COMPARISON OF THE LIFE HISTORIES OF TWO DICOT-FEEDING

PISSONOTUS PLANTHOPPERS (HEMIPTERA: DELPHACIDAE)

by

Aaron Joseph Bossert

An Abstract

of a thesis submitted in partial fulfillment of the

requirements for the degree of

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ABSTRACT

By

Aaron Joseph Bossert

Two species of in the planthopper genus Pissonotus (Homoptera: Delphacidae), P. piceus Van Duzee and P. delicatus Van Duzee, although physically very similar, feed on very different host plants in very different habitats. Pissonotus piceus feeds exclusively on a semiaquatic plant, whereas P. delicatus feeds on a dry upland adapted plant. In this study collection data were used to develop descriptions and keys to P. piceus nymphal instars. These data were also used to demonstrate that P. piceus populations respond to habitat disruption with an increase in the macropterous wing form. Field and greenhouse observations from 2009 and 2010 were used compare life histories and behaviors of P. piceus, which has few sap feeding competitors and numerous predators, to P. delicatus, which has numerous sap feeding competitors and few predators. Field collections were used to assess the insect and spider communities of the two respective host plants.

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(Hemiptera: Delphacidae)

by

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LIST OF ABBREVIATIONS

AIC = Akaikie Information Criterion

AICc = Akaike Information Criterion corrected for small sample size

ΔAIC = The information difference from the top ranked model

ca = circa

cm = centimeter

K = The number of model parameters

l = liter

m = meter

SE = Standard Error

w_i = Akaike weight

This thesis is written in the style required by the Annals of the Entomological Society of America

CHAPTER 1

INTRODUCTION

Planthoppers are a group of insects within the Order Hemiptera and Superfamily Fulgoroidea that consists of more than 11,000 described species. The Fulgoroidea is currently divided into 21 families, the largest of which is the Delphacidae. Delphacidae and Cixiidae are considered basal taxa among extant planthoppers (Urban and Cryan 2006, Urban *et al*. 2011). The delphacid planthoppers consist of more than 2,100 described species and occur in terrestrial environments worldwide (Wilson *et al*. 1994, Urban *et al* 2011). Delphacid planthoppers are phytophagous insects that use their sucking mouthparts to feed on the phloem tissues of a wide variety of plants; 85 species of delphacids are recognized as significant pests of 25 plant crops (Wilson and O'Brien 1987; Wilson 2005; Urban *et al*. 2011). Pest delphacids can directly damage their host plants through oviposition, which may leave openings in plant tissues allowing bacterial and fungal spores to enter, and by the feeding of active large populations on a host plant (Denno and Roderick 1990). Delphacids also serve as vectors of plant pathogens; 29 species in 17 genera are vectors of 4 phytoplasmas and 27 viruses (Urban *et al*. 2011). These phytoplasmas and viruses damage several significant food crops such as rice, maize, wheat, barley, sugarcane, and oats (O'Brien and Wilson 1985, Wilson and O'Brien 1987, Wilson 2005, Hogenhout *et al*. 2009, Urban *et al*. 2011).

Urban *et al.* (2011) remarked that, given their agricultural importance, it is unsurprising that the most damaging species of delphacids have been extensively investigated. While detailed observations of life histories, behavior, genetics, physiology, chemical resistance, and host plant relationships are available for these species, such information is minimal for species occurring on plants of little economic value. Often life history and systematic studies for these species have been restricted to those that have been recently described (Cronin and Wilson 2007), occur in unique environments (Denno and Roderick 1990, Wheeler 2003), or feed on plants that are either of conservation concern, or are related to or occur in the same area as those that are economically important (Wilson and Claridge 1985). Plant host data are either entirely absent or weakly supported for many planthoppers that are not economically significant. Often such data are derived from collection labels rather than direct observations of feeding, oviposition, and nymphal development (Wilson *et al.*, 1994). Of the known delphacid planthopper-host plant relationships, monocot feeders make up a majority of the collected data. Wilson *et al.* (1994) found that 65% of worldwide host plant records were comprised of delphacids feeding on monocots; this percentage rose to 92% when only mainland continental records were used.

Closely related planthoppers, or those that feed on the same or similar plants, often share similar traits, but such relationships do not allow detailed comparisons or complex evaluations of community interaction and life strategies. These similarities allow only general inferences about unstudied planthoppers, especially those on eudicots. Further research is required on these species in order to understand detailed facets of their life histories, such as overwintering habits in temperate species, and accurate host plant records. Detailed studies of the life histories of economically unimportant species, such as *Prokelisia* spp., have provided insights about those of economic importance (Denno and Roderick 1990). Furthermore, benign delphacid species have become problematic or invasive after introduction to new habitats (Yang *et al.* 2001), a shift to introduced host plants (Metcalfe 1969), or have developed the capacity to transmit a pathogen to an introduced crop (Laguna *et al.* 2000).

Life history and community comparisons are often used to evaluate seasonal trends in community structure and diversity in a specific habitat (Gonzon *et al.* 2006), to compare communities of related native and introduced plants (Ando *et al.* 2010), to analyze the impacts of different herbivore feeding guilds on single or co-occurring plant species (Meyer 1993, Peeters *et al.* 2001), to measure the impact of arthropod communities on different agricultural crops or crop varieties (Whitehouse *et al.* 2005), to observe the effect of patch size on various insect guilds (Raupp and Denno 1979), and to study biodiversity across natural features such as edge or grassland habitats (Tscharntke and Greiler 1995, Dangerfield *et al.* 2003). Studies of arthropod communities existing in very different habitat types are less common, and are typically part of a larger suite of research goals such as the inventory of invertebrates in an ecological preserve (Rios-Casanova *et al.* 2010).

The delphacid genus *Pissonotus* includes 43 species that occur in North, Central, and South America and the Caribbean (Bartlett and Dietz 2000). The only species of *Pissonotus* that has been studied in detail is *P. quadripustulatus* Van Duzee on the sea oxeye daisy (*Borrichia frutescens* (L.)DC. Asteraceae) which occurs in salt-marshes (Moon *et al.* 2000; Moon and Stiling 2002, 2003, 2005, 2006). This delphacid is a multivoltine planthopper with overlapping generations consisting solely of brachypters. Individuals have been observing feeding on leaf tissues, and females preferentially oviposit on low quality *B. frutescents* plants with hardened stems in order to reduce egg parasitism (Moon and Stiling 2005, 2006). The presence of lepidoptera stem borers has been shown to negatively affect population sizes of *P. quadripustulatus* as they degrade host plant quality (Moon and Stiling 2005). The addition of nitrogen and/or the removal of hymenopteran parasitoids through sticky traps resulted in a positive effect on population size, but only in the absence of stem borers (Moon and Stiling 2006). The addition of nitrogen had a strong positive effect on population sizes up to two years after nitrogen treatments were ended (Moon and Stiling 2003). Improvement in host plant quality by adding nitrogenous fertilizer or shading of host plants increased *P. quadripustulatus* densities but also resulted in a higher level of egg parasitism. The increase in salinity of *B. frutescens* plants, through the addition of salt to the substrate, resulted in an increase in hopper densities due to increased stem toughness which decreased egg parasitism (Moon and Stiling 2006).

The focus of this study was to compare the life histories of two species of *Pissonotus* which feed on different host plants in very different habitats. *Pissonotus piceus* Van Duzee feeds on the emergent aquatic mild water-pepper (*Persicaria hydropiperoides* Michx.; Polygonaceae) and *P. delicatus* Van Duzee feeds on the dry upland Curlycup Gumweed (*Grindelia squarrosa* (Pursh) Dunal; Asteraceae). The life histories of *P. piceus* and *P. delicatus* were assessed during this study using a variety of methods. Historical collections were used to create nymphal descriptions and a key to the instars of *P. piceus* and also to examine the effects of climate and environmental change on the proportion of macropters and brachypters in *P. piceus* populations. Life histories traits of *P. piceus* and *P. delicatus* were described and compared using samples gathered during the summers of 2009 and 2010. Non-target insects and spiders collected during these sampling periods were preserved and sorted in order to better understand the community composition of the planthoppers and their respective host plants. These arthropods were sorted to species of co-occurring members of the sap-feeding guild and potential competitors or predators. Morphospecies identification, which has been shown to efficiently evaluate arthropod communities as long as a few assumptions are met (New 1998), was used for all other collected specimens. Live specimens were collected in the field and reared under greenhouse conditions in order to observe general behavior and identify any parasites that might have been present in field collected specimens.

CHAPTER 2

MATERIALS AND METHODS

Study Organisms

Planthopper species considered in this study are shown in Figure 2.1 and their host plant species are shown in Figure 2.2.

Pissonotus piceus Van Duzee

Pissonotus piceus was described by Van Duzee (1894) from a male brachypter. Descriptions and illustrations of the male genitalia were provided by Morgan and Beamer (1949) and Bartlett and Deitz (2000). This species is easily recognized as it is a polished brown-orange to dark chestnut-brown. The frons is pale, brown dorsally and black near the clypeus. Macropterous and brachypterous individuals occur in the same populations. The forewings bear a white distal transverse band in brachypters; but are translucent in macropters. Nymphs are typically light to dark stramineous with a chestnut-brown mark on the frons. Its distribution includes southern Canada, central and eastern United States, Central America, and northern South America. *Pissonotus piceus* has been recorded on a variety of plants, but has only been recorded feeding, ovipositing, and undergoing nymphal development on *Persicaria hydropiperoides* Michx. (Bartlett and Deitz 2000; Wilson pers. obs.); it is the only recorded delphacid to feed on a member of the Polygonaceae.

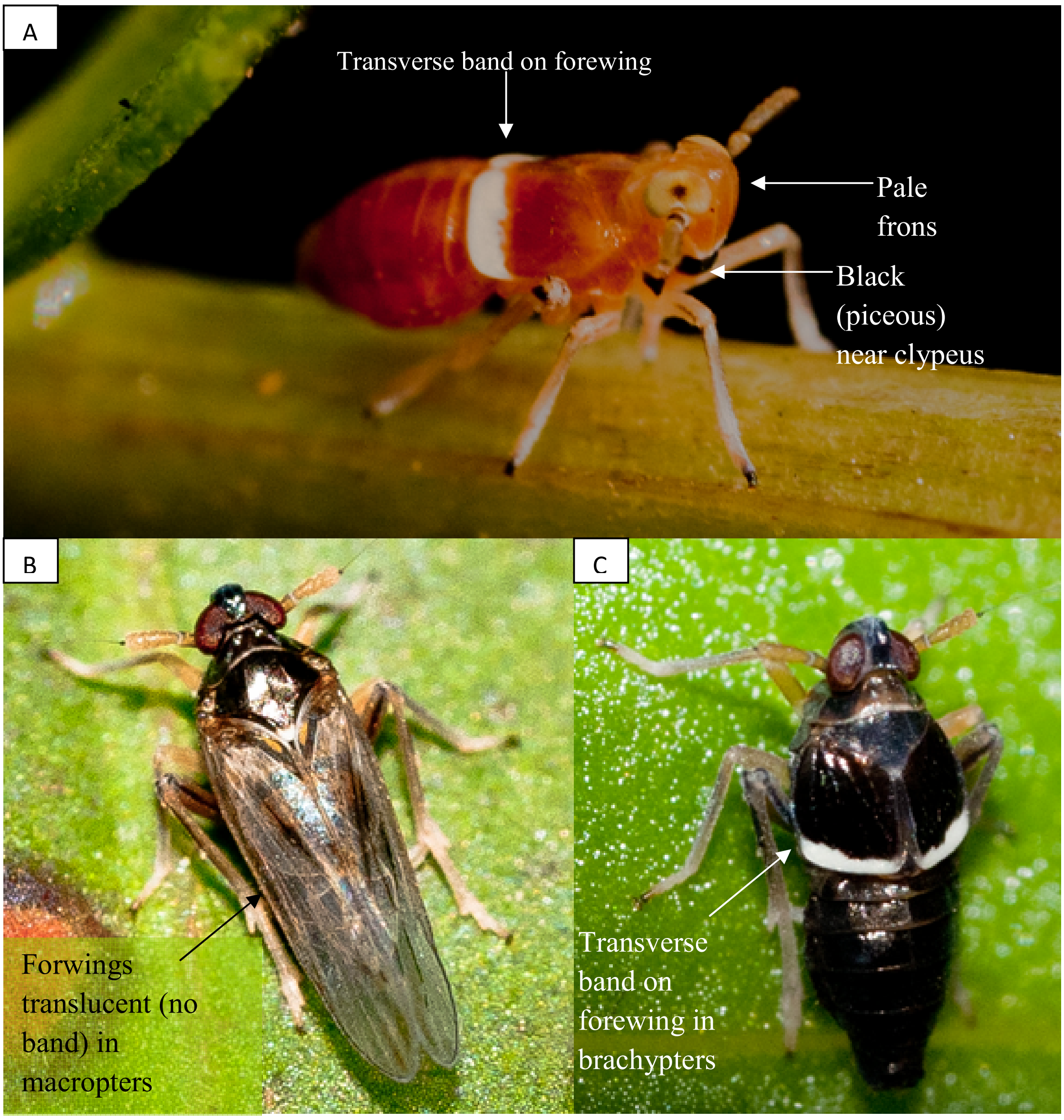


Figure 2.1 Photographs of planthoppers taken during the 2009-2010 study. **(A)** *Pissonotus delicatus* brachypter showing brown-orange coloring. **(B)** *P. piceus* macropter showing dark chestnut-brown coloring. **(C)** *P. piceus* brachypter showing dark-chestnut brown coloring.

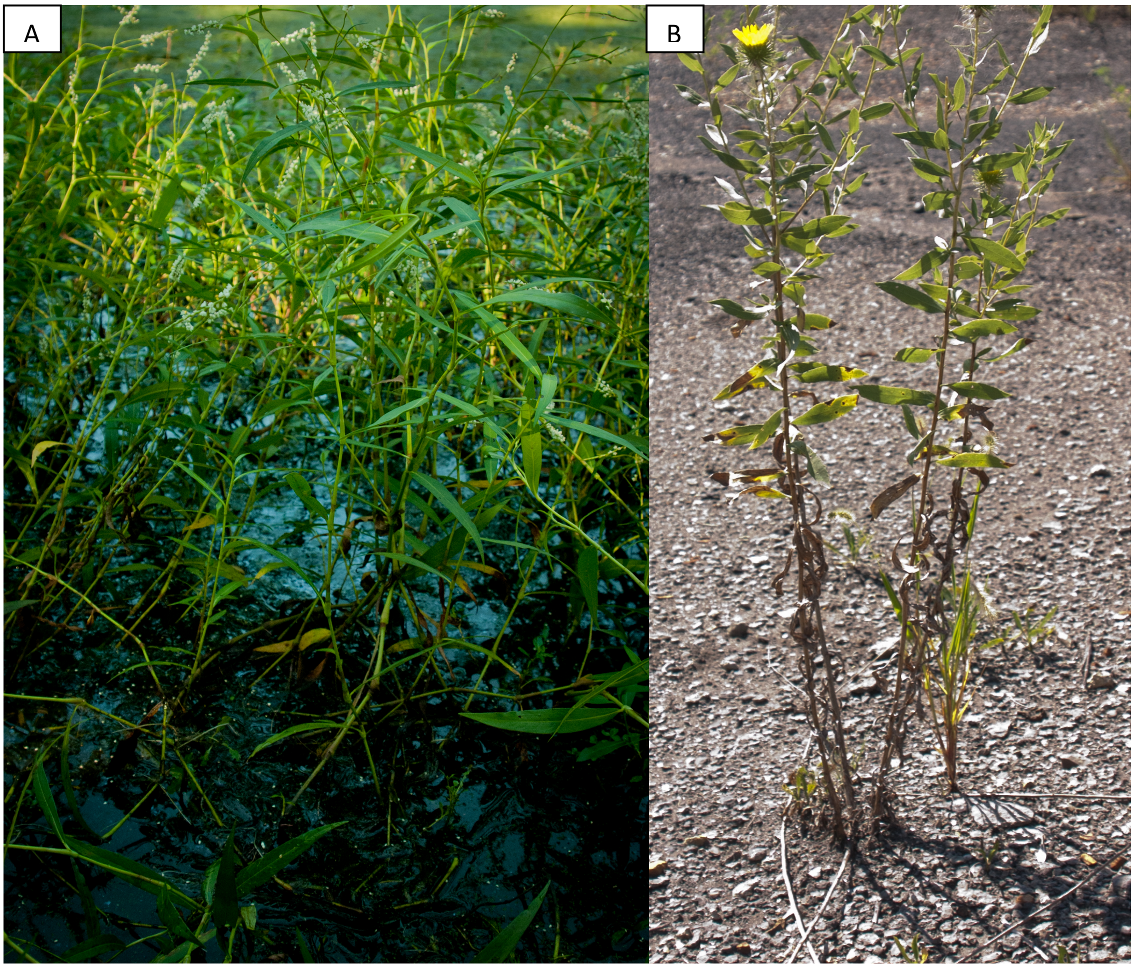


Figure 2.2 Photographs of *Pissonotus* host plants taken during the 2009-2010 study. **(A)** A dense mat of *Persicaria hydropiperoides*. **(B)** A solitary *Grindelia squarrosa*.

