ma	-13.17	-26.57
6/5/2007	B	23	CT3	Scarites	F	Ma	-21.25	-21.67
6/5/2007	B	33	FA	Scarites	M	Ma	-27.18	-27.88
6/5/2007	B	35	FA	Cicindela	M	Br	-23.80	-26.35
6/5/2007	B	37	CT4	Calosoma	F	Ma	-28.79	-32.04
6/5/2007	B	47	NT5	Scarites	F	Ma	-26.99	-30.05
6/5/2007	BA	1	AL	Calosoma	M	Ma	-25.36	-31.54
6/5/2007	BA	1	AL	Calosoma	M	Ma	-27.61	-31.68
6/5/2007	BA	6	AL	Calosoma	F	Ma	-28.90	-32.27
6/5/2007	BA	6	AL	Calosoma	M	Ma	-29.82	-31.13
6/5/2007	BA	6	AL	Scarites	M	Ma	-29.64	-30.57
6/5/2007	BA	9	AL	Calosoma	M	Ma	-17.57	-20.66
6/5/2007	BA	10	AL	Calosoma	F	Ma	-28.97	-31.07
6/5/2007	C	6	NT1	Scarites	M	Ma	-28.10	-30.07
6/5/2007	C	7	NT1	Cyclotrachelus	F	Br	-23.02	-27.44
6/5/2007	C	13	CT2	Scarites	F	Ma	-26.18	-26.56
6/5/2007	C	17	CT2	Calosoma	M	Ma	-30.09	-32.07
6/5/2007	C	17	CT2	Scarites	M	Ma	-27.32	-29.68
6/5/2007	C	17	CT2	Scarites	F	Ma	-28.10	-28.22
6/5/2007	C	25	CT3	Scarites	M	Ma	-25.45	-26.48
6/5/2007	C	27	CT3	Cicindela	M	Ma	-20.46	-22.83
6/5/2007	C	27	CT3	Cratacanthus	F	Ma	-23.72	-24.69
6/5/2007	C	35	FA	Scarites	M	Ma	-26.12	-29.40
6/5/2007	C	35	FA	Scarites	F	Ma	-24.47	-25.23
6/5/2007	C	43	NT5	Cicindela	F	Ma	-24.68	-24.59
6/5/2007	C	43	NT5	Scarites	F	Ma	-25.40	-28.69
6/5/2007	C	47	NT5	Scarites	F	Ma	-28.07	-27.67
6/5/2007	CA	1	AL	Calosoma	M	Ma	-28.30	-31.40
6/5/2007	CA	2	AL	Cicindela	F	Ma	-26.96	-26.27
6/5/2007	CA	6	AL	Calosoma	M	Ma	-28.16	-30.30
6/5/2007	CA	9	AL	Calosoma	M	Ma	-28.19	-30.91
6/6/2007	A	7	NT1	Cyclotrachelus	M	Br	-18.20	-21.75
6/6/2007	AA	1	AL	Calosoma	F	Ma	-26.91	-32.07
6/6/2007	AA	1	AL	Cyclotrachelus	F	Br	-27.79	-29.43
6/6/2007	AA	2	AL	Calosoma	M	Ma	-17.90	-26.46
6/6/2007	AA	6	AL	Calosoma	F	Ma	-27.16	-32.23
6/6/2007	AA	9	AL	Calosoma	M	Ma	-28.44	-31.82
6/6/2007	AA	10	AL	Calosoma	M	Ma	-25.29	-29.11
6/6/2007	AA	10	AL	Cicindela	F	Ma	-22.81	-23.87

6/6/2007	B	3	NT1	Cyclotrachelus	F	Br	-22.41	-20.96
6/6/2007	B	5	NT1	Cicindela	M	Ma	-25.28	-25.48
6/6/2007	B	6	NT1	Cyclotrachelus	F	Br	-25.09	-27.26
6/6/2007	B	7	NT1	Scarites	F	Ma	-27.35	-27.92
6/6/2007	B	17	CT2	Scarites	F	Ma	-27.65	-26.98
6/6/2007	B	27	CT3	Poecilus	M	Ma	-21.43	-23.98
6/6/2007	B	35	FA	Scarites	M	Ma	-25.36	-27.65
6/6/2007	B	36	CT4	Scarites	M	Ma	-24.51	-26.76
6/6/2007	B	37	CT4	Scarites	M	Ma	-23.60	-22.71
6/6/2007	B	37	CT4	Scarites	F	Ma	-20.77	-20.18
6/6/2007	BA	1	AL	Cicindela	M	Ma	-27.27	-26.92
6/6/2007	BA	2	AL	Cicindela	M	Ma	-24.94	-25.05
6/6/2007	BA	6	AL	Calosoma	F	Ma	-28.99	-32.41
6/6/2007	BA	6	AL	Calosoma	F	Ma	-26.13	-29.64
6/6/2007	BA	6	AL	Calosoma	M	Ma	-29.64	-32.45
6/6/2007	BA	9	AL	Calosoma	F	Ma	-27.89	-28.00
6/6/2007	BA	9	AL	Scarites	F	Ma	-26.86	-29.57
6/6/2007	BA	10	AL	Calosoma	M	Ma	-27.60	-30.84
6/6/2007	C	3	NT1	Pasimachus	F	Br	-21.20	-27.56
6/6/2007	C	3	NT1	Scarites	M	Ma	-23.05	-24.99
6/6/2007	C	7	NT1	Scarites	M	Ma	-26.38	-26.56
6/6/2007	C	13	CT2	Calosoma	F	Ma	-27.75	-28.49
6/6/2007	C	13	CT2	Cyclotrachelus	F	Br	-25.39	-30.41
6/6/2007	C	23	CT3	Scarites	F	Ma	-21.71	-25.81
6/6/2007	C	25	CT3	Scarites	M	Ma	-22.74	-25.05
6/6/2007	C	25	CT3	Scarites	F	Ma	-14.55	-18.45
6/6/2007	C	27	CT3	Scarites	F	Ma	-20.59	-24.03
6/6/2007	C	35	FA	Scarites	M	Ma	-19.35	-24.15
6/6/2007	C	36	CT4	Scarites	M	Ma	-23.05	-24.99
6/6/2007	C	37	CT4	Scarites	M	Ma	-24.05	-28.35
6/6/2007	C	45	NT5	Scarites	M	Ma	-27.32	-29.37
6/6/2007	C	46	NT5	Scarites	F	Ma	-21.19	-19.97
6/6/2007	C	47	NT5	Cicindela	M	Ma	-22.59	-22.31
6/6/2007	CA	2	AL	Cicindela	M	Ma	-26.03	-25.96
6/6/2007	CA	9	AL	Cicindela	M	Ma	-20.64	-20.81
6/6/2007	CA	10	AL	Calosoma	F	Ma	-20.32	-27.11
6/7/2007	A	3	NT1	Scarites	M	Ma	-24.07	-25.23
6/7/2007	A	7	NT1	Cratacanthus	M	Br	-16.73	-15.51
6/7/2007	A	7	NT1	Scarites	M	Ma	-26.68	-27.05
6/7/2007	A	23	CT3	Cyclotrachelus	M	Br	-23.89	-27.10