Pissonotus delicatus Van Duzee

Like *P. piceus, P. delicatus* was described by Van Duzee (1897) from a male brachypter. Descriptions and illustrations of the male genitalia were provided by Morgan and Beamer (1949) and Bartlett and Deitz (2000). This species is easily recognized as it is a polished, orange to dark brown-orange. The frons is pale honey-yellow with a dark piceous band on the clypeus. Macropterous and brachypterous individuals occur in the same populations. The forewings bear a distal transverse white band in brachypters but are translucent in macropters. Nymphs are typically light to dark stramineous with a dark mark on the frons. Its distribution is principally western and central United States and adjacent Mexico and Canada. It is reported from Quebec west to Washington and south to Mexico and Jamaica (Bartlett and Deitz 2000). *Pissonotus delicatus* nymphs collected from *Heterotheca subaxillaris* (Lam.) Britt.and Rusby (Asteraceae) were described by Wilson and Tsai (1991). *Pissonotus delicatus* has been recorded feeding, ovipositing, and undergoing nymphal development on several members of the Asteraceae (*Grindelia squarrosa* (Pursh) Dunal, *Heterotheca subaxillaris* (Lam.) Britt. and Rusby, and *Prionopsis ciliata* Nutt) (Wilson and Tsai 1991). There is considerable variability in the shape of male reproductive anatomy (Morgan and Beamer 1949, Bartlet and Deitz 2000). Variability in male genitalia shape and dentition suggests, along with different host affinities, that *P. delicatus* may be a complex of sibling species occurring on different composite host plants (Wilson and Tsai 1991).

Persicaria hydropiperoides (Michx.) Small

Persicaria hydropiperoides (= *Polygonum hydropiperoides* Michx. = mild water-pepper = swamp smartweed) is a perennial member of the Polygonaceae. It occurs from Quebec, Canada, west to Alaska and south through Mexico, Central America, and South America. In the United States it flowers from June to November and can be found on wet banks and clearings, shallow water, marshes, moist prairies, and ditches (eFloras 2011). *Persicaria hydropiperoides* is considered an obligate wetland species in the North Central region of the United States (PLANTS 2011). The genus *Persicaria* includes beneficial species many of which are obligate wetland species. The genus also includes weedy wetland species, such as the mile-a-minute weed (*Persicaria perfoliata* (L.) H. Gross) which is considered extremely invasive (Hough-Goldstein *et al.* 2008, 2009).

Grindelia squarrosa (Pursh) Dunal

Grindelia squarrosa (= curlytop gumweed) is a perennial member the Asteraceae. It occurs from Quebec west to the Northwest Territories and British Columbia and south to Mexico; it has been introduced to the Ukraine (PLANTS 2011). It flowers from July to October and can be found at disturbed sites, plains, hills, roadsides, along streams, and in sands, clays, and subalkaline soils. It is commonly found on shale barrens. *G. squarrosa* is a facultative upland species in the North Central region of the United States (PLANTS 2011).

Study Sites

Study areas and site plots are shown in Figure 2.3.

Lake Cena

Lake Cena, Pertle Springs, University of Central Missouri, Johnson County, is the largest lake in a chain of human-made bodies of water constructed in 1869. The lake is fed by three upstream bodies of water (Draper Lake, Lily Pond, and Racehorse Lake, and drains into Lions Lake). The lake is 567 m across at its widest point and has a maximum depth of ca. 6 m. The lake is 234 m above sea level. The lake was drained and altered in 1994 to counter the effects of eutrophication and to allow for the installation of a water pump facility to provide irrigation for the adjacent golf course. The characteristic plant community prior to its alteration consisted of dense mats of *Persicaria hydropiperoides* and *Justica americana* (L.) Vahl. (Acanthaceae) over a majority of the shallow areas with intermittent clusters of *Ludwigia peploides* (Kunth.) P.H. Raven (Onagraceae). *Nymphaea odorata* Aiton have been introduced since the alteration and now occupy all of the deeper area once covered by the mats. Samples of *Pissonotus piceus* used for "historic data analysis" were collected from a study site consisting of patches of *Persicaria hydropiperoides* located in the eastern-most portions of the lake (Figure 2.3C)

Racehorse Lake

Racehorse Lake is the third largest lake in the chain and is fed by a stream from Duck Pond, and drains into both directly into Lake Cena and indirectly into Lily Pond. The lake is 112 m at its widest point and has a maximum depth of ca. 2 m. The surface of the lake is 240 m above sea level. *Persicaria hydropiperoides* is the dominant aquatic

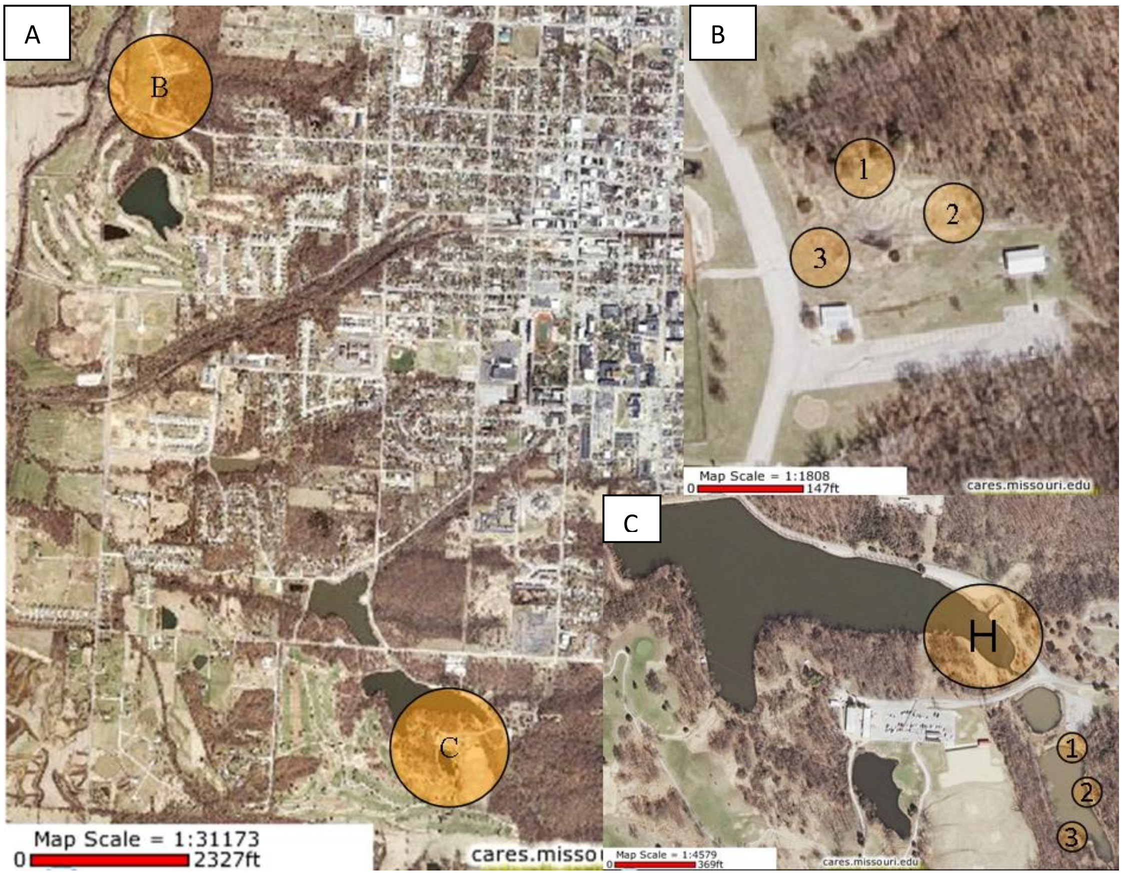


Figure 2.3 Aerial photographs of historic and 2009-2010 study sites (CARES 2011). **(A)** Warrensburg, Missouri showing position of Cave Hollow study site (B) as well as Lake Cena and Racehorse Lake study sites (C). **(B)** Cave Hollow study site showing study plots (1, 2, 3). **(C)** Lake Cena historic study site (H) and Racehorse Lake study sites (1, 2, 3).

plant along the eastern and southern margins of this lake. Three plots were selected at this study site based on maximum distance from one another (Figure 2.3C).

Cave Hollow Shale Barrens

Cave Hollow in Warrensburg is situated between a golf course to the south, a sports complex to the west, U.S. Highway 50 to the north, residential housing to the east, and cemeteries to the south- and north-east. The Shale Barren study site in the western edge of the park is south facing, and ranges 10 m in elevation from 222 to 232 m above sea level. The shale barren plant community is dominated by *G. squarrosa, Desmanthus illinoensis* (Michx.) MacMill. ex B.L. Rob. & Fernald, and several grasses. Three plots were chosen at this study site based on maximum distance from one another, maximum purity of *G. squarrosa* stands, and varying elevation (Figure 2.3B).

Morphological and Environmental Response Study (Historic Data)

Specimens were collected by S. W. Wilson from 1985 to 2004 at Lake Cena, using a modified leaf blower (Wilson *et al.* 1993). Specimens were taken from the blower collection net using an aspirator. Adult male voucher specimens of *P. piceus* for each sample were pinned, identified, and stored in the UCM entomology collection. The remaining individuals from each sample day were stored in 2 dram vials containing ~70% isopropyl alcohol. The samples for each collection period were sorted to developmental stage (1^{st} instar nymphs through adult); 5^{th} instar nymphs and adults were also sorted to gender and wing morph. Complete collection data are found in Appendix A.

First through fifth instars of *P. piceus* were used to develop a key and descriptions of instar stages. Measurements and morphological characteristics were recorded for ten individuals of each instar. The fifth instar is described in detail but only major differences are described for fourth through first instars. Arrangement and number of pits is provided for the fifth and fourth instars; this information is not given for earlier instars because the pits are extremely difficult to discern (those that could be readily observed are illustrated). Length was measured from apex of vertex to apex of abdomen, width across the widest part of the body, and thoracic length along the midline from the anterior margin of the pronotum to the posterior margin of the metanotum.

Based on the planthopper ecology literature, entomological collection data, and preliminary field observations, nine hypotheses that may explain the increase in macroptery incidence were formulated. Using data collected for each parameter in Table 2.1, *a priori* models were developed for each hypothesis (Table 2.2). An information theoretic approach was used to evaluate *a priori* hypotheses regarding macroptery incidence (Burnham and Anderson 2002). Incidence among fifth instar nymphs and adults were analyzed using Binary Logistic Regression (1= macropters, 0= brachypters) in MINITAB (Minitab 2007) to model and weigh covariate effect on macroptery incidence. Using Akaike's information criterion ($AIC = -2ll + 2\theta$, where ll is log-likelihood and θ is the number of parameters) adjusted for small sample sizes ($AICc = -2ll + 2\theta + [2\theta(\theta+1))/(n-\theta-1)]$, where n is the sample size) values, the best model for covariance structure was selected (Akaike 1973, Hurvich and Tsai 1989, Sileshi 2006). AIC is not dependent directly upon sample size, and AICc takes into account the number of parameters in a model (Dayton 2003, Johnson and Omland 2004).

Table 2.1 Description of selected covariates for macroptery incidence analysis for *Pissonotus piceus* from historic collection surveys in Lake Cena, Warrensburg, Missouri, 1985-2004. avgT, Prec, and Day covariate consist of three perioids: 1-10, 11-20, and 21-30/31 days prior to sampling.

Covariate	Abbreviation	Description
Gender	Gen	Gender of sampled *Pissonotus* planthopper
Average Temperature	avgT	Average of high and low temperatures recorded for sampling period
Highest Precipitation	Prec	Amount rainfall collected during largest precipitation event for sampling period
Day Length	Day	Average day light hours for sampling period
Month	Mon	Month in which sample was taken
Year	Yr	Year in which sample was taken

Table 2.2 Descriptions and expected direction of *a priori* macroptery incidence models for *Pissonotus piceus* from historic collection surveys in Lake Cena, Warrensburg, Missouri, 1985-2004

Hypothesis	Model	Model Structure	Expected Result
No abiotic impact	(.)	β_0	–
Positive influence of male gender	(Gen)	$\beta_0 + \beta_1$(Gen)	$\beta_1 > 0$
Positive influence of increased average temp	(avgT)	$\beta_0 + \beta_1$(avgT1-10) + β_2(avgT11-20) + β_3(avgT21-30/31)	$\beta_1 > 0$, $\beta_2 > 0$, $\beta_3 > 0$
Negative influence of high precipitation events	(Prec)	$\beta_0 + \beta_1$(Prec1-10) + β_2(Prec11-20) + β_3(Prec21-30/31)	$\beta_1 < 0$, $\beta_2 < 0$, $\beta_3 < 0$
Negative influence of increased day length	(Day)	$\beta_0 + \beta_1$(Day1-10) + β_2(Day11-20) + β_3(Day21-30/31)	$\beta_1 < 0$, $\beta_2 < 0$, $\beta_3 < 0$
Positive influence in successive generations	(Mon)	$\beta_0 + \beta_1$(Jul) + β_2(Aug) + β_3(Sep) + β_4(Oct)	$\beta_1 > 0$, $\beta_2 > 0$, $\beta_3 > 0$, $\beta_4 > 0$
Positive influence in years after alteration	(Yr)	$\beta_0 + \beta_1$(1985) + β_2(1989) + β_3(1990) + β_4(2000) + β_5(2001)	$\beta_1 > 0$, $\beta_2 > 0$, $\beta_3 > 0$, $\beta_4 > 0$
Positive influence in successive generations, and in years after alteration, Negative influence of increase in day length	(subGlobalT)	$\beta_0 + \beta_1$(Jul) + β_2(Aug)… + β_{12}(Day21-30/31)	$\beta_{(Day)} < 0$, $\beta_{(Mon)} > 0$, $\beta_{(Yr)} > 0$
Positive influence of increased average temp, Negative influence of high precipitation events	(subGlobalC)	$\beta_0 + \beta_1$(avgT1-10) + β_2(avgT11-20)… + β_6(Prec21-30/31)	$\beta_{(avgT)} > 0$, $\beta_{(Prec)} < 0$
Positive influence of male gender, increased average temp, successive generations, years after alteration, Negative influence of high precipitation events and increased day length	(Global)	$\beta_0 + \beta_1$(Gen) + β_2(avgT1-10)… + β_{19}(Prec21-30/31)	$\beta_{(Gen)} > 0$, $\beta_{(avgT)} > 0$, $\beta_{(Mon)} > 0$, $\beta_{(Yr)} > 0$, $\beta_{(Day)} < 0$, $\beta_{(Prec)} < 0$

AICc and Akaike weights (w_i) were used to predict the most-parsimonious model (Burnham and Anderson 2002). The probability of a model approximating the measured variance is represented by w_i. Relative covariate importance was determined from models comprising the 95% confidence set (w_i = 0.950 - -Burnham and Anderson 2002). A complete listing of covariates for initial consideration is found in Appendix A.

Behavioral Observations and Community Analysis (2009-2010 Study)

During the 2010 sampling season the modified leaf blower was used to collect specimens in order to assess and compare the arthropod communities of the host plants of *P. piceus* and *P. delicatus.* Samples were taken from three locations around Racehorse Lake, and three locations at Cave Hollow. Complete collection data are listed in Appendix B and C. Separate collection nets were used for each of the three sample locations at each of the two study sites. The collection net from each site was placed in an individual one gallon plastic bag, labeled with its collection data, and placed in a deep freezer. All plant materials and severely damaged insect specimens were discarded; the remaining insects were pinned with their individual collection data. Specimens not suitable for dry storage were stored in 2 dram vials containing ~70% isopropyl alcohol with their collection data. These vouchers are stored in the UCM entomology collection. The samples for each collection period were sorted to species; "morphospecies" were designated based upon morphological characteristics when species identification was not possible. Species diversity and evenness were calculated for the community analysis using the Shannon-Weiner diversity index.

Field Obersvations

During the 2009 and 2010 sampling seasons, observations of feeding and mating behavior, inter- and intraspecific interactions and ovipositing of the two *Pissonotus* species were made before and after sample collections at each respective sampling site and each study location.

Greenhouse Observations

Leaf litter samples were collected from the Cave Hollow and Racehorse Lake study sites during October 2009 in order to determine the overwintering stage and sites of the planthoppers. Samples were taken at intervals of 1, 3, 9, and 12 m from plot #4 at each of the study locations. Samples were placed in brown paper bags and labeled with their location and date. Samples were also collected of exposed persisting plant materials of *G. squarrosa* and *P. hydropiperoides.* These samples were processed using a Berlese funnel for one week in an attempt to remove any invertebrates from the materials to a collection jar. Collection jars were examined daily for emerged arthropods.

During the 2009 sampling season approximately 100 *P. hydropiperoides* and 20 *G. squarrosa* plants were collected from their respective study sites and transferred to the UCM Department of Biology and Earth Sciences greenhouse. The *P. hydropiperoides* were potted collectively in two plastic tubs (151 l). The potting substrate in each tub was collected along with the plants from the Racehorse Lake study site. The *G. squarrosa* plants were potted individually in plastic pots (3 l) in soil taken from the greenhouse. These plants were covered with a mesh netting (ca. 51 x 61 cm) which prevented planthoppers from escaping the enclosures. Target planthopper specimens were present on these stock plants from their initial transfer to the greenhouse; 25 *P. piceus* individuals were transferred to each *P. hydropiperoides* stock enclosure; *P. delicatus* individuals were already abundant on transferred *G. squarrosa* plants in the stock enclosures.

During April 2010, plant specimens were again collected from their respective study sites and transferred to the greenhouse. Sixty *P. hydropiperoides* and 20 *G. squarrosa* were collected. These plants were individually potted, and covered with a ca. 25 x 51 cm. mesh sock enclosure. All insects and spiders were removed from these individually potted specimens before being placed in the enclosures. These plants were examined for the emergence of any insects from plant stems. During the August 2010 collection period, five adult *P. piceus* individuals were placed on 20 of the *P. hydropiperoides* specimens selected at random using a random number generator and five adult *P. delicatus* individuals were placed on each of the 20 *G. squarrosa* specimens. These were examined weekly for behavioral observations and the emergence of any parasitoids. On 4 October 2010, each of the 40 plant specimens with transferred planthoppers was placed in an individual plastic bag and stored in a deep freezer. After a period of no less than 1 week these samples were individually sorted and all insects present on each specimen were stored in a 2 dram vial containing ~70% isopropyl alcohol. During the laboratory study greenhouse plant specimens were watered twice weekly and examined for emerged parasites and planthopper behaviors.