6/7/2007	A	33	FA	Cratacanthus	M	Ma	-21.52	-22.40
6/7/2007	A	33	FA	Cyclotrachelus	M	Br	-22.32	-28.88
6/7/2007	A	43	NT5	Cicindela	F	Ma	-24.26	-23.16
6/7/2007	A	45	NT5	Cicindela	F	Ma	-22.96	-22.54
6/7/2007	AA	1	AL	Calosoma	M	Ma	-29.51	-32.75
6/7/2007	AA	1	AL	Cyclotrachelus	M	Br	-26.19	-31.41
6/7/2007	AA	6	AL	Calosoma	M	Ma	-28.84	-30.88
6/7/2007	AA	6	AL	Cyclotrachelus	F	Br	-25.58	-26.93
6/7/2007	AA	10	AL	Calosoma	M	Ma	-28.81	-31.42
6/7/2007	B	3	NT1	Cicindela	M	Ma	-19.10	-20.39
6/7/2007	B	3	NT1	Cratacanthus	M	Ma	-27.75	-27.88
6/7/2007	B	15	CT2	Cicindela	F	Ma	-23.24	-23.04
6/7/2007	B	16	CT2	Scarites	F	Ma	-22.76	-25.14
6/7/2007	B	26	CT3	Poecilus	F	Ma	-24.47	-25.07
6/7/2007	B	25	CT3	Scarites	M	Ma	-26.87	-27.52
6/7/2007	B	26	CT3	Scarites	F	Ma	-24.51	-24.90
6/7/2007	B	27	CT3	Scarites	F	Ma	-26.55	-29.84
6/7/2007	B	33	FA	Scarites	M	Ma	-17.20	-28.06
6/7/2007	B	33	FA	Scarites	M	Ma	-24.03	-26.88
6/7/2007	B	35	FA	Cicindela	M	Ma	-21.54	-21.86
6/7/2007	B	36	CT4	Scarites	F	Ma	-27.16	-28.83
6/7/2007	B	37	CT4	Poecilus	M	Ma	-28.29	-28.67
6/7/2007	BA	1	AL	Calosoma	M	Ma	-27.38	-29.85
6/7/2007	BA	1	AL	Cratacanthus	M	Ma	-18.00	-16.53
6/7/2007	BA	2	AL	Cicindela	M	Ma	-23.59	-24.55
6/7/2007	BA	6	AL	Calosoma	F	Ma	-29.98	-31.95
6/7/2007	BA	6	AL	Poecilus	F	Ma	-23.14	-27.09
6/7/2007	BA	6	AL	Scarites	F	Ma	-27.26	-29.26
6/7/2007	BA	10	AL	Calosoma	F	Ma	-29.68	-32.05
6/7/2007	BA	10	AL	Poecilus	M	Ma	-27.12	-29.38
6/7/2007	BA	10	AL	Scarites	M	Ma	-27.37	-29.06
6/7/2007	C	5	NT1	Cyclotrachelus	F	Br	-22.32	-24.92
6/7/2007	C	6	NT1	Cyclotrachelus	F	Br	-22.42	-24.58
6/7/2007	C	6	NT1	Cyclotrachelus	F	Br	-25.15	-25.86
6/7/2007	C	7	NT1	Cyclotrachelus	F	Br	-22.51	-25.27
6/7/2007	C	7	NT1	Cyclotrachelus	M	Br	-27.08	-28.14
6/7/2007	C	17	CT2	Cratacanthus	M	Ma	-14.25	-14.59
6/7/2007	C	23	CT3	Scarites	M	Ma	-26.71	-27.59
6/7/2007	C	25	CT3	Cyclotrachelus	M	Br	-22.59	-25.12
6/7/2007	C	25	CT3	Scarites	M	Ma	-22.39	-25.95
6/7/2007	C	27	CT3	Poecilus	F	Ma	-26.47	-27.49

6/7/2007	C	33	FA	Cyclotrachelus	F	Br	-26.69	-29.02
6/7/2007	C	33	FA	Scarites	F	Ma	-26.15	-27.83
6/7/2007	C	37	CT4	Scarites	M	Ma	-28.31	-28.63
6/7/2007	C	43	NT5	Cratacanthus	M	Br	-19.16	-20.00
6/7/2007	C	43	NT5	Cyclotrachelus	M	Br	-22.09	-27.88
6/7/2007	CA	1	AL	Calosoma	M	Ma	-26.42	-31.94
6/7/2007	CA	1	AL	Calosoma	M	Ma	-28.07	-31.01
6/7/2007	CA	2	AL	Calosoma	M	Ma	-29.64	-31.89
6/7/2007	CA	2	AL	Cicindela	M	Ma	-27.61	-28.68
6/7/2007	CA	6	AL	Cicindela	M	Ma	-27.05	-27.34
6/7/2007	CA	9	AL	Cicindela	M	Ma	-26.92	-26.60
6/7/2007	CA	9	AL	Cratacanthus	F	Br	-26.44	-27.72
6/9/2007	A	27	CT3	Cratacanthus	M	Ma	-20.23	-20.58
6/9/2007	A	43	NT5	Cratacanthus	M	Ma	-27.07	-27.31
6/9/2007	A	47	NT5	Cratacanthus	F	Ma	-24.61	-25.45
6/9/2007	AA	1	AL	Calosoma	M	Ma	-29.29	-31.97
6/9/2007	AA	1	AL	Cyclotrachelus	M	Br	-25.58	-29.11
6/9/2007	AA	2	AL	Calosoma	F	Ma	-23.06	-26.63
6/9/2007	AA	2	AL	Cyclotrachelus	M	Br	-25.02	-25.49
6/9/2007	AA	2	AL	Scarites	M	Ma	-32.53	-28.75
6/9/2007	AA	6	AL	Calosoma	M	Ma	-26.27	-28.49
6/9/2007	AA	9	AL	Calosoma	M	Ma	-30.90	-33.25
6/9/2007	B	5	NT1	Scarites	M	Ma	-18.12	-21.94
6/9/2007	B	6	NT1	Cicindela	M	Ma	-20.68	-21.56
6/9/2007	B	37	CT4	Cratacanthus	F	Ma	-25.98	-24.72
6/9/2007	B	47	NT5	Scarites	M	Ma	-24.67	-25.28
6/9/2007	BA	6	AL	Calosoma	F	Ma	-30.11	-32.40
6/9/2007	BA	6	AL	Calosoma	M	Ma	-29.57	-31.27
6/9/2007	BA	9	AL	Calosoma	M	Ma	-28.85	-31.58
6/9/2007	BA	9	AL	Calosoma	F	Ma	-28.92	-30.43
6/9/2007	BA	10	AL	Calosoma	M	Ma	-30.47	-33.86
6/9/2007	C	7	NT1	Calosoma	M	Ma	-29.85	-32.21
6/9/2007	C	7	NT1	Cyclotrachelus	F	Br	-22.70	-26.11
6/9/2007	C	15	CT2	Calosoma	M	Ma	-28.89	-32.01
6/9/2007	C	16	CT2	Cratacanthus	M	Br	-25.95	-27.88
6/9/2007	C	17	CT2	Cicindela	M	Ma	-23.03	-23.53
6/9/2007	C	26	CT3	Cratacanthus	M	Ma	-28.34	-28.69
6/9/2007	C	27	CT3	Cratacanthus	F	Ma	-19.01	-19.47
6/9/2007	C	33	FA	Cratacanthus	M	Ma	-19.35	-22.02
6/9/2007	C	36	CT4	Scarites	M	Ma	-23.80	-25.24
6/9/2007	C	37	CT4	Scarites	M	Ma	-27.90	-28.71

6/9/2007	C	43	NT5	Calosoma	F	Ma	-28.29	-29.45
6/9/2007	C	47	NT5	Cratacanthus	M	Ma	-19.54	-19.43
6/9/2007	CA	2	AL	Cicindela	M	Ma	-26.76	-28.06
6/9/2007	CA	6	AL	Calosoma	M	Ma	-28.48	-30.55
6/9/2007	CA	6	AL	Scarites	F	Ma	-25.43	-26.71
6/9/2007	CA	9	AL	Calosoma	M	Ma	-26.64	-28.97
6/9/2007	CA	9	AL	Cratacanthus	M	Ma	-16.23	-17.88
6/9/2007	CA	10	AL	Calosoma	M	Ma	-28.13	-29.07
6/10/2007	A	3	NT1	Cratacanthus	M	Ma	-22.55	-21.32
6/10/2007	A	7	NT1	Calosoma	F	Ma	-28.25	-30.98
6/10/2007	A	13	CT2	Cicindela	M	Ma	-25.78	-26.73
6/10/2007	A	16	CT2	Calosoma	F	Ma	-29.24	-32.72
6/10/2007	A	17	CT2	Cicindela	F	Ma	-27.13	-27.57
6/10/2007	A	23	CT3	Scarites	M	Ma	-21.38	-25.81
6/10/2007	A	23	CT3	Scarites	F	Ma	-17.38	-20.25
6/10/2007	AA	1	AL	Cyclotrachelus	M	Br	-25.22	-27.34
6/10/2007	AA	2	AL	Cicindela	M	Ma	-19.91	-20.91
6/10/2007	AA	9	AL	Calosoma	M	Ma	-28.00	-30.29
6/10/2007	B	7	NT1	Calosoma	M	Ma	-28.81	-31.63
6/10/2007	B	16	CT2	Cratacanthus	M	Ma	-17.20	-17.97
6/10/2007	B	16	CT2	Scarites	M	Ma	-22.29	-23.58
6/10/2007	B	23	CT3	Scarites	F	Ma	-27.79	-28.20
6/10/2007	B	35	FA	Cicindela	F	Br	-23.04	-27.56
6/10/2007	B	36	CT4	Scarites	F	Ma	-20.10	-24.02
6/10/2007	B	37	CT4	Poecilus	M	Ma	-25.23	-26.16
6/10/2007	BA	1	AL	Cicindela	M	Ma	-23.82	-24.25
6/10/2007	BA	1	AL	Cratacanthus	F	Ma	-15.49	-17.70
6/10/2007	BA	2	AL	Cicindela	M	Ma	-29.42	-27.36
6/10/2007	BA	6	AL	Calosoma	F	Ma	-28.36	-30.65
6/10/2007	BA	10	AL	Calosoma	M	Ma	-29.06	-31.12
6/10/2007	C	5	NT1	Calosoma	M	Ma	-29.14	-31.80
6/10/2007	C	5	NT1	Cratacanthus	M	Br	-26.30	-28.54
6/10/2007	C	6	NT1	Cyclotrachelus	F	Br	-23.46	-25.96
6/10/2007	C	16	CT2	Cratacanthus	M	Br	-17.44	-18.04
6/10/2007	C	16	CT2	Scarites	M	Ma	-25.68	-26.51
6/10/2007	C	23	CT3	Scarites	M	Ma	-23.56	-26.82
6/10/2007	C	25	CT3	Cratacanthus	M	Br	-19.52	-21.78
6/10/2007	C	25	CT3	Scarites	F	Ma	-28.14	-27.89
6/10/2007	C	26	CT3	Cratacanthus	M	Br	-27.40	-29.11
6/10/2007	C	26	CT3	Cyclotrachelus	F	Br	-25.12	-26.80
6/10/2007	C	33	FA	Calosoma	M	Ma	-27.50	-29.42

6/10/2007	C	35	FA	Calosoma	F	Ma	-28.34	-30.18
6/10/2007	C	45	NT5	Cyclotrachelus	M	Br	-20.42	-23.86
6/10/2007	C	47	NT5	Calosoma	F	Ma	-26.81	-30.22
6/10/2007	CA	1	AL	Cicindela	M	Ma	-19.06	-21.19
6/10/2007	CA	6	AL	Calosoma	M	Ma	-25.88	-24.52
6/10/2007	CA	9	AL	Calosoma	F	Ma	-29.34	-31.28
6/10/2007	CA	9	AL	Cicindela	M	Ma	-24.23	-26.58
6/10/2007	CA	10	AL	Calosoma	F	Ma	-28.84	-29.58
6/10/2007	CA	10	AL	Cicindela	M	Ma	-27.73	-28.23
6/13/2007	A	3	NT1	Cratacanthus	F	Ma	-27.02	-28.19
6/13/2007	A	7	NT1	Cicindela	F	Ma	-22.26	-23.09
6/13/2007	A	15	CT2	Cratacanthus	M	Ma	-25.97	-26.74
6/13/2007	A	23	CT3	Cicindela	F	Ma	-21.39	-22.98
6/13/2007	A	27	CT3	Cicindela	F	Ma	-25.19	-24.26
6/13/2007	A	27	CT3	Cratacanthus	F	Ma	-17.71	-20.71
6/13/2007	A	27	CT3	Scarites	F	Ma	-23.67	-23.61
6/13/2007	A	37	CT4	Cyclotrachelus	F	Br	-28.17	-31.00
6/13/2007	A	37	CT4	Scarites	M	Ma	-24.27	-27.68
6/13/2007	AA	6	AL	Calosoma	M	Ma	-29.44	-32.86
6/13/2007	AA	6	AL	Cicindela	M	Ma	-27.80	-29.44
6/13/2007	AA	6	AL	Cyclotrachelus	F	Br	-23.92	-30.81
6/13/2007	AA	10	AL	Calosoma	M	Ma	-28.08	-30.48
6/13/2007	AA	10	AL	Cyclotrachelus	M	Br	-27.03	-29.94
6/13/2007	B	6	NT1	Cratacanthus	M	Ma	-29.10	-26.60
6/13/2007	B	17	CT2	Scarites	F	Ma	-27.17	-28.69
6/13/2007	B	26	CT3	Cratacanthus	F	Ma	-26.50	-28.02
6/13/2007	B	33	FA	Cratacanthus	M	Ma	-19.32	-19.42
6/13/2007	B	33	FA	Scarites	M	Ma	-24.59	-27.08
6/13/2007	BA	1	AL	Calosoma	M	Ma	-27.18	-29.58
6/13/2007	BA	2	AL	Calosoma	M	Ma	-26.79	-30.37
6/13/2007	BA	9	AL	Calosoma	F	Ma	-26.53	-31.75
6/13/2007	BA	10	AL	Poecilus	F	Ma	-25.07	-26.60
6/13/2007	C	5	NT1	Calosoma	F	Ma	-31.57	-30.61
6/13/2007	C	5	NT1	Scarites	F	Ma	-21.18	-22.29
6/13/2007	C	6	NT1	Cratacanthus	M	Ma	-20.18	-21.60
6/13/2007	C	7	NT1	Cratacanthus	F	Br	-24.96	-27.23
6/13/2007	C	23	CT3	Cratacanthus	M	Ma	-22.74	-24.66
6/13/2007	C	25	CT3	Cratacanthus	M	Ma	-19.01	-22.16
6/13/2007	C	43	NT5	Cicindela	M	Ma	-24.17	-24.49
6/13/2007	C	47	NT5	Cratacanthus	F	Ma	-27.69	-29.03
6/13/2007	CA	1	AL	Calosoma	M	Ma	-29.08	-30.32

6/13/2007	CA	6	AL	Calosoma	F	Ma	-29.74	-32.67
6/13/2007	CA	9	AL	Cicindela	M	Ma	-27.01	-26.77
7/19/2007	A	7	NT1	Tetracha	F	Ma	-24.95	-26.50
7/19/2007	A	16	CT2	Calosoma	F	Ma	-27.91	-29.20
7/19/2007	A	16	CT2	Cicindela	M	Ma	-24.78	-23.63
7/19/2007	A	26	CT3	Calosoma	M	Ma	-28.91	-31.62
7/19/2007	A	26	CT3	Cyclotrachelus	F	Br	-25.78	-26.40
7/19/2007	A	27	CT3	Cicindela	M	Ma	-23.12	-24.09
7/19/2007	A	33	FA	Calosoma	M	Ma	-29.33	-29.85
7/19/2007	A	33	FA	Cicindela	M	Ma	-22.76	-24.58
7/19/2007	A	36	CT4	Calosoma	M	Ma	-28.09	-30.09
7/19/2007	A	37	CT4	Calosoma	M	Ma	-28.08	-30.92
7/19/2007	A	37	CT4	Calosoma	F	Ma	-27.94	-29.07
7/19/2007	AA	1	AL	Calosoma	M	Ma	-27.50	-29.65
7/19/2007	AA	10	AL	Calosoma	M	Ma	-28.94	-29.46
7/19/2007	C	7	NT1	Cratacanthus	M	Br	-23.01	-22.79
7/19/2007	C	23	CT3	Cratacanthus	M	Ma	-26.72	-27.00
7/19/2007	C	25	CT3	Cratacanthus	F	Ma	-20.47	-27.48
7/19/2007	C	27	CT3	Calosoma	M	Ma	-28.78	-30.40
7/19/2007	C	35	FA	Cratacanthus	M	Ma	-16.80	-18.60
7/19/2007	C	43	NT5	Cratacanthus	M	Ma	-25.30	-24.96
7/19/2007	C	43	NT5	Poecilus	F	Ma	-26.99	-27.07
7/19/2007	C	46	NT5	Calosoma	M	Ma	-29.43	-29.91
7/19/2007	CA	1	AL	Calosoma	M	Ma	-27.50	-30.03
7/19/2007	CA	1	AL	Pasimachus	M	Br	-24.82	-28.63
7/19/2007	CA	2	AL	Calosoma	M	Ma	-28.54	-31.32
7/19/2007	CA	6	AL	Calosoma	M	Ma	-28.89	-30.42
7/19/2007	CA	9	AL	Calosoma	M	Ma	-28.52	-29.26
7/19/2007	CA	9	AL	Tetracha	F	Ma	-26.90	-26.66
7/19/2007	CA	10	AL	Calosoma	M	Ma	-28.18	-29.18
7/20/2007	B	3	NT1	Calosoma	F	Ma	-27.83	-29.18
7/20/2007	B	3	NT1	Tetracha	F	Ma	-24.71	-26.25
7/20/2007	B	5	NT1	Calosoma	F	Ma	-30.62	-31.43
7/20/2007	B	5	NT1	Cratacanthus	F	Ma	-28.02	-28.04
7/20/2007	B	5	NT1	Scarites	M	Ma	-24.38	-28.39
7/20/2007	B	7	NT1	Calosoma	M	Ma	-30.26	-26.28
7/20/2007	B	13	CT2	Calosoma	M	Ma	-31.74	-29.48
7/20/2007	B	13	CT2	Scarites	F	Ma	-26.74	-26.18
7/20/2007	B	15	CT2	Calosoma	M	Ma	-30.08	-31.65
7/20/2007	B	16	CT2	Calosoma	M	Ma	-24.99	-28.53
7/20/2007	B	17	CT2	Calosoma	M	Ma	-25.91	-26.44