CHAPTER 3

RESULTS AND DISCUSSION

Morphological and Environmental Response Study (Historic Data)

Adults of each planthopper collected during this study had their genitalia dissected and identity confirmed. Those of *P. piceus* and *P. delicatus* are consistent with those described by Morgan and Beamer (1949) and Bartlett and Deitz (2000). *P. delicatus* nymphs were consistent with those described by Wilson and Tsai (1991), and *P. piceus* nymphs were described for this study.

Between August 1985 and September 2004, 4,850 *P. piceus* specimens were collected from Lake Cena and sorted to developmental stage, wing form, and gender (Appendix A). The summarized data and collection information for the study by month are shown in Table 3.1. Data used for historic macroptery incidence modeling are shown in Table 3.2. A graphical representation of total collected individuals per developmental stage is shown in Figure 3.1, percent of developmental stages over historic collection data in Figure 3.2, and proportion of stages collected in Figure 3.3.

Instar Descriptions

Fifth instar (Figure 3.4 A-D, 3.6 E). Length 2.2 ± 0.33; thoracic length 0.7 ± 0.06; width 0.9 ± 0.09 mm. Body cream to brown with brown markings on frons. Area between inner and outer carinae with nine pits on each side; four pits between each out carina and eye. Pronotal plates subtraingular (in dorsal view); anterior margin convex; each plate with a weak posterolaterally directed carina and nine pits extending anteriorly from near middorsal line posterolaterally to lateral margin. Abdominal segments five to eight with the following number of pits on either side of midline; tergite five with one pit, six to eight with three pits, segment nine with three pits. mesonotal wingpad extending beyond metanotal wingpad in machropters; Metatibia with two spines on lateral aspect of shaft, an apical transverse row of five spines on plantar surface and a subtriangular flattened movable spur with one apical tooth and eight to nine other teeth on posterior margin. Pro- and mesotarsi with two tarsomeres, tarsomere one wedge-shaped; tarsomere two subconical, with pair of apical claws. Metatarsi with three tarsomeres; tarsomere one with apical transverse row of six to seven spines; tarsomere two with apical transverse row of four spines; tarsomere three subconical, with pair of apical claws.

Fourth instar (Figure 3.5 D, 3.6 D). Length 1.5 ± 0.05; thoracic length 0.6 ± 0.03; width 0.6 ± 0.02 mm. Metatibial spur slightly smaller, with one apical tooth and four to five teeth on margin. Metatarsi with two tarsomeres; tarsomere one with apical transverse row of six spines; tarsomere two subconical with two to three spines in the middle of tarsomere on plantar surface. Abdominal segments five to eight with each the following number of pits on either side of midline; targite five with one pit, six to eight each with three, segment nine with three.

Third instar (Figure 3.5 C, 3.6 C). Length 1.3 ± 0.05; thoracic length 0.5 ± 0.02; width 0.5 ± 0.01 mm. Metatibial spur smaller; with one apical and one or two marginal teeth. Metatarsomere one with apical transverse row of five spines on plantar surface.

Table 3.1 Total collection values of *Pissonotus piceus* specimens collected at Lake Cena, Warresnburg, Missouri for each month between 1985 and 2004.

Instar	April	May	June	July	August	September	October	November
Adults	25	120	58	94	581	1362	630	159
5ths	10	11	15	64	148	253	30	3
4ths	6	23	7	15	152	306	68	15
3rds	5	47	31	19	122	508	79	12
2nds	5	44	35	81	278	595	87	7
1sts	10	11	15	64	148	253	30	3

Table 3.2 Total collection values of *Pissonotus piceus* 5th instar and adult specimens collected at Lake Cena, Warresnburg, Missouri for each month between 1985 and 2004.

Year	April	May	June	July	August	September	October	November	Total
1985	0	0	0	0	2	34	0	0	36
1989	14	10	11	27	288	90	113	76	629
1990	0	40	9	19	6	198	40	38	350
1999	0	0	0	5	0	0	0	0	5
2000	0	0	0	0	0	18	72	0	90
2001	0	0	0	0	0	1	11	0	12
2004	0	0	0	0	0	40	0	0	40
Total	14	50	20	51	296	381	236	114	1162

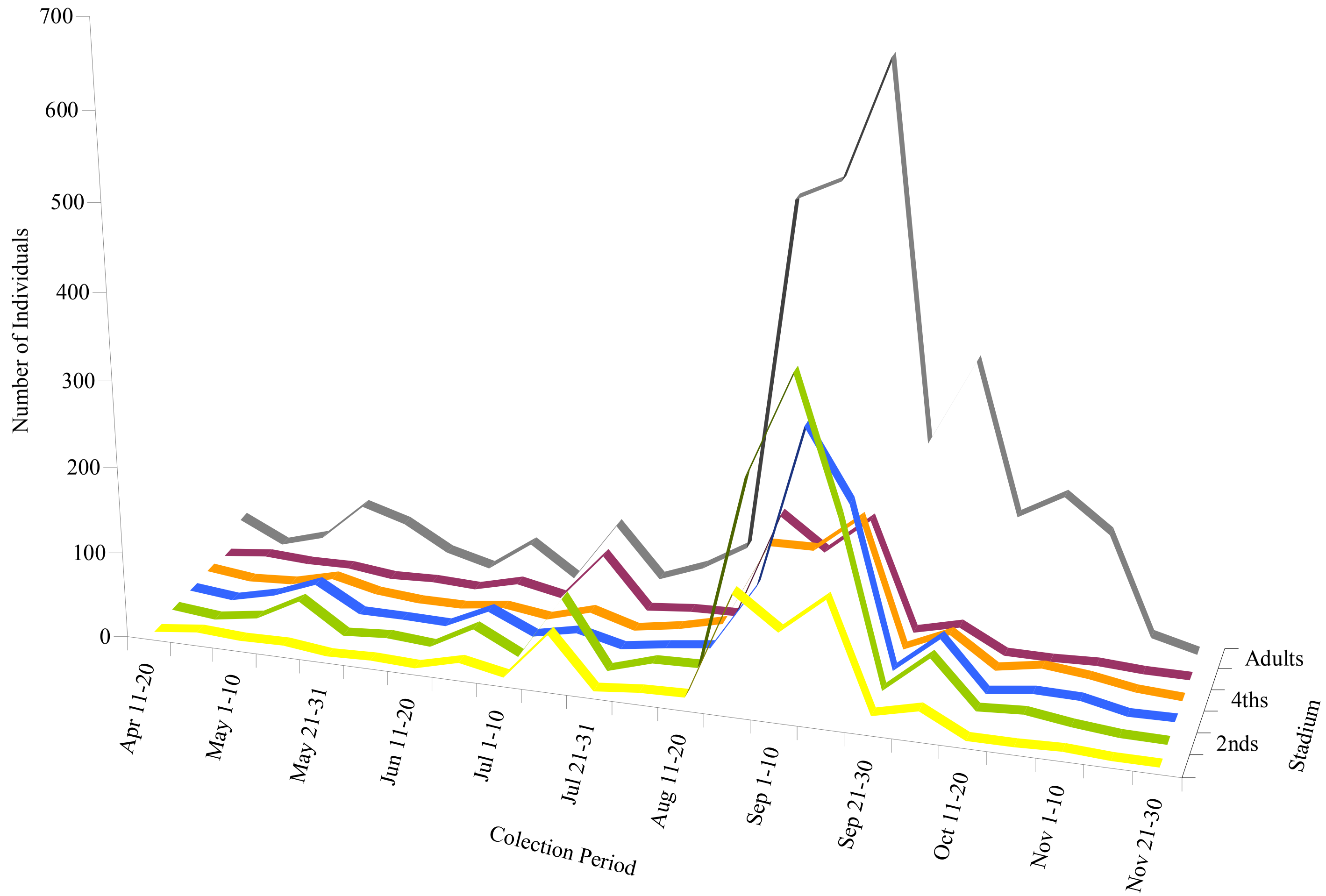


Figure 3.1 Total collected values of *Pissonotus piceus* individuals per instar sorted by collection period.

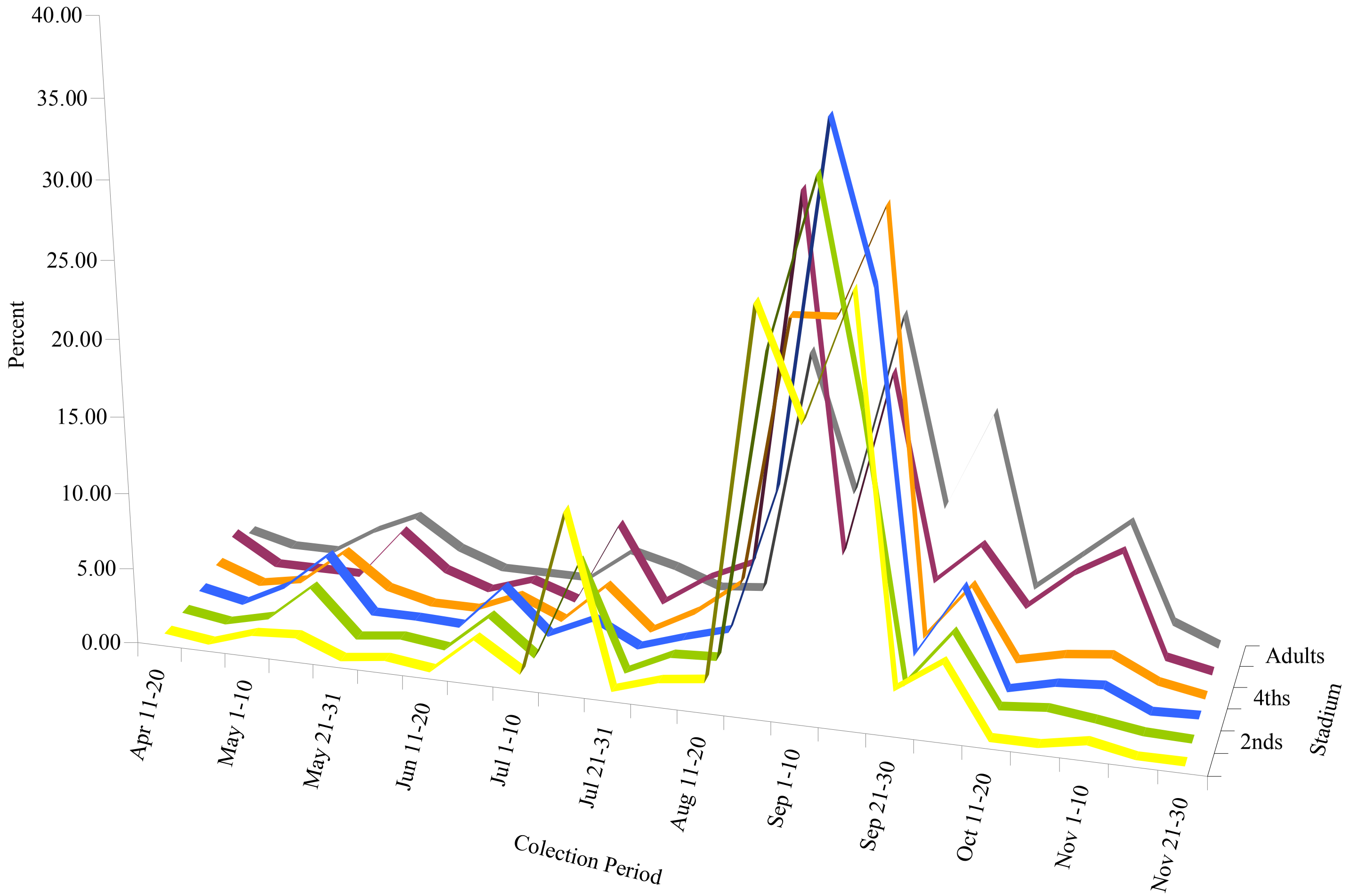


Figure 3.2 Percent of total developmental stage present during each collection period of historic *Pissonotus piceus* data.

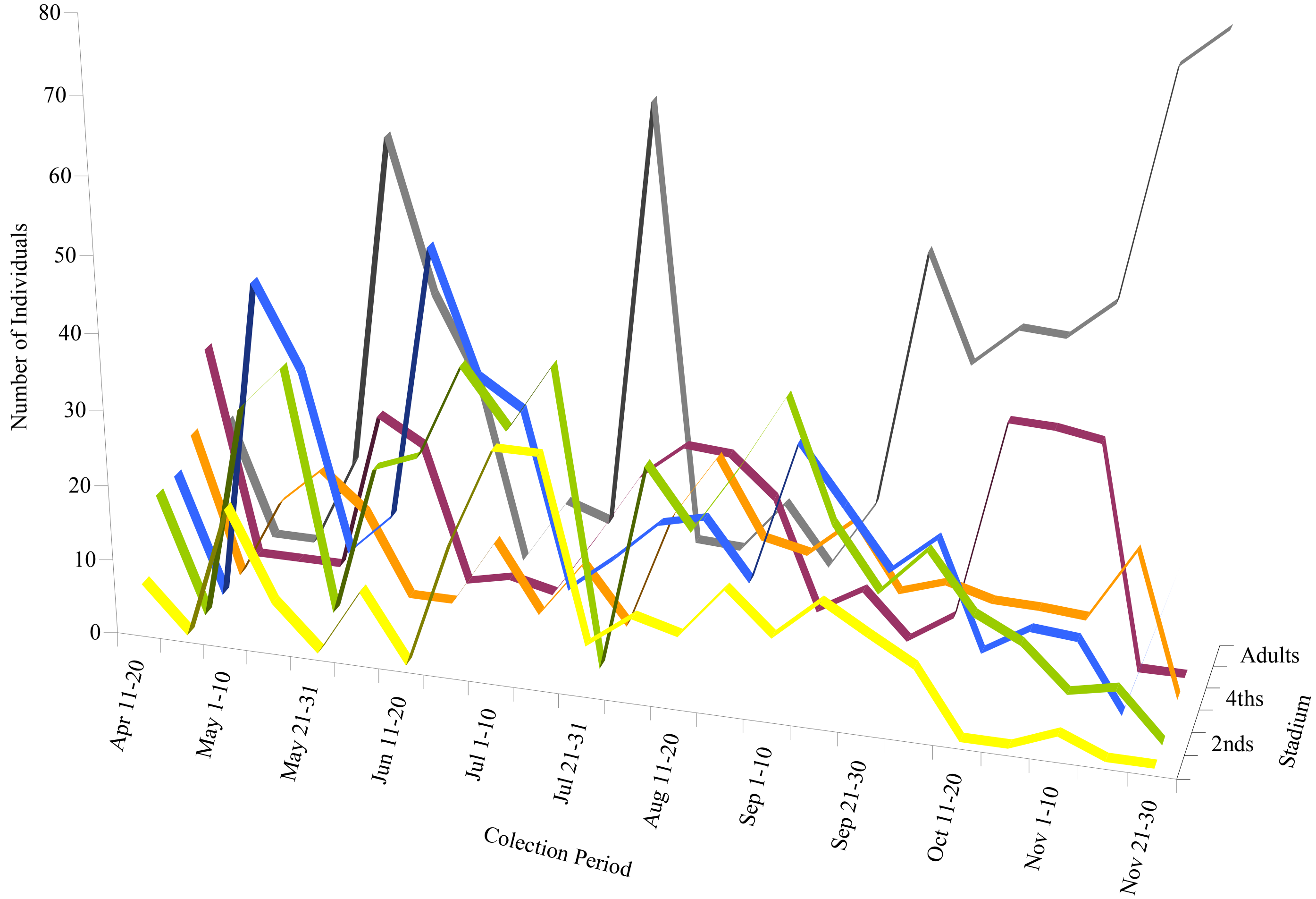


Figure 3.3 Percent of developmental stage present during each collection period of historic *Pissonotus piceus* data.

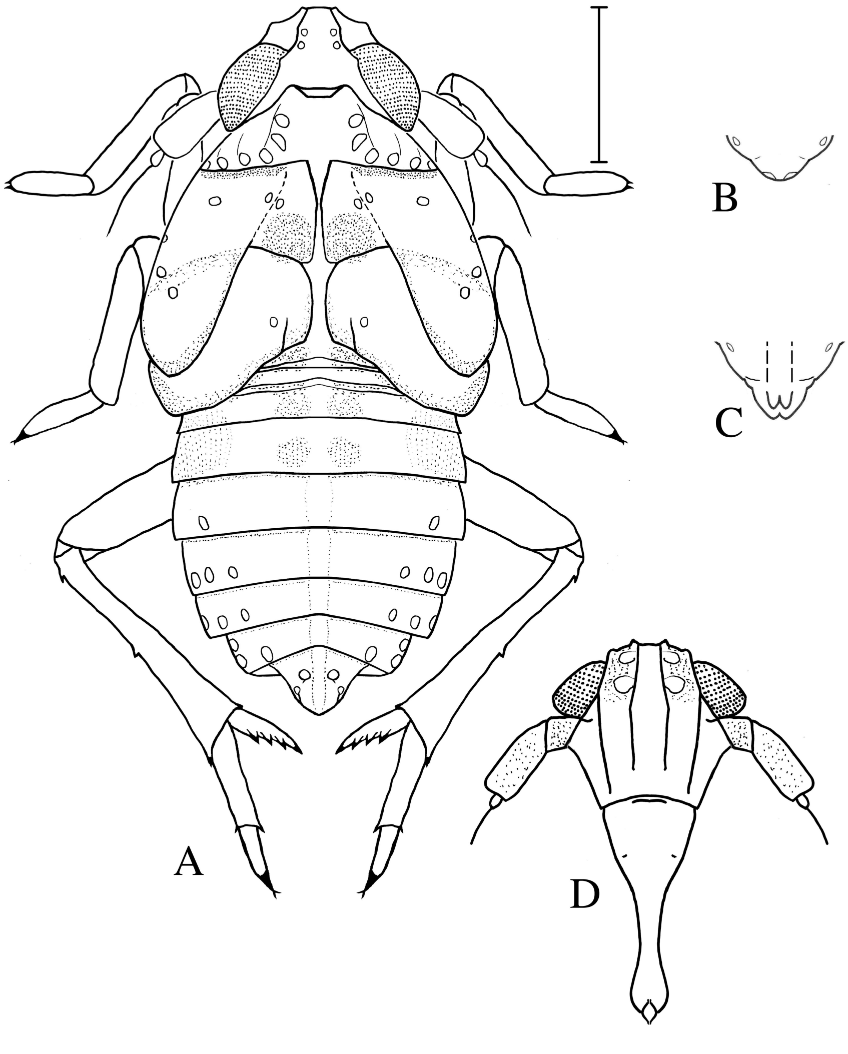


Figure 3.4 *Pissonotus piceus* fifth instar. **(A)** Habitus. **(B)** Ventral view of apex of abdomen male. **(C)** Ventral view of apex of abdomen female. **(D)** Frontal view of head. Bar = 0.5 mm.

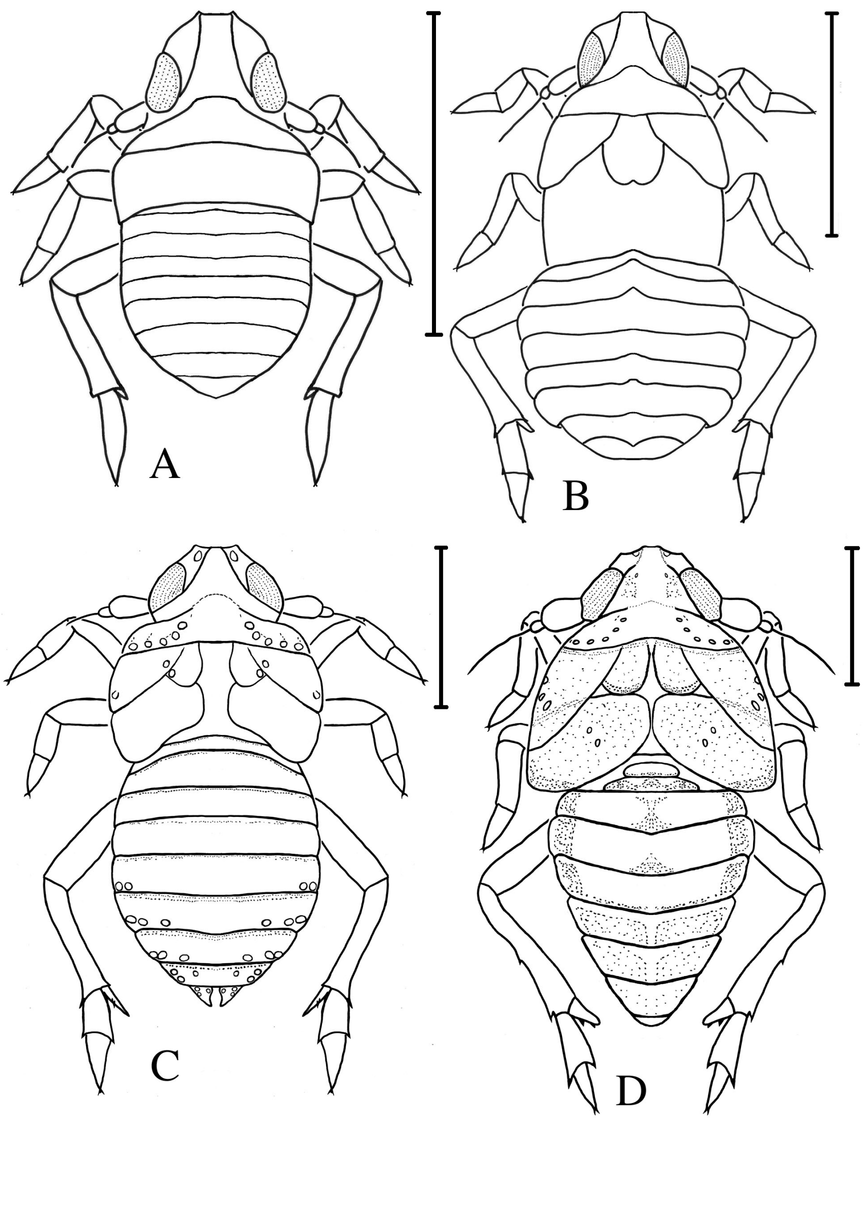


Figure 3.5 *Pissonotus piceus* nymphs. **(A)** First instar. **(B)** Second instar. **(C)** Third instar. **(D)** Fourth instar. Bar = 0.5 mm.

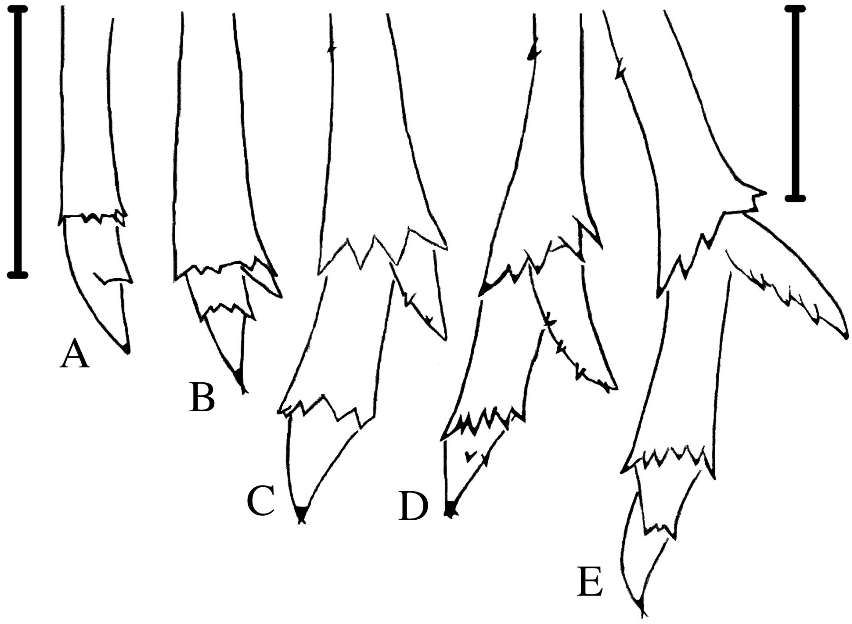


Figure 3.6 *Pissonotus piceus* apices of metathoracic legs, plantar surface. **(A)** First instar. **(B)** Second instar. **(C)** Third instar. **(D)** Fourth instar. **(E)** Fifth instar. Scale for A-C on left and D-E on right. Bar = 0.25 mm.

Second instar (Figure 3.5 B, 3.6 B). Length 1.1 ± 0.03; thoracic length 0.3 ± 0.02; width 0.3 ± 0.01 mm. Metatibia with apical row of three spines; spur small with no marginal teeth.

First instar (Figure 3.5 A, 3.6 A). Length 0.9 ± 0.03; thoracic length 0.2 ± 0.02; width 0.2 ± 0.02 mm. Metatibia lacking spines on shaft.

<u>Key to larval instars</u>

1 Metatarsi with apical transverse row of 6 or 7 spines (Figure 3.6 D-E)…...……………**2**

1 Metatarsi with apical transverse row of 5 or fewer spines (Figure 3.6 A-C)...………….**3**

2 Mesonotal wingpad extending nearly to apex of metanotal wingpad in macropters, half covering metanotal winpad in brachypters; metatarsi with three tarsomeres, tarsomere 2 with four apical spines (Figure 3.4 A, 3.6 E)……………………………….**fifth instar**

2 Mesonotal wingpad covering lateral half of metanotal wingpad or less; metatarsi with first tarsomere partially subdivided bearing 2 weak spines in middle (Figure 3.5 D, 3.6 D)…………………………………………………...**fourth instar**

3 Metatarsi 1 with apical transverse row of 5 spines, mesothoracic wingpad weakly developed (Figure 3.5 C-3.6 C)..……………………………………….**third instar**

3 Metatarsi 1 with apical transverse row of 3 spines; mesothoracic wingpads not developed (Figure 3.5 A-B, 3.6 A-B)..……**4**

4 Body length >1.0 mm; metatibia with a small spine on shaft in basal half (Figure 3.5 B, 3.6 B)……………………………....…….……………………………...**second instar**

4 Body length <1.0 mm; metatibia without spine on shaft (Figure 3.5 A, 3.6 A) ……………………………………………………………………………..**first instar**

<u>Habitat Alteration Effect on Wing Form</u>

Three *a priori* models were determined to hold 99.8% of w_i (Table 3.2). The best supported model was (subGlobalT) (w_i= 0.959) (Table 3.3). The 11 parameters in (subGlobalT) were average day length for 1-10, 11-20, and 21-30/31 days prior to sample collection, values for July, August, September, and October, and values for 1985, 1989, 1990, 2000, and 2001. Values for April, May, June, November, 1999, and 2004 were left out of the analyses due to convergence failure; the failure of 2004 to converge is a result of its similarity with data from 1985. Hierarchical increases in month and year parameters positively influenced the macroptery incidence. Coefficients for covariates and odds ratios from the top model are presented in Table 3.4 to indicate parameter influence. Incidence of macroptery by gender of *P. piceus* for each sample month and year is shown in Figure 3.7.

Pissonotus piceus, like *P. delicatus*, is a trivoltine species with overlapping generations that contain macropterous and brachypterous wing forms. Wing form has been shown to be influenced by nitrogen intake during nymphal feeding with reduced nitrogen uptake resulting in nymphs developing into macropterous adults (Denno and Roderick 1990). As population density increases, the nitrogen content of the plant is reduced. Macropters develop flight capable wings and associated muscles, and thus have increased dispersal ability relative to brachypters. The macroptery incidence of males is typically higher than that of females due to the lower energy investment required by males for reproduction and a higher selective value in males dispersing to seek females during courtship (Denno and Roderick 1990).

The proportion of 5th instar nymphs and adult macropters of *P. piceus* and *P. delicatus* increased in the third generation of the year. Population densities reach their highest level during this generation which can result in a decrease in host plant nitrogen content. Since *P. piceus* occurs on a host plant that lives in a nutrient rich environment and has not been observed to crowd on single plants, alternative explanations need to be developed as to why macroptery increases in the third generation. An increase in temperature during development can decrease the time spent in a single stadium (Wilson and McPherson 1981) which could result in less nitrogen imbibed during each stadium. Temperature was the only factor in the second highest ranked model which suggests that an increase in temperature resulted in an increased probability of collecting macropters (Table 3.2). Temperature as it influences wing length needs to be evaluated further.

The high incidence of brachyptery in *P. piceus and P. delicatus* and the complete lack of macropters in *P. quadripustulatus* suggest that these species normally occur on stable host plant populations. Another factor affecting the proportions of macropters/brachypters is habitat stability which is the persistence of a host plant long enough to support 10 consecutive generations of planthoppers (Denno and Roderick 1990). The highest ranked model dealing with macroptery incidence used daylight hours, month, and year as parameters. Daylight hours had a minimal negative impact while month and year parameters had a strong positive impact. While the strong positive influence of month corresponds to the increase in macropters during the third yearly generation, the increase of macropters in the years 2000 and 2001 merits further evaluation. In 1994, Lake Cena was drained and the main channel bulldozed to increase its maximum depth. This alteration resulted in the destruction of the dense *P. hydropiperoides* mats and left a habitat unsuitable for mat redevelopment in much of their previous habitat. This disruption in habit stability had a direct impact on the proportion *P. piceus* macropters (Figure 3.3).

Behavioral Observations and Community Analysis (2009-2010 Study)

A total of 1,666 insect and spider specimens was collected from Cave Hollow and Racehorse Lake in Warrensburg during 2010 and was sorted to 309 morphological species (Cave Hollow Appendix B, Racehorse Lake Appendix C). Species richness, evenness, and diversity data for the study sites at Cave Hollow and Racehorse Lake are provided in Table 3.5 and Table 3.6 respectively.

Pissonotus delicatus Field Observations

Brachypterous adults of *P. delicatus* were observed feeding on the stems of *G. squarrosa* below leaf petioles during observations conducted at the Cave Hollow study site during September 2009. In 2010, *P. delicatus* was first collected on 5 May, but first observed on *G. squarrosa* in early April when specimens of *G. squarrosa* were being transplanted to the greenhouse. During this study *P. delicatus* was never found on its host plant if *Campylenchia latipes* (Say) (Homoptera: Membracidae) was present; however, *P. delicatus* was observed on plants with *Lepyronia quadrangularis* (Say)

Table 3.3 Model selection statistics for macroptery incidence models for *Pissonotus piceus* from historic collection surveys in Lake Cena, Warrensburg, Missouri, 1985-2004.

Model	AIC_c	ΔAIC_c	w_i	K	$-2\log(£)$
(subGlobalT)	1225.97	0.00	0.959	11	1191.394
(avgT)	1233.11	7.15	0.026	5	1220.890
(subGlobalC)	1234.46	8.49	0.013	8	1212.456

AICc is the Akaike Information Criterion corrected for small sample size, ΔAICc is information difference from the top ranked model, w_i is the Akaike weight, and K is the number of model parameters.

Table 3.4 Parameter estimates, standard errors (*SE*), odds ratios, and odds ratio 95% confidence intervals (*CI*) for macroptery incidence models for *Pissonotus piceus* from historic collection surveys in Lake Cena, Warrensburg, Missouri, 1985-2004.

Parameter	Estimate	*SE*	*p*	Odds ratio	Lower *CI*	Upper *CI*
Intercept	1.93	2.348	0.41	-	-	-
Day Length*						
◦Day 1-10	0.782	0.226	0.00	2.19	1.4	3.41
◦Day 11-20	-0.089	0.257	0.72	0.91	0.55	1.51
◦Day 21-30/31	-1.16	0.356	0.00	0.31	0.16	0.63
Month						
◦July	1.901	0.853	0.02	6.69	1.26	35.65
◦August	3.573	0.575	0.00	35.61	11.53	119.97
◦September	3.271	0.453	0.00	26.34	10.84	63.97
◦October	2.065	0.484	0.00	7.88	3.05	20.36
Year						
◦1985	0.467	0.515	0.36	1.60	0.58	4.38
◦1989	0.672	0.431	0.11	1.96	0.84	4.56
◦1990	0.947	0.419	0.02	2.58	1.13	5.86
◦2000	3.211	0.567	0.00	24.81	8.17	75.33
◦2001	2.147	0.718	0.00	8.56	2.1	34.97

*Covariate values for 1-10, 11-20, and 21-30/31 days prior to sample

Table 3.5 Raw and calculated biodiversity values by group for Cave Hollow, Warrensburg, Missouri, May-September 2010.

Category	Individuals	Species Richness	Species Diversity	Species Evenness
Total	882	144	3.533	0.711
Coleoptera	176	31	2.704	0.787
Diptera	91	37	2.959	0.819
Hemiptera	410	40	1.907	0.517
Hymenotera	99	24	1.777	0.559
Arachnida	106	12	1.579	0.635

Table 3.6 Raw and calculated biodiversity values by group for Racehorse Lake, Warrensburg, Missouri, May-September 2010.