7/20/2007	B	27	CT3	Calosoma	M	Ma	-25.94	-30.52
7/20/2007	B	27	CT3	Cratacanthus	F	Ma	-21.31	-22.43
7/20/2007	B	27	CT3	Scarites	F	Ma	-22.86	-25.15
7/20/2007	B	36	CT4	Calosoma	F	Ma	-29.58	-30.85
7/20/2007	B	36	CT4	Poecilus	F	Ma	-24.26	-22.64
7/20/2007	B	45	NT5	Cyclotrachelus	M	Br	-27.06	-29.42
7/20/2007	B	47	NT5	Calosoma	F	Ma	-29.67	-31.59
7/20/2007	BA	1	AL	Calosoma	F	Ma	-29.12	-30.69
7/20/2007	BA	1	AL	Cicindela	F	Ma	-24.16	-26.67
7/20/2007	BA	1	AL	Cratacanthus	M	Br	-26.67	-28.58
7/20/2007	BA	2	AL	Calosoma	M	Ma	-28.56	-30.25
7/20/2007	BA	2	AL	Cratacanthus	F	Ma	-27.04	-25.89
7/20/2007	BA	2	AL	Scarites	M	Ma	-24.95	-27.74
7/20/2007	BA	6	AL	Scarites	F	Ma	-26.25	-28.88
7/20/2007	BA	6	AL	Scarites	F	Ma	-28.58	-31.13
7/20/2007	BA	9	AL	Scarites	M	Ma	-17.66	-20.56
7/20/2007	BA	10	AL	Calosoma	F	Ma	-28.69	-31.26
7/27/2007	A	5	NT1	Cicindela	M	Ma	-25.57	-27.94
7/27/2007	A	5	NT1	Pasimachus	M	Br	-23.99	-25.60
7/27/2007	A	6	NT1	Calosoma	F	Ma	-29.31	-29.89
7/27/2007	A	7	NT1	Cicindela	M	Ma	-25.49	-24.08
7/27/2007	A	7	NT1	Cyclotrachelus	M	Br	-26.69	-29.76
7/27/2007	A	16	CT2	Cicindela	M	Ma	-26.09	-25.72
7/27/2007	A	33	FA	Tetracha	M	Ma	-21.93	-25.29
7/27/2007	A	35	FA	Cyclotrachelus	F	Br	-22.73	-25.70
7/27/2007	A	35	FA	Tetracha	F	Ma	-21.83	-24.78
7/27/2007	A	37	CT4	Cicindela	M	Ma	-24.55	-27.49
7/27/2007	A	47	NT5	Cyclotrachelus	M	Br	-25.90	-28.53
7/27/2007	AA	1	AL	Calosoma	M	Ma	-27.98	-28.60
7/27/2007	AA	1	AL	Cyclotrachelus	F	Br	-25.82	-27.93
7/27/2007	AA	1	AL	Tetracha	F	Ma	-24.44	-25.49
7/27/2007	AA	2	AL	Tetracha	F	Ma	-23.72	-27.65
7/27/2007	AA	9	AL	Tetracha	M	Ma	-25.35	-23.59
7/27/2007	AA	10	AL	Tetracha	F	Ma	-24.82	-25.18
7/27/2007	B	6	NT1	Tetracha	F	Ma	-24.04	-24.87
7/27/2007	B	23	CT3	Calosoma	M	Ma	-27.93	-30.24
7/27/2007	B	25	CT3	Poecilus	F	Ma	-27.03	-26.76
7/27/2007	B	43	NT5	Cyclotrachelus	M	Br	-25.31	-27.53
7/27/2007	BA	1	AL	Calosoma	M	Ma	-28.31	-29.63
7/27/2007	BA	2	AL	Calosoma	F	Ma	-29.06	-31.00
7/27/2007	BA	6	AL	Scarites	M	Ma	-25.04	-28.31

7/27/2007	BA	6	AL	Scarites	M	Ma	-23.09	-22.37
7/27/2007	C	5	NT1	Calosoma	F	Ma	-27.90	-31.04
7/27/2007	C	6	NT1	Cratacanthus	F	Ma	-19.55	-23.19
7/27/2007	C	7	NT1	Calosoma	M	Ma	-28.35	-28.92
7/27/2007	C	15	CT2	Cratacanthus	F	Ma	-21.81	-21.97
7/27/2007	C	17	CT2	Calosoma	F	Ma	-27.20	-27.38
7/27/2007	C	23	CT3	Calosoma	F	Ma	-29.16	-29.43
7/27/2007	C	26	CT3	Tetracha	F	Ma	-20.39	-23.84
7/27/2007	C	27	CT3	Calosoma	M	Ma	-29.56	-29.92
7/27/2007	C	33	FA	Calosoma	F	Ma	-29.70	-29.55
7/27/2007	C	33	FA	Cratacanthus	F	Ma	-25.94	-27.28
7/27/2007	C	37	CT4	Calosoma	M	Ma	-29.91	-29.95
7/27/2007	C	37	CT4	Cyclotrachelus	F	Br	-24.76	-30.05
7/27/2007	C	43	NT5	Calosoma	M	Ma	-27.77	-29.93
7/27/2007	CA	1	AL	Calosoma	M	Ma	-26.97	-26.93
7/27/2007	CA	2	AL	Calosoma	F	Ma	-28.06	-27.98
7/27/2007	CA	2	AL	Cratacanthus	F	Ma	-24.08	-21.20
7/27/2007	CA	6	AL	Scarites	F	Ma	-27.93	-28.97
7/27/2007	CA	6	AL	Scarites	F	Ma	-28.40	-30.08
7/27/2007	CA	6	AL	Tetracha	F	Ma	-22.67	-28.43
7/27/2007	CA	9	AL	Calosoma	F	Ma	-29.24	-29.06
7/27/2007	CA	9	AL	Cratacanthus	F	Ma	-20.16	-21.48
7/27/2007	CA	10	AL	Calosoma	M	Ma	-28.96	-30.09
7/27/2007	CA	10	AL	Cratacanthus	F	Ma	-18.70	-18.08
8/3/2007	A	5	NT1	Cicindela	M	Ma	-20.92	-23.18
8/3/2007	A	6	NT1	Cicindela	F	Ma	-20.35	-23.05
8/3/2007	A	7	NT1	Tetracha	F	Ma	-21.33	-22.00
8/3/2007	A	13	CT2	Calosoma	M	Ma	-25.50	-29.96
8/3/2007	A	16	CT2	Cicindela	M	Ma	-21.46	-22.00
8/3/2007	A	17	CT2	Cicindela	F	Ma	-26.37	-25.20
8/3/2007	A	25	CT3	Poecilus	F	Ma	-28.50	-28.97
8/3/2007	A	43	NT5	Calosoma	M	Ma	-20.90	-26.70
8/3/2007	A	45	NT5	Calosoma	F	Ma	-29.22	-30.44
8/3/2007	A	45	NT5	Tetracha	F	Ma	-21.62	-24.85
8/3/2007	A	46	NT5	Cicindela	M	Ma	-22.59	-23.39
8/3/2007	AA	1	AL	Calosoma	F	Ma	-28.56	-27.63
8/3/2007	AA	1	AL	Calosoma	M	Ma	-28.41	-26.09
8/3/2007	AA	1	AL	Tetracha	M	Ma	-23.06	-20.94
8/3/2007	AA	2	AL	Calosoma	M	Ma	-26.58	-28.46
8/3/2007	AA	2	AL	Cicindela	F	Ma	-22.59	-22.68
8/3/2007	AA	6	AL	Calosoma	F	Ma	-25.91	-27.99

8/3/2007	AA	9	AL	Tetracha	F	Ma	-21.20	-22.68
8/3/2007	AA	10	AL	Cicindela	F	Ma	-25.51	-25.25
8/3/2007	AA	10	AL	Tetracha	M	Ma	-23.75	-24.25
8/3/2007	B	5	NT1	Calosoma	M	Ma	-28.26	-30.97
8/3/2007	B	5	NT1	Pasimachus	M	Br	-18.84	-24.48
8/3/2007	BA	1	AL	Calosoma	M	Ma	-29.50	-31.08
8/3/2007	BA	1	AL	Calosoma	F	Ma	-25.35	-26.49
8/3/2007	BA	2	AL	Calosoma	F	Ma	-28.96	-27.65
8/3/2007	BA	6	AL	Calosoma	M	Ma	-24.64	-27.95
8/3/2007	C	3	NT1	Cratacanthus	F	Ma	-26.96	-27.68
8/3/2007	C	7	NT1	Pasimachus	M	Br	-20.23	-20.79
8/3/2007	C	15	CT2	Calosoma	F	Ma	-28.26	-31.80
8/3/2007	C	23	CT3	Cratacanthus	F	Ma	-22.33	-24.61
8/3/2007	C	25	CT3	Pasimachus	F	Br	-25.37	-25.22
8/3/2007	C	26	CT3	Cratacanthus	F	Ma	-27.46	-28.32
8/3/2007	C	35	FA	Cratacanthus	M	Br	-22.78	-21.96
8/3/2007	C	45	NT5	Cicindela	M	Ma	-25.46	-27.72
8/3/2007	C	45	NT5	Pasimachus	M	Br	-28.43	-27.99
8/3/2007	C	47	NT5	Calosoma	F	Br	-24.88	-29.82
8/3/2007	C	47	NT5	Scarites	M	Ma	-28.37	-28.47
8/3/2007	CA	1	AL	Calosoma	M	Ma	-28.31	-30.46
8/3/2007	CA	6	AL	Scarites	M	Ma	-27.24	-30.41
8/3/2007	CA	10	AL	Pasimachus	F	Br	-20.32	-22.33
8/10/2007	A	3	NT1	Cicindela	M	Ma	-23.34	-23.84
8/10/2007	A	6	NT1	Pasimachus	M	Br	-22.28	-22.35
8/10/2007	A	6	NT1	Tetracha	M	Ma	-23.11	-24.34
8/10/2007	A	7	NT1	Calosoma	M	Ma	-23.19	-23.38
8/10/2007	A	7	NT1	Cyclotrachelus	F	Br	-26.15	-27.65
8/10/2007	A	13	CT2	Calosoma	F	Ma	-23.22	-25.04
8/10/2007	A	15	CT2	Calosoma	F	Ma	-25.35	-25.30
8/10/2007	A	16	CT2	Cicindela	M	Ma	-26.02	-27.55
8/10/2007	A	17	CT2	Cyclotrachelus	F	Br	-26.33	-27.95
8/10/2007	A	25	CT3	Calosoma	F	Ma	-25.49	-28.97
8/10/2007	A	25	CT3	Pasimachus	F	Br	-25.77	-25.53
8/10/2007	A	25	CT3	Tetracha	M	Ma	-19.70	-24.37
8/10/2007	A	27	CT3	Calosoma	M	Ma	-18.08	-22.23
8/10/2007	A	33	FA	Scarites	F	Ma	-20.67	-21.08
8/10/2007	A	36	CT4	Cyclotrachelus	M	Br	-28.22	-28.17
8/10/2007	A	37	CT4	Calosoma	F	Ma	-21.98	-25.23
8/10/2007	A	37	CT4	Cicindela	M	Ma	-23.35	-24.18