Category	Individuals	Species Richness	Species Diversity	Species Eveness
Total	784	168	3.584	0.699
Coleoptera	82	27	2.534	0.769
Diptera	361	61	2.187	0.532
Hemiptera	71	22	2.557	0.827
Hymenotera	105	45	3.015	0.792
Arachnida	165	13	1.398	0.545

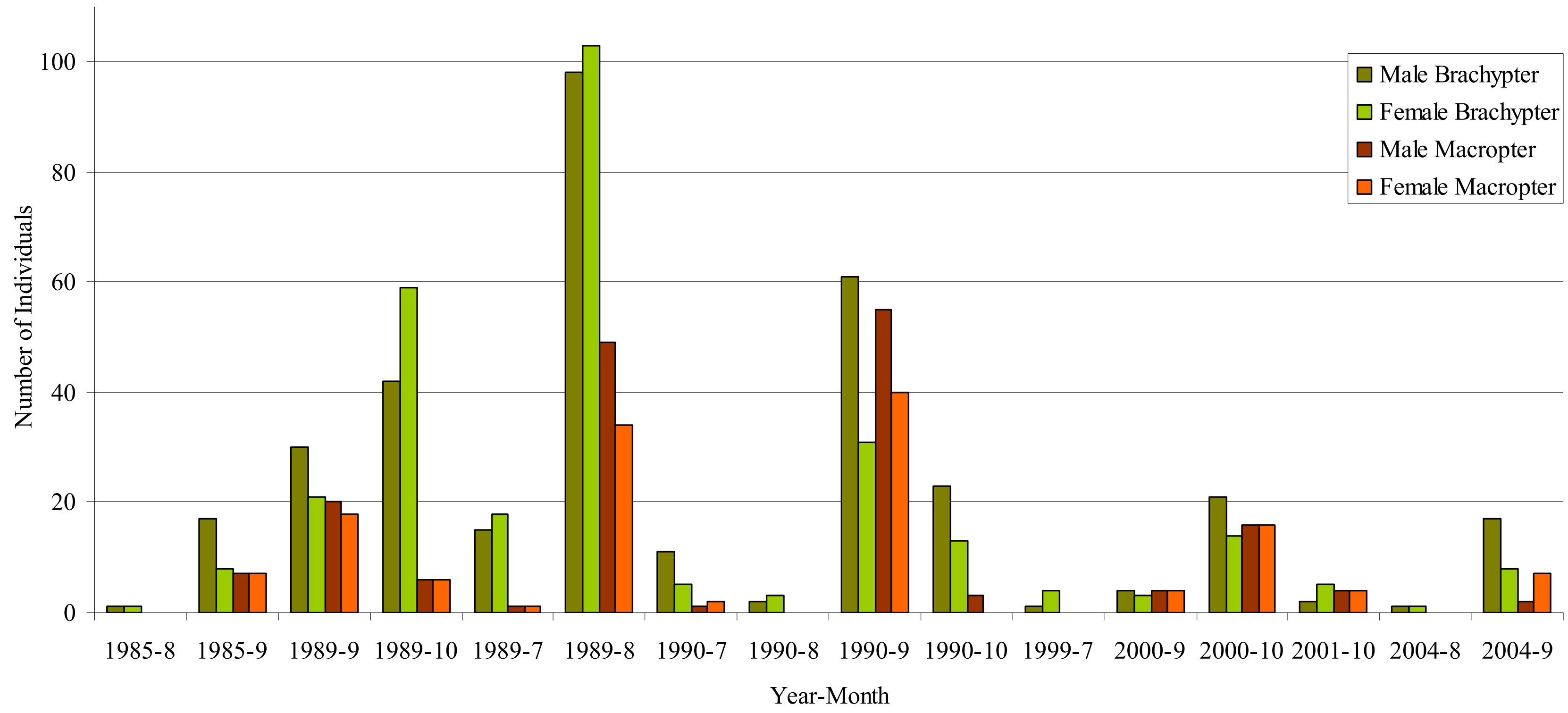
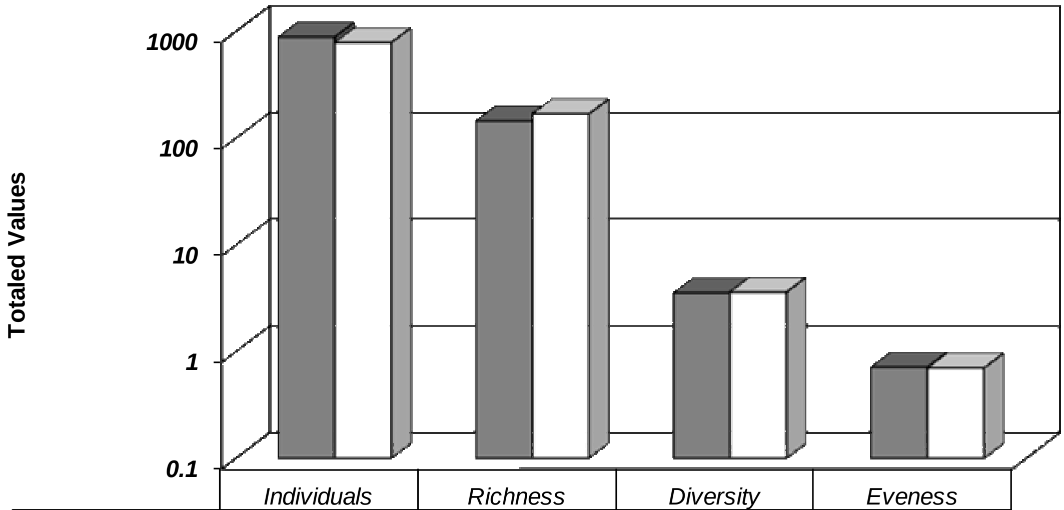
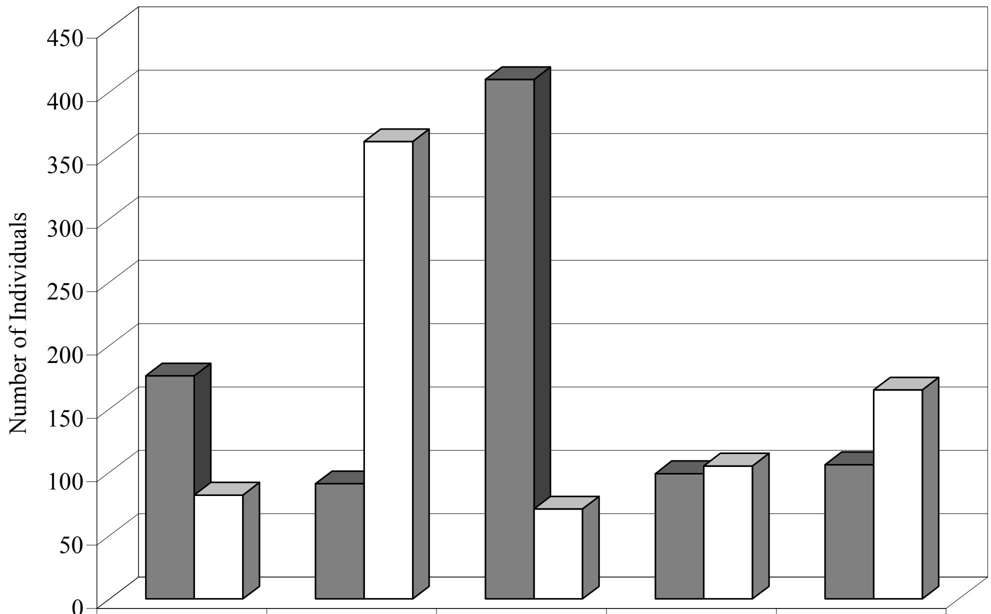


Figure 3.7 Total collected individuals of brachypters and macropters for each gender of *Pissonotus piceus* taken during the July, August, September, and October sampling periods from Lake Cena historic data.



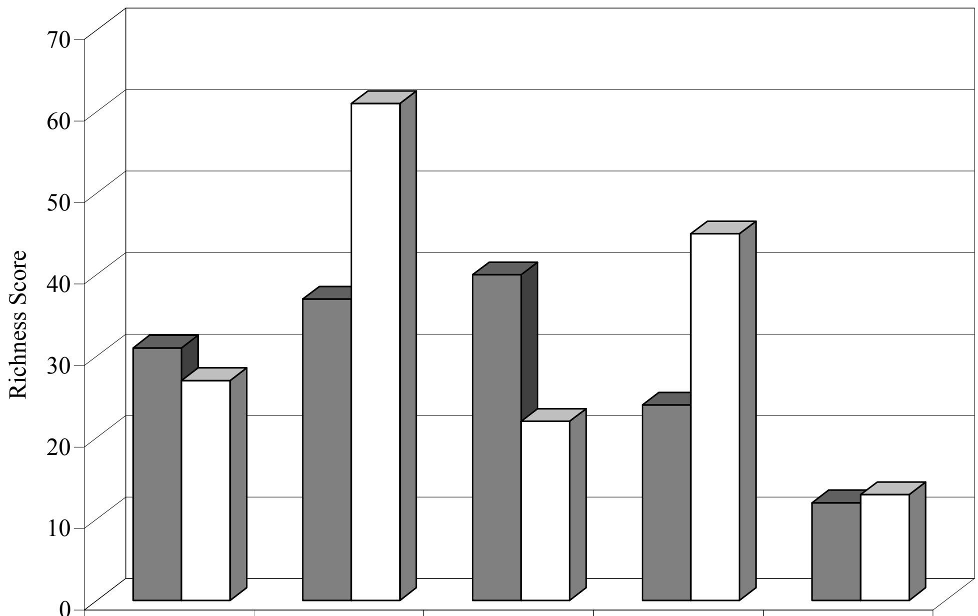
	Individuals	Richness	Diversity	Eveness
Cave Hollow	882	144	3.533	0.711
Racehorse Lake	784	168	3.584	0.699

Figure 3.8 Total calculated biodiversity values for insects and spiders collected from the Racehorse Lake and Cave Hollow study sites in 2010.



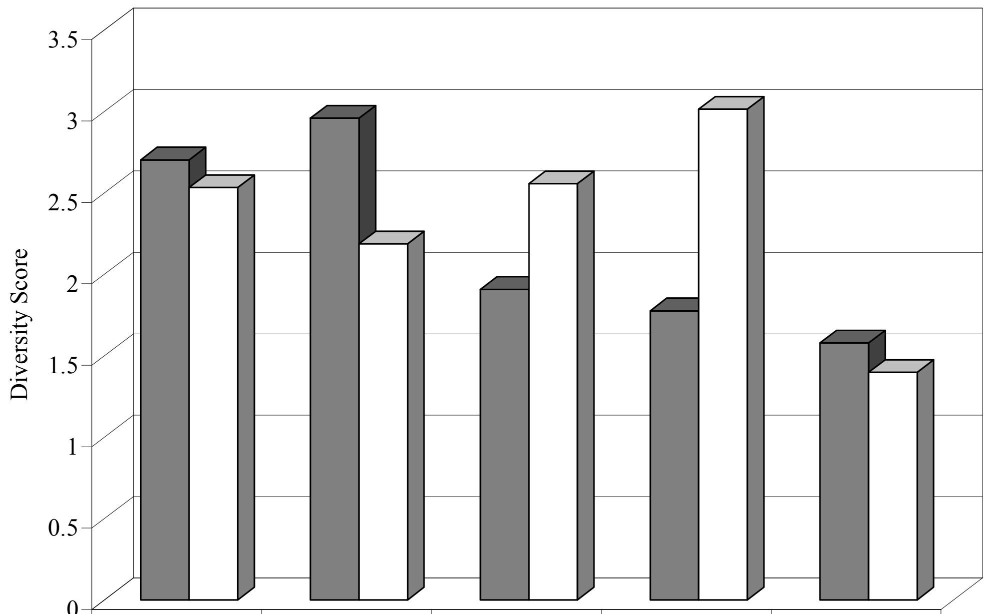
	Coleoptera	Diptera	Hemiptera	Hymenoptera	Araneae
■ Cave Hollow	176	91	410	99	106
□ Racehorse Lake	82	361	71	105	165

Figure 3.9 Total individuals collected of insects and spiders collected from the Racehorse Lake and Cave Hollow study sites in 2010.



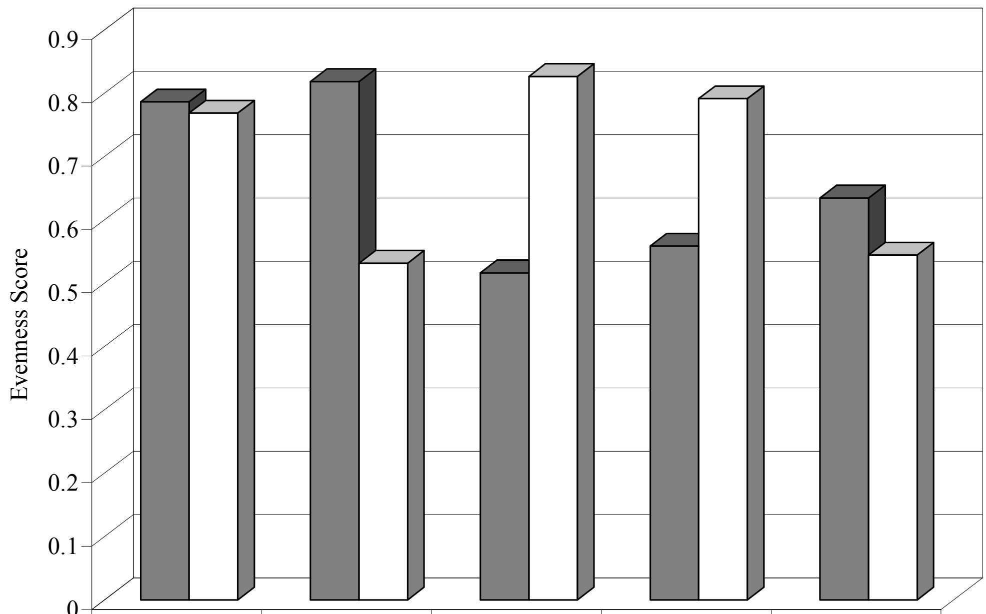
	Coleoptera	Diptera	Hemiptera	Hymenoptera	Araneae
Cave Hollow	31	37	40	24	12
Racehorse Lake	27	61	22	45	13

Figure 3.10 Species richness by order for insects and spiders collected from the Racehorse Lake and Cave Hollow study sites in 2010.



	Coleoptera	Diptera	Hemiptera	Hymenoptera	Araneae
■ Cave Hollow	2.704	2.959	1.907	1.777	1.579
□ Racehorse Lake	2.534	2.187	2.557	3.015	1.398

Figure 3.11 Species diversity by order for insects and spiders collected from the Racehorse Lake and Cave Hollow study sites in 2010.



	Coleoptera	Diptera	Hemiptera	Hymenoptera	Araneae
■ Cave Hollow	0.787	0.819	0.517	0.559	0.635
□ Racehorse Lake	0.769	0.532	0.827	0.792	0.545

Figure 3.12 Species evenness by order for insects and spiders collected from the Racehorse Lake and Cave Hollow study sites in 2010.

(Homoptera: Cercropidae) and various cicadellid species, but never in close proximity. During July, when temperatures reached over 32°C, *P. delicatus* was observed clustering in the unopened flowering heads of *G. squarrosa* between 0900 and 1100. They were never observed in opened or opening flowering heads. Efforts were made to collect individuals from these locations, but the sticky compound on the flowering heads made extraction difficult. Adults and nymphs left the flowering heads as early as 1000, and all individuals were completely absent by 1300. Adults and later stage nymphs were observed feeding on plant stems above the first branching of side stems from the main shoot where plant tissues were less woody. Brachypterous females were observed ovipositing on *G. squarrosa* main stems above the first few stem divisions. Individuals were never observed on the leaves of *G. squarrosa*. When disturbed by the investigator, brachypterous *P. delicatus* would circle the plant stems, only jumping as a last resort. Macropters appeared more prone to flee via jumping; all immatures behaved as brachypters. During this study, feeding behavior usually was observed after movement away from the flowering heads, but individuals became difficult to find along plot edges after 1200. *Lepyronia quadrangular* was observed feeding in locations similar to those of *P. delicatus*. *Pissonotus delicatus* specimens were last collected on 14 September.

Pissonotus piceus Field Observations

Pissonotus piceus specimens were collected for the laboratory study from the Racehorse Lake study site during September, 2009. Attempts were made to collect *P. piceus* during April, 2010, but their host plants were still dormant. They were first collected during 2010 on 5 May. Only a few specimens of *P. piceus* were collected before July. *P. piceus* individuals were not observed feeding during this study. Adults were often observed positioned on the basal leaves, but never observed feeding there. The presence of "hopper-burn" feeding damage on the leaves of *P. hydropiperoides* suggests *P. piceus* may feed there. Individuals were never observed above the basal leaves of *P. hydropiperoides.* Oviposition was never observed in the field. Nymphs and adults were observed standing and moving on the water surface numerous times. Individuals were never observed in close proximity to other arthropod species during this study. *Pissonotus piceus* was observed between 0900 and 1400, but did not appear to behave differently throughout the day. Macropterous and brachypterous adults, along with nymphs, jumped as soon as the investigator began to attempt to collect them. Only brachypterous adults were observed to circle plant stems rather than immediately jumping. Adults were last collected and observed in the field on the 14 September.

Litter Samples

No homopterans were collected from the leaf litter samples processed using the Berlese funnels.

Pissonotus delicatus Laboratory Observations

Pissonotus delicatus was first observed under laboratory settings during September and October 2009. Gravid brachypterous females were observed feeding under leaf petioles on the upper middle portion of the stems of *G. squarrosa*. During October, individuals were observed on enclosure walls but not on plant tissues. Both the plants and planthoppers died by mid-October. Observations of *P. delicatus* began again

August, 2010, when new individuals were transferred to the greenhouse; no individuals survived from the previous rearing attempt. Observations were made twice weekly between 0900 and 1600 from August to October, 2010. Adults and nymphs were observed feeding on the upper stems of *G. squarrosa* and were found in equal amounts on plant stems, leaves, and enclosure mesh until late September, when individuals were again seen only on the enclosure mesh. Gravid brachypterous females were observed in August, September, and October; however oviposition was not observed during the laboratory study. All nymphs developed into brachypterous adults. No parasites emerged within the enclosures containing *G. squarrosa* and *P. delicatus* during the laboratory study. By October all but three *G. squarrosa* host plants had died.

Pissonotus piceus Laboratory Observations

A total of 20 *Pissonotus piceus* individuals were collected in the field during the first week of September, 2009, and transferred to the greenhouse for observations in September and October. During September they were observed positioned on *P. hydropiperoides* and the enclosure mesh, feeding and ovipositing behaviors could not be confirmed. During October adults and immatures were only observed on the enclosure netting. No activity was observed after October even though living *P. hydropiperoides* specimens persisted. Observations were made through March, 2010, but no planthopper activity was detected. Between 14 and 24 April, numerous (50+) macropterous and brachypterous *P. piceus* adults were observed on the netting of the enclosure. All adults stuck on enclosure walls were collected into vials. No further planthopper specimens or activity was observed after April. New field collected specimens were transplanted to greenhouse enclosures during August. Five individuals were transplanted to each enclosure. Transplanted individuals were observed feeding on the lower stems of *P. hydropiperoides,* and also sitting on upper stems, leaves, and enclosure walls. Oviposition was not observed during the laboratory study. Macropters and brachypters were observed during the laboratory study. No parasites were found within the enclosures containing *P. hydropiperoides* and *P. piceus* during the laboratory study.