8/10/2007	A	37	CT4	Cratacanthus	F	Ma	-22.92	-20.83
8/10/2007	A	43	NT5	Cicindela	F	Ma	-22.46	-25.20
8/10/2007	A	47	NT5	Calosoma	M	Ma	-28.13	-27.25
8/10/2007	AA	1	AL	Calosoma	M	Ma	-27.27	-29.90
8/10/2007	AA	1	AL	Scarites	F	Ma	-23.52	-25.60
8/10/2007	AA	1	AL	Tetracha	F	Ma	-24.44	-27.75
8/10/2007	AA	2	AL	Calosoma	F	Ma	-29.37	-29.20
8/10/2007	AA	2	AL	Tetracha	F	Ma	-26.67	-29.00
8/10/2007	AA	6	AL	Calosoma	F	Ma	-22.51	-27.03
8/10/2007	AA	6	AL	Cratacanthus	F	Ma	-22.00	-21.78
8/10/2007	AA	6	AL	Tetracha	M	Ma	-23.42	-27.42
8/10/2007	AA	9	AL	Scarites	F	Ma	-23.56	-27.59
8/10/2007	AA	9	AL	Tetracha	M	Ma	-24.36	-28.07
8/10/2007	AA	10	AL	Tetracha	M	Ma	-25.80	-27.98
8/10/2007	B	7	NT1	Tetracha	F	Ma	-23.14	-22.47
8/10/2007	B	13	CT2	Calosoma	M	Ma	-29.98	-30.24
8/10/2007	B	26	CT3	Poecilus	F	Ma	-25.36	-25.84
8/10/2007	B	27	CT3	Pasimachus	M	Br	-17.29	-21.60
8/10/2007	B	37	CT4	Calosoma	M	Ma	-30.28	-31.92
8/10/2007	B	37	CT4	Calosoma	F	Ma	-27.99	-28.95
8/10/2007	BA	1	AL	Calosoma	M	Ma	-29.11	-30.28
8/10/2007	BA	1	AL	Scarites	F	Ma	-19.37	-27.69
8/10/2007	BA	2	AL	Calosoma	F	Ma	-28.33	-29.89
8/10/2007	BA	6	AL	Scarites	F	Ma	-22.23	-24.74
8/10/2007	BA	6	AL	Scarites	F	Ma	-25.64	-27.24
8/10/2007	BA	10	AL	Calosoma	M	Ma	-29.35	-31.31
8/10/2007	C	7	NT1	Cyclotrachelus	M	Br	-27.66	-30.26
8/10/2007	C	13	CT2	Tetracha	F	Ma	-24.23	-26.62
8/10/2007	C	23	CT3	Scarites	F	Ma	-23.89	-25.67
8/10/2007	C	26	CT3	Cyclotrachelus	M	Br	-25.97	-28.55
8/10/2007	C	26	CT3	Pasimachus	M	Br	-27.16	-29.79
8/10/2007	C	26	CT3	Tetracha	F	Br	-24.77	-26.87
8/10/2007	C	35	FA	Scarites	F	Ma	-24.12	-27.16
8/10/2007	C	36	CT4	Calosoma	F	Ma	-26.47	-25.61
8/10/2007	C	37	CT4	Pasimachus	M	Br	-22.31	-25.76
8/10/2007	C	47	NT5	Cyclotrachelus	F	Br	-26.66	-27.70
8/10/2007	CA	1	AL	Pasimachus	M	Br	-17.16	-20.37
8/10/2007	CA	6	AL	Calosoma	M	Ma	-26.80	-31.21
8/10/2007	CA	6	AL	Scarites	F	Ma	-27.40	-29.06
8/10/2007	CA	9	AL	Calosoma	M	Ma	-29.43	-31.76
8/10/2007	CA	9	AL	Scarites	M	Ma	-21.09	-22.55
8/10/2007	CA	9	AL	Tetracha	M	Ma	-22.17	-24.58

8/10/2007	CA	10	AL	Calosoma	F	Ma	-28.10	-31.32
8/10/2007	CA	10	AL	Pasimachus	M	Br	-28.00	-29.43
8/17/2007	A	5	NT1	Cyclotrachelus	M	Br	-26.20	-29.75
8/17/2007	A	7	NT1	Tetracha	F	Ma	-27.08	-25.78
8/17/2007	A	13	CT2	Cyclotrachelus	M	Br	-26.73	-27.85
8/17/2007	A	17	CT2	Cicindela	M	Ma	-24.53	-26.09
8/17/2007	A	26	CT3	Tetracha	F	Ma	-15.76	-24.48
8/17/2007	A	27	CT3	Calosoma	M	Ma	-27.30	-28.71
8/17/2007	A	37	CT4	Cyclotrachelus	M	Br	-25.07	-26.70
8/17/2007	A	37	CT4	Scarites	M	Ma	-27.04	-27.28
8/17/2007	A	43	NT5	Tetracha	F	Ma	-24.09	-25.40
8/17/2007	A	46	NT5	Cicindela	M	Ma	-24.52	-24.35
8/17/2007	A	46	NT5	Tetracha	F	Ma	-24.24	-26.12
8/17/2007	A	47	NT5	Calosoma	F	Ma	-27.95	-23.65
8/17/2007	A	47	NT5	Tetracha	M	Ma	-27.08	-28.57
8/17/2007	AA	1	AL	Calosoma	F	Ma	-23.26	-24.95
8/17/2007	AA	6	AL	Calosoma	F	Ma	-25.52	-28.57
8/17/2007	AA	6	AL	Calosoma	F	Ma	-21.42	-27.24
8/17/2007	AA	6	AL	Cicindela	M	Ma	-27.26	-27.98
8/17/2007	AA	6	AL	Cratacanthus	F	Ma	-25.55	-25.56
8/17/2007	AA	6	AL	Cyclotrachelus	F	Br	-23.61	-25.55
8/17/2007	AA	9	AL	Calosoma	M	Ma	-24.77	-26.77
8/17/2007	AA	9	AL	Tetracha	M	Ma	-27.21	-28.59
8/17/2007	AA	10	AL	Calosoma	F	Ma	-28.18	-29.58
8/17/2007	AA	10	AL	Cicindela	M	Ma	-25.06	-27.33
8/17/2007	AA	10	AL	Tetracha	M	Ma	-23.89	-26.17
8/17/2007	B	6	NT1	Pasimachus	F	Br	-25.82	-29.34
8/17/2007	B	17	CT2	Calosoma	F	Ma	-28.56	-30.41
8/17/2007	B	17	CT2	Pasimachus	M	Br	-21.82	-25.22
8/17/2007	B	25	CT3	Poecilus	F	Ma	-20.33	-21.93
8/17/2007	B	26	CT3	Calosoma	M	Ma	-28.96	-29.93
8/17/2007	B	35	FA	Calosoma	F	Ma	-27.45	-29.71
8/17/2007	BA	1	AL	Scarites	F	Ma	-27.44	-30.09
8/17/2007	BA	2	AL	Calosoma	M	Ma	-28.92	-30.27
8/17/2007	BA	6	AL	Scarites	F	Ma	-28.11	-27.94
8/17/2007	BA	10	AL	Scarites	M	Ma	-20.11	-25.63
8/17/2007	C	7	NT1	Cyclotrachelus	F	Br	-25.03	-27.63
8/17/2007	C	17	CT2	Calosoma	F	Ma	-27.39	-29.02
8/17/2007	C	17	CT2	Cyclotrachelus	M	Br	-27.40	-30.29
8/17/2007	C	36	CT4	Calosoma	M	Ma	-29.64	-30.70
8/17/2007	C	36	CT4	Cyclotrachelus	F	Br	-25.02	-30.58

8/17/2007	C	36	CT4	Pasimachus	M	Br	-28.73	-31.62
8/17/2007	CA	6	AL	Calosoma	F	Ma	-28.17	-27.86
8/17/2007	CA	6	AL	Scarites	M	Ma	-25.32	-27.52
8/17/2007	CA	6	AL	Scarites	F	Ma	-27.60	-29.08
8/17/2007	CA	9	AL	Calosoma	F	Ma	-26.45	-28.88
8/17/2007	CA	10	AL	Calosoma	F	Ma	-27.55	-28.93
8/31/2007	A	3	NT1	Cicindela	F	Ma	-23.70	-24.07
8/31/2007	A	3	NT1	Tetracha	M	Ma	-22.00	-22.59
8/31/2007	A	5	NT1	Cicindela	F	Ma	-25.29	-25.50
8/31/2007	A	6	NT1	Cratacanthus	M	Br	-21.51	-22.02
8/31/2007	A	6	NT1	Tetracha	F	Ma	-25.02	-24.12
8/31/2007	A	7	NT1	Calosoma	M	Ma	-26.28	-28.73
8/31/2007	A	7	NT1	Cicindela	M	Ma	-27.44	-26.02
8/31/2007	A	15	CT2	Tetracha	M	Ma	-24.44	-29.35
8/31/2007	A	25	CT3	Cicindela	M	Ma	-19.24	-20.84
8/31/2007	A	25	CT3	Cratacanthus	F	Ma	-19.41	-18.00
8/31/2007	A	27	CT3	Cicindela	M	Ma	-20.97	-23.73
8/31/2007	A	27	CT3	Tetracha	F	Ma	-22.43	-25.88
8/31/2007	A	35	FA	Calosoma	F	Ma	-24.63	-26.22
8/31/2007	A	35	FA	Tetracha	F	Ma	-24.70	-25.85
8/31/2007	A	37	CT4	Cicindela	M	Ma	-24.97	-23.24
8/31/2007	A	43	NT5	Cicindela	F	Ma	-22.51	-21.91
8/31/2007	A	47	NT5	Calosoma	M	Ma	-30.12	-30.14
8/31/2007	AA	1	AL	Calosoma	M	Ma	-29.85	-30.71
8/31/2007	AA	2	AL	Calosoma	M	Ma	-27.59	-28.30
8/31/2007	AA	6	AL	Calosoma	F	Ma	-26.99	-28.24
8/31/2007	AA	6	AL	Pasimachus	M	Br	-23.17	-23.12
8/31/2007	AA	6	AL	Tetracha	F	Ma	-24.59	-24.81
8/31/2007	AA	9	AL	Tetracha	M	Ma	-23.63	-23.53
8/31/2007	AA	10	AL	Calosoma	F	Ma	-24.86	-26.10
8/31/2007	B	6	NT1	Calosoma	F	Ma	-27.07	-27.74
8/31/2007	B	7	NT1	Pasimachus	M	Br	-26.01	-27.75
8/31/2007	B	17	CT2	Calosoma	M	Ma	-29.92	-30.28
8/31/2007	B	25	CT3	Calosoma	F	Ma	-27.97	-28.61
8/31/2007	B	33	FA	Calosoma	F	Ma	-27.93	-29.12
8/31/2007	B	37	CT4	Calosoma	M	Ma	-28.63	-30.16
8/31/2007	B	46	NT5	Calosoma	F	Ma	-27.60	-30.36
8/31/2007	B	46	NT5	Scarites	M	Ma	-28.46	-28.88
8/31/2007	B	46	NT5	Tetracha	M	Ma	-26.96	-28.99
8/31/2007	BA	1	AL	Cratacanthus	F	Br	-25.61	-21.64
8/31/2007	BA	1	AL	Pasimachus	F	Br	-20.16	-23.78

8/31/2007	BA	2	AL	Calosoma	M	Ma	-18.14	-25.51
8/31/2007	BA	2	AL	Pasimachus	F	Br	-27.64	-28.06
8/31/2007	BA	9	AL	Calosoma	F	Ma	-28.61	-30.56
8/31/2007	BA	9	AL	Tetracha	F	Ma	-23.43	-24.79
8/31/2007	BA	10	AL	Calosoma	M	Ma	-28.23	-31.60
8/31/2007	BA	10	AL	Tetracha	M	Ma	-21.96	-24.67
8/31/2007	C	5	NT1	Calosoma	M	Ma	-23.34	-26.89
8/31/2007	C	13	CT2	Cicindela	F	Ma	-27.49	-26.88
8/31/2007	C	17	CT2	Cratacanthus	F	Ma	-17.02	-17.37
8/31/2007	C	25	CT3	Calosoma	F	Ma	-21.40	-25.89
8/31/2007	C	25	CT3	Pasimachus	M	Br	-21.75	-25.42
8/31/2007	C	27	CT3	Tetracha	M	Ma	-22.38	-26.21
8/31/2007	CA	1	AL	Calosoma	F	Ma	-28.87	-30.29
8/31/2007	CA	2	AL	Calosoma	M	Ma	-30.07	-29.86
8/31/2007	CA	2	AL	Pasimachus	F	Br	-19.11	-26.71
8/31/2007	CA	6	AL	Calosoma	M	Ma	-30.99	-32.18
8/31/2007	CA	9	AL	Calosoma	F	Ma	-27.40	-28.69
8/31/2007	CA	9	AL	Calosoma	F	Ma	-28.09	-27.99
8/31/2007	CA	9	AL	Calosoma	F	Ma	-28.22	-27.37
8/31/2007	CA	10	AL	Calosoma	M	Ma	-26.19	-27.04
9/5/2007	A	7	NT1	Cicindela	M	Ma	-24.07	-26.16
9/5/2007	A	17	CT2	Cicindela	M	Ma	-25.67	-24.51
9/5/2007	A	17	CT2	Tetracha	M	Ma	-23.79	-25.81
9/5/2007	A	25	CT3	Cratacanthus	F	Ma	-19.79	-17.05
9/5/2007	A	27	CT3	Cicindela	M	Ma	-23.41	-22.73
9/5/2007	A	36	CT4	Tetracha	M	Ma	-24.08	-28.65
9/5/2007	A	37	CT4	Cicindela	M	Ma	-24.19	-23.16
9/5/2007	A	37	CT4	Tetracha	F	Ma	-25.25	-27.24
9/5/2007	A	43	NT5	Tetracha	M	Ma	-26.55	-27.11
9/5/2007	A	46	NT5	Pasimachus	F	Br	-21.39	-24.41
9/5/2007	AA	1	AL	Calosoma	M	Ma	-21.07	-25.76
9/5/2007	AA	2	AL	Calosoma	M	Ma	-27.83	-25.94
9/5/2007	AA	6	AL	Calosoma	F	Ma	-26.68	-27.25
9/5/2007	AA	10	AL	Calosoma	M	Ma	-28.30	-33.79
9/5/2007	AA	10	AL	Cratacanthus	M	Br	-25.50	-25.06
9/5/2007	AA	10	AL	Tetracha	M	Ma	-17.62	-19.09
9/5/2007	B	7	NT1	Calosoma	F	Ma	-30.68	-30.56
9/5/2007	B	17	CT2	Calosoma	F	Ma	-23.38	-29.94
9/5/2007	BA	1	AL	Calosoma	M	Ma	-28.07	-30.42
9/5/2007	BA	2	AL	Calosoma	F	Ma	-26.27	-29.59
9/5/2007	BA	6	AL	Calosoma	M	Ma	-28.63	-29.08