Pissonotus piceus overwinters as a third generation adult in the semiaquatic substrate near its host plant. Several studies have documented the ability of planthoppers and leafhoppers to withstand periods of submergence in water. *Prokelisia marginata* (Van Duzee) can rest submerged under leaves of *Spartina alterniflora* (Loisel.; Poaceae) during high tide (Arndt 1915). These planthoppers remained submerged up to 48 hours without incurring negative effects (Arndt 1915). Metcalf (1920) described four cicadellids, one acanaloniid, one cixiid, and four delphacids that withstand prolonged periods of submergence during high tides. The cicadellid *Macrosteles fascifrons* (Stål) was able to withstand twice daily submergence in 1°C iceberg laden tidal waters, with densities at their greatest in areas with the longest periods of submergence (DeLong 1970). No other planthopper has been reported to overwinter under water.

Emergence of *P. piceus* in the greenhouse in April suggests this delphacid overwinters as adults in the dense mats of its host plant which can become inundated with water. Adults emerge in the spring and deposit eggs in persisting *P. hydropiperoides* stems. These eggs would hatch in May after *P. hydropiperoides* has begun to produce leaves. The abundance of first instar *P. piceus* (Figure 3.1-.3) indicates that subsequent generations emerge in July and late August. The life cycle of this species appears similar to that of *P. quadripustulatus* which feeds on the leaves and oviposits in the woody stems of its semiaquatic host plant. The available data for *P. delicatus* was insufficient to provide an accurate phenology, but similar emergence and pre-overwintering behavior of *P. piceus* and *P. delicatus* suggest similar phenologies. The overwintering stage of *P. delicatus* was not determined even though numerous litter samples taken near *G. squarrosa* stands were examined. Collection data suggest that it overwinters as either a fifth instar nymph or an adult.

Life history strategies of insects can be greatly influenced by interactions with competitors and predators (Tallamy and Denno 1981, D□bel and Denno 1994). The only abundant member of the sap-feeding guild in the *P. hydropiperoides* community was *P. piceus.* This lack of competing sap-feeders, which would serve as alternative prey, may lead to increased predation pressure on *P. piceus*. In aquatic habitats predators that mainly prey on emerging aquatic invertebrates turn to terrestrial food sources between emergences thus affecting terrestrial herbivores (Henschel *et al.* 2001). Spiders play an important role as major predators of marsh inhabiting planthoppers (Cronin *et al.* 2004, Denno and Roderick 1990) and are able to track substrate vibrations produced by courting leafhoppers (Virant-Doberlet *et al.* 2011). Frequent interruptions of feeding due to the presence of abundant predators could reduce nitrogen intake and result in developing nymphs responding in a functionally similar manner to a drop in host plant nitrogen levels ultimately resulting in a higher proportion of macropters. Further research is required to assess these hypotheses.

The life histories of *P. piceus* and *P. delicatus* are very similar, but the host plants they persist on are very different and occupy very different habitats with different arthropod communities. Although the two habitats have very similar biodiversity values

(Tables 3.5-.6, Figures 3.8), the communities are taxonomically dissimilar (Tables 3.5-.6, Figures 3.9-.12). Samples from *G. squarrosa* had similar richness of Coleoptera and Araneae as those collected from *P. hydropiperoides*, but had twice as many Hemiptera, and half as many Diptera and Hymenoptera. The collection data suggest *P. delicatus* has more sap-feeding guild competitors (Appendix B and C), and fewer predators and parasitoids. This may explain why *P. delicatus* spends some time resting in the sticky flower heads of *G. squarrosa* as a possible defense, but otherwise spends a great deal of time feeding out in the open and is not quick to flee. *Grindelia squarrosa* plants are more architecturally complex than those of *P. hydropiperoides,* but do not occur in close proximity to one another and form dense mats. This lack of overall habitat complexity leaves *P. delicatus* individuals at risk of desiccation and exposure to high ground temperatures. To compensate for this, *P. delicatus* individuals primarily feed on the upper portion of their host plants during morning, and retreat to shaded resting spots during the hottest time of the day.

It appears that *P. piceus* has little to no competition from sap-feeders, and limited competition from the small number of chewing-guild competitors. It is likely subject to higher predation pressure from Hymenoptera and Araneae between periods of aquatic insect emergence. The planthoppers inhabit an extremely complex mat-forming host-plant community which provides them ample shade and little risk of desiccation as well as protection from predators and parasitoids. This allows feeding for long periods of time with a lower risk of predation. Further, nymphs and adults can walk on and hop from the water surface. This explains why it was difficult to observe *P. piceus* in the field as they do not occur in high densities and use their host plants and dense mats for shelter. They also are difficult to find because nymphs are light-colored, and closely resemble both the flower petals and seeds of their host plant. Adults are either light-brown and resemble their host plant's flowers, or are dark and easily hidden on the dark surface of the water. The value of this for predator avoidance needs to be further evaluated.

CHAPTER 4

CONCLUSION

Comparison of the life histories of these delphacids revealed that they have similar life histories and seasonal phenologies. *P. piceus* and *P. delicatus* have five nymphal instars before molting to either macropterous or brachypterous adults. They are both monophagous on stable host plants and occur in abundance as brachypters, except when their habitat is significantly disturbed. Large disturbances in stable host populations was shown to cause an increase in the proportion of macropters in *P. piceus* and would likely cause similar changes in *P. delicaus.* They have similar phenologies with the emergence of 5th instar nymphs or adults in early spring, three overlapping generations occurring in May, July, and late August, and beginning winter dormancy again as 5th instar nymphs or adults. However, they have different overwintering sites as *P. piceus* overwinters in the semiaquatic substrate at the base of its host plant, but *P. delicatus* likely disperse away from its upland host plants as they often have very little litter at the base. They also differ in feeding sites on their host plants and time of day during which they feed. Their communities of potential competitors are very different with few sap-feeders on *P. hydropiperoides* but a significant number of weevils. There appear to be numerous sap-feeders and chewing-feeders on *G. squarrosa.* Both species are likely to have similar pressure from coleopteran predators, but the abundance of spiders suggest that these are important predators on *P. piceus* between aquatic insect emergence periods.

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APPENDIX A

Appendix A.1 Collection data and covariate values for 1985.

Month	**Apr**		**May**			**Jun**			**Jul**			**Aug**			**Sep**			**Oct**			**Nov**		
Days	**11-20**	**21-30**	**1-10**	**11-20**	**21-30**	**1-10**	**11-20**	**21-30**	**1-10**	**11-20**	**21-31**	**1-10**	**11-20**	**21-31**	**1-10**	**11-20**	**21-30**	**1-10**	**11-20**	**21-30**	**1-10**	**11-20**	**21-30**
Totals																							
Total Males	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**	**7**	**12**	0	0	0	0	0	0	0
Total Females	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**	**3**	**8**	**4**	0	0	0	0	0	0
Machropters																							
Lmales	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**2**	**2**	**3**	0	0	0	0	0	0
Lfemales	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**2**	**2**	**3**	0	0	0	0	0	0
LM5ths	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LF5ths	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Brachypters																							
Smales	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**	**6**	**11**	0	0	0	0	0	0	0
Sfemales	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**	**1**	**6**	**1**	0	0	0	0	0	0
SM5ths	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SF5ths	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pre-Fifths																							
4ths	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3rds	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2nds	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1sts	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Temperature																							
High											**92.00**	**94.00**	**93.00**	**90.00**	**94.00**	**88.00**	**82.00**						
Low											**58.00**	**57.00**	**58.00**	**55.00**	**59.00**	**52.00**	**39.00**						
Average											**76.04**	**66.13**	**72.60**	**70.09**	**78.95**	**61.35**	**50.36**						
Average High											**86.97**	**83.70**	**81.90**	**79.64**	**89.90**	**77.10**	**66.60**						
Average Low											**65.11**	**62.30**	**63.30**	**60.55**	**68.00**	**57.70**	**46.50**						
Precipitation																							
Highest											**1.28**	**1.12**	**1.25**	**2.72**	**0.00**	**0.18**	**2.89**						
Average											**0.55**	**0.37**	**0.68**	**1.43**	**0.00**	**0.08**	**0.77**						
Total											**1.67**	**1.85**	**4.07**	**2.85**	**0.00**	**0.26**	**5.42**						
# of Events											**3.00**	**5.00**	**6.00**	**2.00**	**0.00**	**3.00**	**7.00**						
Day Hours																							
Average	**13.10**	**13.48**	**13.85**	**14.15**	**14.43**	**14.65**	**14.75**	**14.75**	**14.73**	**14.50**	**14.25**	**13.93**	**13.60**	**13.18**	**12.75**	**13.35**	**12.30**	**11.53**	**11.13**	**10.68**	**10.33**	**9.95**	**9.68**

Appendix A.2 Collection data and covariate values for 1989.

Month	Apr		May			Jun			Jul			Aug			Sep			Oct			Nov		
Days	**11-20**	**21-30**	**1-10**	**11-20**	**21-30**	**1-10**	**11-20**	**21-30**	**1-10**	**11-20**	**21-31**	**1-10**	**11-20**	**21-31**	**1-10**	**11-20**	**21-30**	**1-10**	**11-20**	**21-30**	**1-10**	**11-20**	**21-30**
Totals																							
Total Males	2	0	0	0	2	1	1	0	0	1	3	1	3	55	3	6	0	4	7	17	20	1	0
Total Females	3	0	0	0	0	3	0	1	1	2	8	3	3	54	5	6	0	5	14	10	17	2	0
Machropters																							
Lmales	2	0	0	0	0	0	0	0	0	0	1	1	1	0	1	0	0	0	1	2	1	0	0
Lfemales	2	0	0	0	0	0	0	0	0	0	1	1	1	0	1	0	0	0	1	2	1	0	0
LM5ths	0	0	0	0	0	0	0	0	0	0	0	1	6	40	2	17	0	0	2	1	0	0	0
LF5ths	0	0	0	0	0	0	0	0	0	0	0	0	7	25	3	14	0	0	0	3	0	0	0
Brachypters																							
Smales	1	0	0	0	2	1	0	0	0	0	3	1	2	50	3	4	0	4	6	15	20	1	0
Sfemales	1	0	0	0	0	3	0	1	1	2	7	2	2	54	4	6	0	5	13	8	16	2	0
SM5ths	6	0	0	0	4	3	0	1	0	10	2	3	5	37	14	9	0	5	7	5	23	0	0
SF5ths	3	0	0	0	4	1	0	0	0	7	1	1	2	42	4	7	0	6	7	20	13	0	0
Pre-Fifths																							
4ths	6	0	0	0	2	0	0	0	0	2	0	5	22	118	107	112	0	13	5	9	8	0	0
3rds	5	0	0	0	1	0	2	5	3	3	2	9	17	71	248	136	0	10	3	9	11	0	0
2nds	5	0	0	0	0	0	1	0	3	0	0	16	18	36	258	70	0	6	7	10	6	1	0
1sts	2	0	0	0	0	1	0	4	3	0	1	6	8	20	94	15	0	2	0	0	3	0	0
Temperature																							
High	79.00	88.00	73.00	81.00	87.00	81.00	86.00	90.00	95.00	93.00	91.00	93.00	89.00	93.00	90.00	72.00	81.00	82.00	86.00	80.00	68.00	78.00	60.00
Low	29.00	48.00	37.00	42.00	46.00	52.00	48.00	64.00	63.00	66.00	59.00	53.00	57.00	70.00	53.00	48.00	36.00	39.00	30.00	31.00	29.00	19.00	11.00
Average	55.00	69.95	54.40	64.15	70.66	67.70	67.15	75.15	79.20	76.70	75.95	74.75	74.65	87.50	74.10	62.55	58.00	59.25	57.05	59.93	46.90	49.20	38.00
Average High	66.60	80.30	64.50	75.10	80.03	76.40	75.50	84.70	89.40	83.70	84.70	84.50	84.60	96.30	81.80	71.30	70.80	71.40	67.70	69.73	57.60	61.20	49.80
Average Low	43.40	59.60	44.30	53.20	61.30	59.00	58.80	65.60	69.00	69.70	67.20	65.00	64.70	78.70	66.40	53.80	45.20	47.10	46.40	50.14	36.20	37.20	26.20
Precipitation																							
Highest	0.18	0.00	0.82	0.49	0.87	0.58	1.11	0.96	0.06	0.32	0.56	0.01	1.42	1.06	1.47	0.37	0.00	0.12	0.43	1.46	0.00	0.00	0.00
Average	0.18	0.00	0.32	0.23	0.34	0.24	1.00	0.47	0.06	0.29	0.40	0.01	0.59	0.30	0.61	0.20	0.00	0.10	0.24	0.51	0.00	0.00	0.00
Total	0.18	0.00	0.96	0.71	1.72	1.44	4.03	1.89	0.06	0.59	0.80	0.01	2.34	2.74	3.71	0.60	0.00	0.20	0.47	2.04	0.00	0.00	0.00
# of Events	1.00	0.00	3.00	3.00	5.00	6.00	4.00	4.00	1.00	2.00	2.00	1.00	4.00	9.00	6.00	3.00	0.00	2.00	2.00	4.00	0.00	0.00	0.00
Day Hours																							
Average	13.10	13.48	13.85	14.15	14.43	14.65	14.75	14.75	14.73	14.50	14.25	13.93	13.60	13.18	12.75	13.35	12.30	11.53	11.13	10.68	10.33	9.95	9.68

Appendix A.3 Collection data and covariate values for 1990.

Month	Apr		May			Jun			Jul			Aug			Sep			Oct			Nov		
Days	**11-20**	**21-30**	**1-10**	**11-20**	**21-30**	**1-10**	**11-20**	**21-30**	**1-10**	**11-20**	**21-31**	**1-10**	**11-20**	**21-31**	**1-10**	**11-20**	**21-30**	**1-10**	**11-20**	**21-30**	**1-10**	**11-20**	**21-30**
Totals																							
Total Males	0	0	**0**	**12**	**13**	**0**	0	**0**	0	**5**	0	0	0	**3**	**20**	**40**	**29**	**11**	0	0	**10**	**3**	**2**
Total Females	0	0	**0**	**0**	**6**	**4**	0	**0**	0	**3**	0	0	0	**2**	**5**	**24**	**20**	**5**	0	0	**8**	**6**	**2**
Machropters																							
Lmales	0	0	**0**	**0**	**0**	**0**	0	**0**	0	**0**	0	0	0	**0**	**0**	**17**	**10**	**0**	0	0	**1**	**0**	**1**
Lfemales	0	0	**0**	**0**	**0**	**0**	0	**0**	0	**0**	0	0	0	**0**	**0**	**17**	**10**	**0**	0	0	**1**	**0**	**1**
LM5ths	0	0	**0**	**0**	**0**	**0**	0	**0**	0	**1**	0	0	0	**0**	**1**	**19**	**8**	**3**	0	0	**0**	**0**	**1**
LF5ths	0	0	**0**	**0**	**0**	**0**	0	**0**	0	**2**	0	0	0	**0**	**0**	**5**	**8**	**0**	0	0	**0**	**0**	**0**
Brachypters																							
Smales	0	0	**0**	**12**	**12**	**0**	0	**0**	0	**5**	0	0	0	**2**	**19**	**15**	**17**	**10**	0	0	**10**	**3**	**1**
Sfemales	0	0	**0**	**0**	**6**	**4**	0	**0**	0	**3**	0	0	0	**2**	**5**	**7**	**10**	**5**	0	0	**7**	**6**	**1**
SM5ths	0	0	**0**	**0**	**7**	**1**	0	**3**	0	**6**	0	0	0	**0**	**1**	**8**	**1**	**13**	0	0	**2**	**1**	**0**
SF5ths	0	0	**0**	**0**	**2**	**0**	0	**1**	0	**2**	0	0	0	**1**	**2**	**3**	**4**	**8**	0	0	**0**	**3**	**0**
Pre-Fifths																							
4ths	0	0	**3**	**16**	**2**	**0**	0	**4**	0	**11**	0	0	0	**3**	**15**	**49**	**10**	**18**	0	0	**3**	**3**	**0**
3rds	0	0	**12**	**32**	**2**	**3**	0	**19**	0	**4**	0	0	0	**24**	**38**	**67**	**16**	**45**	0	0	**0**	**0**	**1**
2nds	0	0	**8**	**35**	**1**	**5**	0	**25**	0	**8**	0	0	0	**208**	**108**	**137**	**16**	**52**	0	0	**0**	**0**	**0**
1sts	0	0	**5**	**6**	**0**	**1**	0	**9**	0	**5**	0	0	0	**114**	**3**	**125**	**13**	**22**	0	0	**0**	**0**	**0**
Temperature																							
High	**68.00**	**84.00**	**80.00**	**63.00**	**84.00**	**84.00**	**90.00**	**90.00**	**98.00**	**89.00**	**87.00**	**86.00**	**91.00**	**97.00**	**100.00**	**89.00**	**90.00**	**84.00**	**73.00**	**78.00**	**79.00**	**73.00**	**75.00**
Low	**29.00**	**39.00**	**42.00**	**43.00**	**64.00**	**46.00**	**66.00**	**61.00**	**73.00**	**57.00**	**60.00**	**54.00**	**63.00**	**63.00**	**66.00**	**53.00**	**37.00**	**35.00**	**31.00**	**25.00**	**29.00**	**26.00**	**22.00**
Average	**49.85**	**64.45**	**57.10**	**61.35**	**65.81**	**70.20**	**77.90**	**76.30**	**84.10**	**72.90**	**75.21**	**70.55**	**75.50**	**81.51**	**82.80**	**70.00**	**64.50**	**59.35**	**53.55**	**57.05**	**46.70**	**51.58**	**48.10**
Average High	**58.70**	**74.40**	**66.00**	**69.50**	**72.04**	**78.60**	**85.70**	**84.10**	**92.90**	**80.30**	**82.54**	**78.90**	**82.80**	**92.64**	**94.30**	**79.40**	**77.40**	**70.20**	**67.90**	**72.50**	**57.00**	**64.30**	**60.60**
Average Low	**41.00**	**54.50**	**48.20**	**53.20**	**59.59**	**61.80**	**70.10**	**68.50**	**75.30**	**65.50**	**67.90**	**62.20**	**68.20**	**70.40**	**71.30**	**60.60**	**51.60**	**48.50**	**39.20**	**41.60**	**36.40**	**39.40**	**35.60**
Precipitation																							
Highest	**0.58**	**1.66**	**0.87**	**3.86**	**1.54**	**1.21**	**2.46**	**1.06**	**0.17**	**0.42**	**2.07**	**1.40**	**0.50**	**0.00**	**0.02**	**0.01**	**0.12**	**1.43**	**0.01**	**0.00**	**0.77**	**0.00**	**1.16**
Average	**0.23**	**0.56**	**0.28**	**1.01**	**0.57**	**0.60**	**0.86**	**0.40**	**0.17**	**0.22**	**0.68**	**0.64**	**0.22**	**0.00**	**0.02**	**0.34**	**0.12**	**0.43**	**0.01**	**0.00**	**0.22**	**0.00**	**0.67**
Total	**0.92**	**1.70**	**1.38**	**7.12**	**2.31**	**2.40**	**4.32**	**1.22**	**0.17**	**0.91**	**2.74**	**1.92**	**0.90**	**0.00**	**0.04**	**0.02**	**0.12**	**2.58**	**0.01**	**0.00**	**1.10**	**0.00**	**1.34**
# of Events	**4.00**	**3.00**	**5.00**	**7.00**	**4.00**	**4.00**	**5.00**	**3.00**	**1.00**	**4.00**	**4.00**	**3.00**	**4.00**	**0.00**	**2.00**	**3.00**	**1.00**	**6.00**	**1.00**	**0.00**	**5.00**	**0.00**	**2.00**
Day Hours																							
Average	**13.10**	**13.48**	**13.85**	**14.15**	**14.43**	**14.65**	**14.75**	**14.75**	**14.73**	**14.50**	**14.25**	**13.93**	**13.60**	**13.18**	**12.75**	**13.35**	**12.30**	**11.53**	**11.13**	**10.68**	**10.33**	**9.95**	**9.68**

Appendix A.4 Collection data and covariate values for 1999.