9/5/2007	BA	6	AL	Cyclotrachelus	M	Br	-28.39	-27.83
9/5/2007	BA	6	AL	Poecilus	F	Ma	-24.16	-26.25
9/5/2007	BA	9	AL	Calosoma	F	Ma	-27.85	-27.92
9/5/2007	BA	10	AL	Calosoma	M	Ma	-29.01	-29.79
9/5/2007	C	5	NT1	Cicindela	M	Ma	-25.79	-24.99
9/5/2007	C	6	NT1	Calosoma	M	Ma	-19.74	-23.86
9/5/2007	C	7	NT1	Cratacanthus	F	Br	-24.93	-25.49
9/5/2007	C	13	CT2	Cyclotrachelus	M	Br	-24.04	-27.26
9/5/2007	C	15	CT2	Pasimachus	F	Br	-23.57	-27.52
9/5/2007	C	23	CT3	Calosoma	M	Ma	-26.99	-28.95
9/5/2007	C	25	CT3	Calosoma	M	Ma	-25.48	-27.20
9/5/2007	C	27	CT3	Calosoma	F	Ma	-21.80	-25.18
9/5/2007	CA	1	AL	Calosoma	F	Ma	-26.97	-26.68
9/5/2007	CA	2	AL	Calosoma	F	Ma	-27.43	-26.61
9/5/2007	CA	6	AL	Calosoma	F	Ma	-29.79	-31.22
9/5/2007	CA	9	AL	Calosoma	M	Ma	-28.58	-29.98
9/5/2007	CA	10	AL	Calosoma	M	Ma	-22.55	-27.18
9/12/2007	A	3	NT1	Cyclotrachelus	M	Br	-20.44	-23.77
9/12/2007	A	5	NT1	Cicindela	M	Ma	-23.08	-24.39
9/12/2007	A	6	NT1	Cicindela	M	Ma	-25.19	-27.70
9/12/2007	A	6	NT1	Cyclotrachelus	F	Br	-23.85	-26.19
9/12/2007	A	6	NT1	Tetracha	F	Ma	-22.95	-27.05
9/12/2007	A	7	NT1	Calosoma	F	Ma	-28.19	-29.30
9/12/2007	A	7	NT1	Cicindela	M	Ma	-23.25	-28.97
9/12/2007	A	7	NT1	Cyclotrachelus	F	Br	-25.58	-26.47
9/12/2007	A	7	NT1	Tetracha	F	Ma	-23.14	-28.45
9/12/2007	A	13	CT2	Cyclotrachelus	M	Br	-18.73	-21.96
9/12/2007	A	15	CT2	Cicindela	F	Ma	-22.63	-25.01
9/12/2007	A	15	CT2	Cyclotrachelus	F	Br	-27.17	-27.39
9/12/2007	A	17	CT2	Calosoma	M	Ma	-27.57	-29.64
9/12/2007	A	17	CT2	Tetracha	M	Ma	-23.77	-23.85
9/12/2007	A	23	CT3	Calosoma	M	Ma	-28.82	-30.13
9/12/2007	A	23	CT3	Cyclotrachelus	M	Br	-24.18	-27.57
9/12/2007	A	25	CT3	Cicindela	M	Ma	-22.01	-23.13
9/12/2007	A	25	CT3	Cratacanthus	F	Ma	-26.81	-27.35
9/12/2007	A	26	CT3	Cicindela	F	Ma	-23.80	-25.17
9/12/2007	A	27	CT3	Calosoma	M	Ma	-27.34	-28.49
9/12/2007	A	36	CT4	Cicindela	F	Ma	-24.18	-25.08
9/12/2007	A	36	CT4	Tetracha	F	Ma	-23.65	-26.45
9/12/2007	A	37	CT4	Cicindela	M	Ma	-24.73	-25.41
9/12/2007	A	43	NT5	Calosoma	M	Ma	-21.25	-23.00

9/12/2007	A	45	NT5	Cicindela	M	Ma	-22.10	-23.44
9/12/2007	A	46	NT5	Cicindela	M	Ma	-25.88	-27.48
9/12/2007	A	46	NT5	Cyclotrachelus	M	Br	-25.94	-26.98
9/12/2007	A	46	NT5	Tetracha	F	Ma	-17.29	-26.25
9/12/2007	A	47	NT5	Cicindela	M	Ma	-23.23	-25.11
9/12/2007	A	47	NT5	Cyclotrachelus	F	Br	-24.47	-27.37
9/12/2007	A	47	NT5	Tetracha	M	Ma	-22.21	-24.56
9/12/2007	AA	1	AL	Calosoma	M	Ma	-24.52	-26.72
9/12/2007	AA	1	AL	Calosoma	F	Ma	-27.52	-28.76
9/12/2007	AA	2	AL	Calosoma	M	Ma	-26.10	-27.59
9/12/2007	AA	2	AL	Cicindela	M	Ma	-25.81	-27.75
9/12/2007	AA	2	AL	Tetracha	M	Ma	-25.57	-26.85
9/12/2007	AA	6	AL	Calosoma	F	Ma	-24.26	-25.02
9/12/2007	AA	6	AL	Cicindela	M	Ma	-23.08	-25.76
9/12/2007	AA	6	AL	Cyclotrachelus	M	Br	-27.12	-27.85
9/12/2007	AA	6	AL	Cyclotrachelus	M	Br	-21.98	-25.68
9/12/2007	AA	6	AL	Tetracha	M	Ma	-24.53	-24.39
9/12/2007	AA	9	AL	Pasimachus	M	Br	-20.68	-24.87
9/12/2007	AA	10	AL	Calosoma	M	Ma	-26.84	-25.49
9/12/2007	AA	10	AL	Cicindela	F	Ma	-24.13	-25.28
9/12/2007	AA	10	AL	Tetracha	M	Ma	-25.10	-24.55
9/12/2007	B	3	NT1	Tetracha	F	Ma	-26.02	-27.37
9/12/2007	B	5	NT1	Cicindela	F	Ma	-22.07	-22.68
9/12/2007	B	5	NT1	Tetracha	F	Ma	-23.64	-25.87
9/12/2007	B	6	NT1	Calosoma	F	Ma	-29.33	-30.05
9/12/2007	B	7	NT1	Cyclotrachelus	M	Br	-26.73	-28.04
9/12/2007	B	13	CT2	Calosoma	M	Ma	-27.15	-30.58
9/12/2007	B	13	CT2	Cicindela	F	Ma	-22.22	-22.65
9/12/2007	B	13	CT2	Tetracha	F	Ma	-25.24	-26.78
9/12/2007	B	17	CT2	Calosoma	M	Ma	-28.74	-30.58
9/12/2007	B	35	FA	Calosoma	M	Ma	-26.94	-28.20
9/12/2007	B	35	FA	Scarites	F	Ma	-19.50	-23.85
9/12/2007	B	37	CT4	Tetracha	F	Ma	-22.64	-24.27
9/12/2007	B	43	NT5	Pasimachus	F	Br	-22.27	-24.92
9/12/2007	B	46	NT5	Cyclotrachelus	M	Br	-27.29	-28.15
9/12/2007	BA	1	AL	Calosoma	M	Ma	-27.90	-29.00
9/12/2007	BA	1	AL	Tetracha	M	Ma	-26.16	-28.86
9/12/2007	BA	2	AL	Calosoma	M	Ma	-25.59	-27.40
9/12/2007	BA	2	AL	Cicindela	M	Ma	-24.20	-25.39
9/12/2007	BA	2	AL	Tetracha	M	Ma	-26.17	-25.39
9/12/2007	BA	2	AL	Tetracha	M	Ma	-24.12	-25.50

9/12/2007	BA	6	AL	Calosoma	M	Ma	-26.86	-28.06
9/12/2007	BA	6	AL	Scarites	M	Ma	-25.23	-25.51
9/12/2007	BA	6	AL	Tetracha	M	Ma	-21.27	-21.86
9/12/2007	BA	9	AL	Calosoma	M	Ma	-29.43	-30.59
9/12/2007	BA	10	AL	Calosoma	M	Ma	-29.17	-31.47
9/12/2007	C	7	NT1	Cyclotrachelus	M	Br	-25.85	-29.31
9/12/2007	C	7	NT1	Cyclotrachelus	M	Br	-24.54	-27.94
9/12/2007	C	15	CT2	Cyclotrachelus	M	Br	-27.14	-26.82
9/12/2007	C	17	CT2	Pasimachus	F	Br	-22.89	-28.32
9/12/2007	C	23	CT3	Cyclotrachelus	M	Br	-27.23	-27.50
9/12/2007	C	23	CT3	Tetracha	F	Ma	-24.47	-26.52
9/12/2007	C	26	CT3	Cyclotrachelus	F	Br	-27.06	-30.57
9/12/2007	C	33	FA	Tetracha	F	Ma	-25.57	-26.94
9/12/2007	C	35	FA	Calosoma	M	Ma	-26.55	-28.44
9/12/2007	C	36	CT4	Calosoma	M	Ma	-29.41	-29.76
9/12/2007	C	43	NT5	Calosoma	M	Ma	-27.81	-29.71
9/12/2007	C	45	NT5	Cyclotrachelus	M	Br	-26.50	-25.87
9/12/2007	CA	2	AL	Tetracha	M	Ma	-23.32	-21.83
9/12/2007	CA	6	AL	Calosoma	M	Ma	-29.04	-29.40
9/12/2007	CA	6	AL	Cicindela	M	Ma	-18.74	-21.79
9/12/2007	CA	6	AL	Cyclotrachelus	M	Br	-25.56	-25.99
9/12/2007	CA	9	AL	Calosoma	M	Ma	-26.43	-28.89
9/12/2007	CA	9	AL	Cicindela	M	Ma	-23.30	-24.34
9/12/2007	CA	9	AL	Tetracha	M	Ma	-24.39	-26.44
9/12/2007	CA	10	AL	Calosoma	F	Ma	-26.98	-27.24
9/20/2007	A	3	NT1	Cyclotrachelus	M	Br	-24.01	-24.21
9/20/2007	A	5	NT1	Calosoma	M	Ma	-27.18	-26.60
9/20/2007	A	5	NT1	Cicindela	F	Ma	-23.81	-24.20
9/20/2007	A	6	NT1	Cicindela	F	Ma	-25.35	-25.62
9/20/2007	A	6	NT1	Cyclotrachelus	M	Br	-25.66	-25.57
9/20/2007	A	13	CT2	Cicindela	M	Ma	-25.44	-25.48
9/20/2007	A	13	CT2	Poecilus	F	Ma	-14.96	-17.54
9/20/2007	A	15	CT2	Cicindela	M	Ma	-24.06	-25.46
9/20/2007	A	15	CT2	Scarites	M	Ma	-22.49	-23.89
9/20/2007	A	17	CT2	Tetracha	F	Ma	-20.39	-21.08
9/20/2007	A	23	CT3	Calosoma	M	Ma	-23.94	-25.95
9/20/2007	A	25	CT3	Cicindela	M	Ma	-20.11	-23.36
9/20/2007	A	26	CT3	Cicindela	M	Ma	-24.97	-26.56
9/20/2007	A	26	CT3	Cyclotrachelus	M	Br	-26.41	-25.92
9/20/2007	A	27	CT3	Tetracha	M	Ma	-23.35	-22.99
9/20/2007	A	35	FA	Cicindela	F	Ma	-20.63	-22.61