Month	Apr		May			Jun			Jul			Aug			Sep			Oct			Nov		
Days	**11-20**	**21-30**	**1-10**	**11-20**	**21-30**	**1-10**	**11-20**	**21-30**	**1-10**	**11-20**	**21-31**	**1-10**	**11-20**	**21-31**	**1-10**	**11-20**	**21-30**	**1-10**	**11-20**	**21-30**	**1-10**	**11-20**	**21-30**
Totals																							
Total Males	0	0	0	0	0	0	0	0	0	**1**	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Females	0	0	0	0	0	0	0	0	0	**4**	0	0	0	0	0	0	0	0	0	0	0	0	0
Machropters																							
Lmales	0	0	0	0	0	0	0	0	0	**0**	0	0	0	0	0	0	0	0	0	0	0	0	0
Lfemales	0	0	0	0	0	0	0	0	0	**0**	0	0	0	0	0	0	0	0	0	0	0	0	0
LM5ths	0	0	0	0	0	0	0	0	0	**0**	0	0	0	0	0	0	0	0	0	0	0	0	0
LF5ths	0	0	0	0	0	0	0	0	0	**0**	0	0	0	0	0	0	0	0	0	0	0	0	0
Brachypters																							
Smales	0	0	0	0	0	0	0	0	0	**1**	0	0	0	0	0	0	0	0	0	0	0	0	0
Sfemales	0	0	0	0	0	0	0	0	0	**4**	0	0	0	0	0	0	0	0	0	0	0	0	0
SM5ths	0	0	0	0	0	0	0	0	0	**0**	0	0	0	0	0	0	0	0	0	0	0	0	0
SF5ths	0	0	0	0	0	0	0	0	0	**0**	0	0	0	0	0	0	0	0	0	0	0	0	0
Pre-Fifths																							
4ths	0	0	0	0	0	0	0	0	0	**2**	0	0	0	0	0	0	0	0	0	0	0	0	0
3rds	0	0	0	0	0	0	0	0	0	**7**	0	0	0	0	0	0	0	0	0	0	0	0	0
2nds	0	0	0	0	0	0	0	0	0	**70**	0	0	0	0	0	0	0	0	0	0	0	0	0
1sts	0	0	0	0	0	0	0	0	0	**55**	0	0	0	0	0	0	0	0	0	0	0	0	0
Temperature																							
High							**86.00**	**89.00**	**91.00**	**95.00**													
Low							**51.00**	**60.00**	**68.00**	**64.00**													
Average							**69.65**	**75.20**	**80.65**	**80.45**													
Average High							**78.90**	**83.20**	**88.60**	**89.50**													
Average Low							**60.40**	**67.20**	**72.70**	**71.40**													
Precipitation																							
Highest							**0.22**	**3.57**	**0.14**	**0.02**													
Average							**0.12**	**1.04**	**0.12**	**0.02**													
Total							**0.24**	**6.28**	**0.24**	**0.02**													
# of Events							**2.00**	**6.00**	**2.00**	**1.00**													
Day Hours																							
Average	**13.10**	**13.48**	**13.85**	**14.15**	**14.43**	**14.65**	**14.75**	**14.75**	**14.73**	**14.50**	**14.25**	**13.93**	**13.60**	**13.18**	**12.75**	**13.35**	**12.30**	**11.53**	**11.13**	**10.68**	**10.33**	**9.95**	**9.68**

Appendix A.5 Collection data and covariate values for 2000.

Month	Apr		May			Jun			Jul			Aug			Sep			Oct			Nov		
Days	**11-20**	**21-30**	**1-10**	**11-20**	**21-30**	**1-10**	**11-20**	**21-30**	**1-10**	**11-20**	**21-31**	**1-10**	**11-20**	**21-31**	**1-10**	**11-20**	**21-30**	**1-10**	**11-20**	**21-30**	**1-10**	**11-20**	**21-30**
Totals																							
Total Males	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**6**	**5**	0	**42**	0	0	0	0	0
Total Females	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**5**	**2**	0	**30**	0	0	0	0	0
Machropters																							
Lmales	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**3**	**1**	0	**16**	0	0	0	0	0
Lfemales	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**3**	**1**	0	**16**	0	0	0	0	0
LM5ths	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**0**	0	**0**	0	0	0	0	0
LF5ths	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**0**	0	**0**	0	0	0	0	0
Brachypters																							
Smales	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**3**	**1**	0	**21**	0	0	0	0	0
Sfemales	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**2**	**1**	0	**14**	0	0	0	0	0
SM5ths	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**0**	0	**0**	0	0	0	0	0
SF5ths	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**0**	0	**0**	0	0	0	0	0
Pre-Fifths																							
4ths	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**0**	0	**0**	0	0	0	0	0
3rds	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**0**	0	**0**	0	0	0	0	0
2nds	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**0**	0	**0**	0	0	0	0	0
1sts	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**0**	0	**0**	0	0	0	0	0
Temperature																							
High												**95.00**	**84.00**	**95.00**	**95.00**	**104.00**	**100.00**	**89.00**					
Low												**60.00**	**66.00**	**71.00**	**71.00**	**51.00**	**44.00**	**26.00**					
Average												**79.85**	**75.00**	**82.50**	**82.50**	**78.50**	**69.20**	**53.35**					
Average High												**89.80**	**84.00**	**86.00**	**86.00**	**91.00**	**83.30**	**64.20**					
Average Low												**69.90**	**66.00**	**79.00**	**79.00**	**66.00**	**55.10**	**42.50**					
Precipitation																							
Highest												**0.99**	**0.00**	**0.00**	**0.00**	**0.00**	**0.14**	**1.26**					
Average												**0.42**	**0.00**	**0.00**	**0.00**	**0.00**	**0.10**	**0.68**					
Total												**1.71**	**0.00**	**0.00**	**0.00**	**0.00**	**0.31**	**1.37**					
# of Events												**4.00**	**0.00**	**0.00**	**0.00**	**0.00**	**3.00**	**2.00**					
Day Hours																							
Average	**13.10**	**13.48**	**13.85**	**14.15**	**14.43**	**14.65**	**14.75**	**14.75**	**14.73**	**14.50**	**14.25**	**13.93**	**13.60**	**13.18**	**12.75**	**13.35**	**12.30**	**11.53**	**11.13**	**10.68**	**10.33**	**9.95**	**9.68**

Appendix A.6 Collection data and covariate values for 2001.

Month	Apr		May			Jun			Jul			Aug			Sep			Oct			Nov		
Days	**11-20**	**21-30**	**1-10**	**11-20**	**21-30**	**1-10**	**11-20**	**21-30**	**1-10**	**11-20**	**21-31**	**1-10**	**11-20**	**21-31**	**1-10**	**11-20**	**21-30**	**1-10**	**11-20**	**21-30**	**1-10**	**11-20**	**21-30**
Totals																							
Total Males	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**2**	0	0	0
Total Females	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**9**	0	0	0
Machropters																							
Lmales	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**4**	0	0	0
Lfemales	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**4**	0	0	0
LM5ths	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	0	0	0
LF5ths	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	0	0	0
Brachypters																							
Smales	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**2**	0	0	0
Sfemales	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**5**	0	0	0
SM5ths	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	0	0	0
SF5ths	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	0	0	0
Pre-Fifths																							
4ths	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	0	0	0
3rds	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	0	0	0
2nds	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	0	0	0
1sts	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	0	0	0
Temperature																							
High																	**82.00**	**87.00**	**77.00**	**80.00**			
Low																	**41.00**	**39.00**	**35.00**	**28.00**			
Average																	**61.60**	**63.30**	**55.85**	**64.70**			
Average High																	**74.10**	**75.70**	**66.10**	**76.30**			
Average Low																	**49.10**	**50.90**	**45.60**	**53.10**			
Precipitation																							
Highest																	**0.39**	**1.53**	**0.85**	**0.09**			
Average																	**0.39**	**0.92**	**0.85**	**0.05**			
Total																	**0.39**	**3.71**	**0.85**	**0.16**			
# of Events																	**1.00**	**4.00**	**1.00**	**3.00**			
Day Hours																							
Average	**13.10**	**13.48**	**13.85**	**14.15**	**14.43**	**14.65**	**14.75**	**14.75**	**14.73**	**14.50**	**14.25**	**13.93**	**13.60**	**13.18**	**12.75**	**13.35**	**12.30**	**11.53**	**11.13**	**10.68**	**10.33**	**9.95**	**9.68**

Appendix A.7 Collection data and covariate values for 2002.

Month	Apr		May			Jun			Jul			Aug			Sep			Oct			Nov		
Days	**11-20**	**21-30**	**1-10**	**11-20**	**21-30**	**1-10**	**11-20**	**21-30**	**1-10**	**11-20**	**21-31**	**1-10**	**11-20**	**21-31**	**1-10**	**11-20**	**21-30**	**1-10**	**11-20**	**21-30**	**1-10**	**11-20**	**21-30**
Totals																							
Total Males	0	0	0	0	0	0	0	**0**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Females	0	0	0	0	0	0	0	**0**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Machropters																							
Lmales	0	0	0	0	0	0	0	**0**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lfemales	0	0	0	0	0	0	0	**0**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LM5ths	0	0	0	0	0	0	0	**0**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LF5ths	0	0	0	0	0	0	0	**0**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Brachypters																							
Smales	0	0	0	0	0	0	0	**0**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sfemales	0	0	0	0	0	0	0	**0**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SM5ths	0	0	0	0	0	0	0	**0**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SF5ths	0	0	0	0	0	0	0	**0**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pre-Fifths																							
4ths	0	0	0	0	0	0	0	**3**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3rds	0	0	0	0	0	0	0	**2**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2nds	0	0	0	0	0	0	0	**4**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1sts	0	0	0	0	0	0	0	**0**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Temperature																							
High																							
Low																							
Average																							
Average High																							
Average Low																							
Precipitation																							
Highest																							
Average																							
Total																							
# of Events																							
Day Hours																							
Average	**13.10**	**13.48**	**13.85**	**14.15**	**14.43**	**14.65**	**14.75**	**14.75**	**14.73**	**14.50**	**14.25**	**13.93**	**13.60**	**13.18**	**12.75**	**13.35**	**12.30**	**11.53**	**11.13**	**10.68**	**10.33**	**9.95**	**9.68**

Appendix A.8 Collection data and covariate values for 2003.

Month	Apr		May			Jun			Jul			Aug			Sep			Oct			Nov		
Days	**11-20**	**21-30**	**1-10**	**11-20**	**21-30**	**1-10**	**11-20**	**21-30**	**1-10**	**11-20**	**21-31**	**1-10**	**11-20**	**21-31**	**1-10**	**11-20**	**21-30**	**1-10**	**11-20**	**21-30**	**1-10**	**11-20**	**21-30**
Totals																							
Total Males	0	0	0	0	0	0	0	0	0	0	0	**0**	0	0	0	0	0	0	0	0	0	0	0
Total Females	0	0	0	0	0	0	0	0	0	0	0	**0**	0	0	0	0	0	0	0	0	0	0	0
Machropters																							
Lmales	0	0	0	0	0	0	0	0	0	0	0	**0**	0	0	0	0	0	0	0	0	0	0	0
Lfemales	0	0	0	0	0	0	0	0	0	0	0	**0**	0	0	0	0	0	0	0	0	0	0	0
LM5ths	0	0	0	0	0	0	0	0	0	0	0	**3**	0	0	0	0	0	0	0	0	0	0	0
LF5ths	0	0	0	0	0	0	0	0	0	0	0	**0**	0	0	0	0	0	0	0	0	0	0	0
Brachypters																							
Smales	0	0	0	0	0	0	0	0	0	0	0	**0**	0	0	0	0	0	0	0	0	0	0	0
Sfemales	0	0	0	0	0	0	0	0	0	0	0	**0**	0	0	0	0	0	0	0	0	0	0	0
SM5ths	0	0	0	0	0	0	0	0	0	0	0	**2**	0	0	0	0	0	0	0	0	0	0	0
SF5ths	0	0	0	0	0	0	0	0	0	0	0	**3**	0	0	0	0	0	0	0	0	0	0	0
Pre-Fifths																							
4ths	0	0	0	0	0	0	0	0	0	0	0	**4**	0	0	0	0	0	0	0	0	0	0	0
3rds	0	0	0	0	0	0	0	0	0	0	0	**1**	0	0	0	0	0	0	0	0	0	0	0
2nds	0	0	0	0	0	0	0	0	0	0	0	**0**	0	0	0	0	0	0	0	0	0	0	0
1sts	0	0	0	0	0	0	0	0	0	0	0	**0**	0	0	0	0	0	0	0	0	0	0	0
Temperature																							
High																							
Low																							
Average																							
Average High																							
Average Low																							
Precipitation																							
Highest																							
Average																							
Total																							
# of Events																							
Day Hours																							
Average	**13.10**	**13.48**	**13.85**	**14.15**	**14.43**	**14.65**	**14.75**	**14.75**	**14.73**	**14.50**	**14.25**	**13.93**	**13.60**	**13.18**	**12.75**	**13.35**	**12.30**	**11.53**	**11.13**	**10.68**	**10.33**	**9.95**	**9.68**

Appendix A.9 Collection data and covariate values for 2004.

Month	Apr		May			Jun			Jul			Aug			Sep			Oct			Nov		
Days	11-20	21-30	1-10	11-20	21-30	1-10	11-20	21-30	1-10	11-20	21-31	1-10	11-20	21-31	1-10	11-20	21-30	1-10	11-20	21-30	1-10	11-20	21-30
Totals																							
Total Males	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**	**7**	**12**	**0**	0	0	0	0	0	0
Total Females	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**	**3**	**8**	**4**	0	0	0	0	0	0
Machropters																							
Lmales	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**1**	**1**	**0**	0	0	0	0	0	0
Lfemales	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**2**	**2**	**3**	0	0	0	0	0	0
LM5ths	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**0**	**0**	**0**	0	0	0	0	0	0
LF5ths	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**0**	**0**	**0**	0	0	0	0	0	0
Brachypters																							
Smales	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**	**6**	**11**	**0**	0	0	0	0	0	0
Sfemales	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**	**1**	**6**	**1**	0	0	0	0	0	0
SM5ths	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**0**	**0**	**0**	0	0	0	0	0	0
SF5ths	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**0**	**0**	**0**	0	0	0	0	0	0
Pre-Fifths																							
4ths	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**0**	**0**	**0**	0	0	0	0	0	0
3rds	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**0**	**0**	**0**	0	0	0	0	0	0
2nds	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**0**	**0**	**0**	0	0	0	0	0	0
1sts	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**0**	**0**	**0**	0	0	0	0	0	0
Temperature																							
High											**89.00**	**91.00**	**89.00**	**91.00**	**84.00**	**87.00**	**80.00**						
Low											**53.00**	**55.00**	**81.00**	**55.00**	**50.00**	**53.00**	**51.00**						
Average											**77.40**	**72.70**	**66.20**	**80.05**	**69.25**	**70.65**	**66.85**						
Average High											**86.20**	**81.70**	**75.30**	**89.40**	**78.30**	**80.10**	**78.80**						
Average Low											**68.60**	**63.70**	**57.10**	**70.70**	**60.20**	**61.20**	**54.90**						
Precipitation																							
Highest											**2.03**	**0.98**	**1.42**	**1.64**	**0.86**	**0.60**	**0.02**						
Average											**0.62**	**0.43**	**0.75**	**0.69**	**0.86**	**0.58**	**0.02**						
Total											**2.48**	**1.29**	**1.50**	**2.77**	**0.86**	**1.17**	**0.02**						
# of Events											**4.00**	**3.00**	**2.00**	**4.00**	**1.00**	**2.00**	**1.00**						
Day Hours																							
Average	**13.10**	**13.48**	**13.85**	**14.15**	**14.43**	**14.65**	**14.75**	**14.75**	**14.73**	**14.50**	**14.25**	**13.93**	**13.60**	**13.18**	**12.75**	**13.35**	**12.30**	**11.53**	**11.13**	**10.68**	**10.33**	**9.95**	**9.68**

APPENDIX B

Appendix B.1 Hymenoptera collection data for Cave Hollow, Johnson County, Missouri. May-September 2010.