9/20/2007	A	37	CT4	Calosoma	F	Ma	-28.54	-27.16
9/20/2007	A	46	NT5	Tetracha	F	Ma	-23.90	-25.45
9/20/2007	AA	1	AL	Cicindela	M	Ma	-25.44	-26.23
9/20/2007	AA	1	AL	Pasimachus	M	Br	-23.04	-27.12
9/20/2007	AA	1	AL	Tetracha	M	Ma	-24.01	-24.35
9/20/2007	AA	9	AL	Cyclotrachelus	M	Br	-23.44	-25.62
9/20/2007	B	3	NT1	Tetracha	M	Ma	-24.09	-25.90
9/20/2007	B	5	NT1	Cyclotrachelus	F	Br	-22.48	-25.60
9/20/2007	B	6	NT1	Calosoma	M	Ma	-29.19	-31.49
9/20/2007	B	6	NT1	Cyclotrachelus	M	Br	-25.12	-25.30
9/20/2007	B	6	NT1	Tetracha	F	Ma	-22.80	-24.12
9/20/2007	B	15	CT2	Tetracha	F	Ma	-25.00	-25.30
9/20/2007	B	17	CT2	Calosoma	M	Ma	-29.97	-30.48
9/20/2007	B	17	CT2	Cyclotrachelus	M	Br	-27.68	-28.61
9/20/2007	B	33	FA	Tetracha	F	Ma	-26.54	-26.34
9/20/2007	B	35	FA	Tetracha	F	Ma	-25.05	-25.51
9/20/2007	BA	1	AL	Calosoma	M	Ma	-29.42	-30.10
9/20/2007	BA	1	AL	Cicindela	M	Ma	-22.94	-24.63
9/20/2007	BA	2	AL	Tetracha	M	Ma	-22.04	-23.70
9/20/2007	BA	6	AL	Poecilus	F	Ma	-26.01	-26.57
9/20/2007	BA	10	AL	Calosoma	M	Ma	-28.36	-29.37
9/20/2007	C	3	NT1	Cyclotrachelus	M	Br	-25.15	-26.95
9/20/2007	C	7	NT1	Pasimachus	M	Br	-24.83	-26.80
9/20/2007	C	7	NT1	Tetracha	F	Ma	-22.42	-24.99
9/20/2007	C	13	CT2	Pasimachus	M	Br	-26.55	-28.16
9/20/2007	C	17	CT2	Cyclotrachelus	F	Br	-27.96	-23.78
9/20/2007	C	17	CT2	Tetracha	F	Ma	-21.13	-25.59
9/20/2007	C	23	CT3	Cyclotrachelus	M	Br	-21.39	-23.41
9/20/2007	C	26	CT3	Calosoma	M	Ma	-27.84	-28.00
9/20/2007	C	27	CT3	Calosoma	M	Ma	-20.55	-22.95
9/20/2007	C	35	FA	Tetracha	F	Ma	-26.31	-26.71
9/20/2007	C	36	CT4	Calosoma	M	Ma	-28.09	-29.57
9/20/2007	C	36	CT4	Tetracha	F	Ma	-23.42	-26.07
9/20/2007	C	37	CT4	Cicindela	M	Ma	-21.26	-24.09
9/20/2007	C	37	CT4	Cyclotrachelus	M	Br	-25.31	-26.88
9/20/2007	C	37	CT4	Scarites	M	Ma	-25.76	-25.46
9/20/2007	CA	1	AL	Calosoma	M	Ma	-24.63	-25.44
9/20/2007	CA	1	AL	Cyclotrachelus	M	Br	-27.75	-26.84
9/20/2007	CA	1	AL	Tetracha	M	Ma	-20.39	-22.32
9/20/2007	CA	2	AL	Cratacanthus	F	Ma	-23.74	-21.86
9/20/2007	CA	2	AL	Pasimachus	M	Br	-20.03	-24.79

9/20/2007	CA	2	AL	Tetracha	F	Ma	-26.81	-26.03
9/20/2007	CA	6	AL	Calosoma	M	Ma	-28.60	-28.69
9/20/2007	CA	9	AL	Calosoma	M	Ma	-29.06	-27.00
9/20/2007	CA	9	AL	Tetracha	M	Ma	-19.18	-22.86
9/20/2007	CA	10	AL	Calosoma	M	Ma	-26.02	-26.63
9/20/2007	CA	10	AL	Tetracha	F	Ma	-28.73	-29.41

VITA

Sarah Lyn Donelson

Candidate for the Degree of
Doctor of Philosophy

Thesis: CARABID (COLEOPTERA: CARABIDAE) ECOLOGY IN AGROECOSYSTEMS OF THE SOUTHERN GREAT PLAINS

Major Field: Entomology

Biographical: Born in Indianapolis, Indiana

Education: Completed the requirements for the Doctor of Philosophy in Entomology at Oklahoma State University, Stillwater, Oklahoma in July, 2011, Master of Arts Fine Art Photography at Ball State University, Muncie, Indiana in 1992, Bachelor of Science in Biology with a minor in Chemistry at Cameron University, Lawton, Oklahoma in 1998, Post-graduate certification in Scientific Illustration, Science Communication Program, University of California, Santa Cruz, California (1998-1999).

Experience: Senior Agriculturalist, Integrated Pest Management Laboratory, Oklahoma State University, Stillwater, Oklahoma (2009-Present), Research Assistant, Integrated Pest Management Laboratory, Department of Entomology and Plant Pathology, Oklahoma State University, Stillwater, Oklahoma (2005-2009), Research Assistant, Molecular Ecology and Systematics Laboratory, Department of Zoology, Oklahoma State University, Stillwater, Oklahoma (2003-2005).

Professional Memberships: Entomological Society of America, Southwestern Branch of the Entomological Society of America, Phi Kappa Phi Honor Society, Gamma Sigma Delta Honor Society, Beta Beta Beta Biological Honor Society.

Name: Sarah Lyn Donelson Date of Degree: July, 2011

Institution: Oklahoma State University Location: Stillwater, Oklahoma

Title of Study: CARABID (COLEOPTERA: CARABIDAE) ECOLOGY IN AGROECOSYSTEMS OF THE SOUTHERN GREAT PLAINS

Pages in Study: 195 Candidate for the Degree of Doctor of Philosophy

Major Field: Entomology

Scope and Method of Study: In the Southern Great Plains, natural enemy assemblages regularly exert biological control in annual crops. These assemblages have a regulating effect on pest populations which can maintain these populations below economic threshold levels. Carabidae constitute a major part of agricultural fauna and are an important part of the natural enemy assemblages regulating pest populations in agroecosystems of this region. Conservation of carabid beetles in agroecosystems is dependent on knowing their biology. However, carabid biology within diverse agricultural systems of the Southern Great Plains is not well studied. These studies were designed to determine the impact of tillage on carabid biology, elucidate carabid dispersal powers in diversified agricultural systems, ascertain natal origins and describe carabid utilization of a semi-permanent crop, alfalfa.

Findings and Conclusions: This study has quantified carabid colonization of an annual crop (sorghum) from a semi-permanent habitat (alfalfa) and small scale colonization was measureable for some carabid genera. No significant differences were detected between no-till and conventional-tillage within years. Tillage effects were detectable at the genus level in this study. This study found evidence that carabids were moving within and among sorghum and alfalfa with some indication of cyclic colonization based upon stable carbon isotope ratios. Isotope data revealed that diet switching between habitats by carabids was evident in both years. This study has demonstrated that natal origins can be inferred from carbon isotopic compositions transferred to carabid adults from larval dietary intake. Natal origins indicated that alfalfa provided carabids with alternate prey, oviposition sites, overwintering habitat, and refuge from farming operations.

ADVISER'S APPROVAL: Dr. Kristopher L. Giles