Date	5-May-10				24-May-10				8-Jun-10				23-Jun-10				14-Jul-10				29-Jul-10				31-Aug-10				14-Sep-10				
Site	**1**	**2**	**3**	**∑**	**1**	**2**	**3**	**∑**	**1**	**2**	**3**	**∑**	**1**	**2**	**3**	**∑**	**1**	**2**	**3**	**∑**	**1**	**2**	**3**	**∑**	**1**	**2**	**3**	**∑**	**1**	**2**	**3**	**∑**	**∑**
Formicidae sp 1	1	3	0	**4**	0	12	0	**12**	0	1	0	**1**	0	1	0	**1**	1	2	0	**3**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	21
Formicidae sp 2	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Formicidae sp 3	7	3	1	**11**	3	3	0	**6**	0	8	4	**12**	0	11	0	**11**	1	12	0	**13**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	53
Hymenoptera sp 1	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	1
Hymenoptera sp 2	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1	0	0	**1**	0	0	0	**0**	1
Hymenoptera sp 3	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	1	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Hymenoptera sp 4	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	1	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Hymenoptera sp 5	0	0	0	**0**	0	0	0	**0**	0	0	1	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Hymenoptera sp 6	1	0	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Hymenoptera sp 7	0	0	0	**0**	1	0	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Hymenoptera sp 8	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Hymenoptera sp 9	0	0	0	**0**	0	0	0	**0**	0	0	1	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Hymenoptera sp 10	1	0	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Hymenoptera sp 11	1	0	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Hymenoptera sp 12	2	0	0	**2**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	2
Hymenoptera sp 13	1	1	0	**2**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	3
Hymenoptera sp 14	1	0	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Hymenoptera sp 15	0	0	1	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Hymenoptera sp 16	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Hymenoptera sp 17	0	0	0	**0**	0	0	0	**0**	0	0	1	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Hymenoptera sp 18	0	0	0	**0**	1	0	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Hymenoptera sp 19	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Hymenoptera sp 58	1	0	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Hymenoptera sp 59	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	1	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1

Appendix B.2 Coleoptera collection data for Cave Hollow, Johnson County, Missouri. May-September 2010.

Date	5-May-10				24-May-10				8-Jun-10				23-Jun-10				14-Jul-10				29-Jul-10				31-Aug-10				14-Sep-10				
Site	**1**	**2**	**3**	**∑**	**1**	**2**	**3**	**∑**	**1**	**2**	**3**	**∑**	**1**	**2**	**3**	**∑**	**1**	**2**	**3**	**∑**	**1**	**2**	**3**	**∑**	**1**	**2**	**3**	**∑**	**1**	**2**	**3**	**∑**	**∑**
Lixus terminalis LeConte	0	0	0	**0**	0	0	1	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Hypera compta Say	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Hypera meles (Fabricius)	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1	0	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
"Apion" sensu lato	0	4	0	**4**	2	1	3	**6**	1	0	2	**3**	1	0	2	**3**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1	1	0	**2**	18
Tyloderma punctatum complex	0	0	0	**0**	0	0	0	**0**	0	0	1	**1**	0	2	0	**2**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	3
Onychylis nigrirostris (Boheman)	0	2	0	**2**	7	9	1	**17**	0	0	2	**2**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	22
Homorosoma sulcipennis (LeConte)	0	5	0	**5**	10	6	0	**16**	8	0	0	**8**	0	1	1	**2**	0	0	0	**0**	1	0	1	**2**	0	0	0	**0**	0	0	0	**0**	33
Auleutes nebulosus (LeConte)	0	2	0	**2**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	2
Rhinoncus longulus LeConte	0	0	0	**0**	2	2	0	**4**	0	0	1	**1**	9	0	1	**10**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	15
Perigaster cretura Herbst	0	5	5	**10**	1	0	0	**1**	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	13
Pelenomus sulcicollis (Fahraeus)	1	0	0	**1**	7	4	4	**15**	0	0	2	**2**	0	2	0	**2**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	20
Bruchidae sp 1	0	0	0	**0**	1	1	0	**2**	0	0	1	**1**	0	2	0	**2**	0	2	2	**4**	0	0	0	**0**	1	0	0	**1**	0	0	0	**0**	10
Elateridae sp1	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0
Lampyridae sp 1	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	2
Deloyala guttata	0	1	0	**1**	0	1	0	**1**	0	0	2	**2**	0	0	2	**2**	0	0	1	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	7
Chrysomelidae sp 1	0	0	0	**0**	0	0	0	**0**	0	0	2	**2**	0	0	1	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	3
Chrysomelidae sp 3	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	1	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Coccinellidae sp 1	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Mordella sp 1	0	0	0	**0**	1	1	0	**2**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	2
Glipa sp 1	0	0	0	**0**	1	0	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Coleoptera sp 1	1	0	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Coleoptera sp 2	2	0	0	**2**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	3
Coleoptera sp 3	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Coleoptera sp 4	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1	0	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Coleoptera sp 5	0	3	1	**4**	0	1	0	**1**	0	0	1	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	6
Coleoptera sp 6	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Coleoptera sp 7	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	1
Coleoptera sp 8	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Coleoptera sp 9	0	0	0	**0**	1	2	0	**3**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	3
Coleoptera sp 10	0	0	0	**0**	1	0	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Coleoptera sp 11	0	0	0	**0**	1	0	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1

Appendix B.3 Diptera collection data for Cave Hollow, Johnson County, Missouri. May-September 2010.

Date	**5-May-10**				**24-May-10**				**8-Jun-10**				**23-Jun-10**				**14-Jul-10**				**29-Jul-10**				**31-Aug-10**				**14-Sep-10**				
Site	**1**	**2**	**3**	**∑**	**1**	**2**	**3**	**∑**	**1**	**2**	**3**	**∑**	**1**	**2**	**3**	**∑**	**1**	**2**	**3**	**∑**	**1**	**2**	**3**	**∑**	**1**	**2**	**3**	**∑**	**1**	**2**	**3**	**∑**	**∑**
Diptera sp 1	0	0	0	**0**	0	0	0	**0**	0	2	0	**2**	0	0	0	**0**	0	0	1	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	3
Diptera sp 2	2	0	0	**2**	1	0	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	3
Diptera sp 3	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	2	0	**2**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	2
Diptera sp 4	1	0	0	**1**	0	0	0	**0**	0	3	0	**3**	0	1	0	**1**	0	3	0	**3**	0	5	0	**5**	0	2	0	**2**	0	4	0	**4**	19
Diptera sp 5	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Diptera sp 6	1	2	1	**4**	0	1	0	**1**	0	1	10	**11**	0	0	1	**1**	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	18
Diptera sp 7	0	0	0	**0**	1	2	0	**3**	0	0	0	**0**	0	0	1	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	4
Diptera sp 8	1	0	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Diptera sp 9	0	0	0	**0**	0	0	0	**0**	1	0	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Diptera sp 10	2	2	0	**4**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	4
Diptera sp 11	1	0	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Diptera sp 12	1	0	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Diptera sp 13	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1	0	0	**1**	0	0	0	**0**	1
Diptera sp 14	0	0	0	**0**	0	0	0	**0**	0	0	2	**2**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	2
Diptera sp 15	1	0	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Diptera sp 16	3	0	0	**3**	0	2	0	**2**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	5
Diptera sp 17	1	0	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Diptera sp 18	1	0	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Diptera sp 19	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Diptera sp 20	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Diptera sp 21	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	1
Diptera sp 22	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	1
Diptera sp 23	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1	0	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Diptera sp 24	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1	0	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Diptera sp 25	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Diptera sp 26	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Diptera sp 27	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Diptera sp 28	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1	0	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Diptera sp 29	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Diptera sp 30	0	0	0	**0**	0	0	0	**0**	0	0	1	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Diptera sp 31	1	0	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Diptera sp 32	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Diptera sp 33	0	0	0	**0**	0	0	0	**0**	0	0	1	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Diptera sp 34	0	0	0	**0**	0	0	2	**2**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	2
Diptera sp 35	0	0	0	**0**	0	0	1	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Diptera sp 36	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	1
Diptera sp 37	1	1	0	**2**	0	0	0	**0**	0	0	1	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	3

Appendix B.4 Hemiptera collection data for Cave Hollow, Johnson County, Missouri. May-September 2010.

Date	5-May-10				24-May-10				8-Jun-10				23-Jun-10				14-Jul-10				29-Jul-10				31-Aug-10				14-Sep-10				
Site	**1**	**2**	**3**	∑	**1**	**2**	**3**	∑	**1**	**2**	**3**	∑	**1**	**2**	**3**	∑	**1**	**2**	**3**	∑	**1**	**2**	**3**	∑	**1**	**2**	**3**	∑	**1**	**2**	**3**	∑	∑
Cicadellidae sp 8	1	0	0	**1**	0	0	1	**1**	1	3	1	**5**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	7
Cicadellidae sp 13	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Cicadellidae sp 14	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	2
Cicadellidae sp 15	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1	0	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Cicadellidae sp 16	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	2	0	**2**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	2
Cicadellidae sp 17	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1	0	0	**1**	0	0	0	**0**	1
Cicadellidae sp 18	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Cicadellidae sp 19	0	2	0	**2**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	2
Cicadellidae sp 20	1	0	0	**1**	1	0	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	2
Cicadellidae sp 21	0	0	0	**0**	1	0	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Cicadellidae sp 22	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Cicadellidae sp 23	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Cicadellidae sp 24	0	0	0	**0**	1	0	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Cicadellidae sp 25	0	0	0	**0**	0	0	0	**0**	1	0	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Cicadellidae sp 26	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Cicadellidae sp 27	0	0	0	**0**	0	0	0	**0**	1	0	0	**1**	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	2
Cicadellidae sp 28	0	0	0	**0**	2	1	0	**3**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	3
Cicadellidae sp 29	0	0	0	**0**	3	2	0	**5**	1	0	0	**1**	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	7
Cicadellidae sp 30	5	0	0	**5**	0	2	0	**2**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	7
Cicadellidae sp 31	0	0	0	**0**	0	0	0	**0**	4	0	0	**4**	0	6	0	**6**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	11

Appendix B.4 Cont'd Hemiptera collection data for Cave Hollow, Johnson County, Missouri. May-September 2010.

Date	**5-May-10**				**24-May-10**				**8-Jun-10**				**23-Jun-10**				**14-Jul-10**				**29-Jul-10**				**31-Aug-10**				**14-Sep-10**				
Site	**1**	**2**	**3**	∑	**1**	**2**	**3**	∑	**1**	**2**	**3**	∑	**1**	**2**	**3**	∑	**1**	**2**	**3**	∑	**1**	**2**	**3**	∑	**1**	**2**	**3**	∑	**1**	**2**	**3**	∑	∑
Agallia sp 1	0	0	1	**1**	1	0	0	**1**	0	0	0	**0**	1	1	0	**2**	1	3	2	**6**	0	1	0	**1**	0	0	0	**0**	0	1	0	**1**	12
Draeculacephala mollipes	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	2
Jalysus sp 1	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	2
Phylegyas abbreviatus	0	0	0	**0**	2	4	0	**6**	0	0	0	**0**	0	1	0	**1**	0	2	0	**2**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	9
Euschistus servus	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	1	**1**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	2
Euschistus variolus	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	0	0	1	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	2
Thyanta custator	0	0	0	**0**	0	0	0	**0**	0	0	1	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Harmostes sp 1	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	1	1	**2**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	2
Corythucha sp 1	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1	0	0	**1**	0	0	0	**0**	1
Zelus sp 1	1	0	0	**1**	0	0	0	**0**	0	0	0	**0**	3	0	1	**4**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	6
Miridae sp 2	0	0	0	**0**	1	0	0	**1**	0	0	0	**0**	0	0	1	**1**	0	1	1	**2**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	4
Miridae sp 3	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Campylenchia latipes	0	0	0	**0**	0	0	0	**0**	0	24	8	**32**	1	5	11	**17**	0	3	1	**4**	0	1	0	**1**	0	0	0	**0**	0	1	0	**1**	55
Entylia bactiana	1	0	1	**2**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	2
Micrutalis calva	0	0	0	**0**	0	0	0	**0**	0	0	1	**1**	0	0	2	**2**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	4
Lepyronia quadrangularis	0	0	0	**0**	0	0	0	**0**	3	5	0	**8**	1	3	1	**5**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	14
Acanalonia bivitatta	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Scolops sp 1	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	1	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Liburniella ornata	0	0	0	**0**	0	0	0	**0**	0	0	1	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Pissonotus delicatus	47	4	10	**61**	1	0	7	**8**	5	3	2	**10**	58	1	10	**69**	5	4	1	**10**	4	6	0	**10**	40	0	0	**40**	23	2	0	**25**	233

Appendix B.5 Arachnid collection data for Cave Hollow, Johnson County, Missouri. May-September 2010.

Date	**5-May-10**				**24-May-10**				**8-Jun-10**				**23-Jun-10**				**14-Jul-10**				**29-Jul-10**				**31-Aug-10**				**14-Sep-10**				
Site	**1**	**2**	**3**	∑	**1**	**2**	**3**	∑	**1**	**2**	**3**	∑	**1**	**2**	**3**	∑	**1**	**2**	**3**	∑	**1**	**2**	**3**	∑	**1**	**2**	**3**	∑	**1**	**2**	**3**	∑	∑
Spider sp 1	3	7	4	**14**	6	0	0	**6**	1	0	1	**2**	1	3	1	**5**	0	0	2	**2**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	29
Spider sp 2	1	0	0	**1**	1	0	0	**1**	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	4
Spider sp 3	2	0	2	**4**	1	0	0	**1**	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	1	0	0	**1**	0	0	0	**0**	1	0	0	**1**	8
Spider sp 4	0	2	0	**2**	0	0	0	**0**	0	2	0	**2**	0	1	0	**1**	0	1	0	**1**	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	7
Spider sp 5	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Spider sp 6	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Spider sp 7	0	2	0	**2**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	2
Spider sp 8	0	0	0	**0**	0	1	0	**1**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	2
Spider sp 9	0	0	0	**0**	0	0	0	**0**	1	0	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Spider sp 10	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Spider sp 11	0	0	0	**0**	0	0	0	**0**	0	0	2	**2**	2	3	2	**7**	15	7	2	**24**	2	4	0	**6**	3	2	0	**5**	3	2	0	**5**	49
Spider sp 12	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	1

APPENDIX C

Appendix C.1 Hymenoptera collection data for Racehorse Lake, Johnson County, Missouri. May-September 2010.

Date	**5-May-10**				**24-May-10**				**8-Jun-10**				**23-Jun-10**				**14-Jul-10**				**29-Jul-10**				**31-Aug-10**				**14-Sep-10**				
Site	**1**	**2**	**3**	**∑**	**1**	**2**	**3**	**∑**	**1**	**2**	**3**	**∑**	**1**	**2**	**3**	**∑**	**1**	**2**	**3**	**∑**	**1**	**2**	**3**	**∑**	**1**	**2**	**3**	**∑**	**1**	**2**	**3**	**∑**	**∑**
Formicidae sp 4	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	5	0	**5**	0	0	0	**0**	0	0	0	**0**	5
Formicidae sp 5	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	17	**17**	0	0	0	**0**	1	8	8	**17**	1	0	1	**2**	1	0	0	**1**	37
Formicidae sp 6	1	0	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	1	1	**2**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	3
Halictidae sp 1	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1	0	0	**1**	1	0	0	**1**	0	0	0	**0**	0	0	0	**0**	2
Halictidae sp 2	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1	0	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Halictidae sp 3	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Hymenoptera sp 20	0	0	0	**0**	0	0	0	**0**	1	0	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Hymenoptera sp 21	0	0	0	**0**	0	0	0	**0**	1	2	0	**3**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	3
Hymenoptera sp 22	0	0	0	**0**	0	0	1	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Hymenoptera sp 23	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Hymenoptera sp 24	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1	0	0	**1**	0	0	0	**0**	1
Hymenoptera sp 25	0	0	0	**0**	0	0	0	**0**	0	2	0	**2**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	2
Hymenoptera sp 26	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	2	1	0	**3**	0	0	0	**0**	4
Hymenoptera sp 27	3	0	0	**3**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	3
Hymenoptera sp 28	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	1	**1**	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	2
Hymenoptera sp 29	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1	0	0	**1**	0	0	0	**0**	1
Hymenoptera sp 30	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Hymenoptera sp 31	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1	0	0	**1**	0	0	0	**0**	1
Hymenoptera sp 32	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	1	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Hymenoptera sp 33	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	2

Appendix C.1 Cont'd Hymenoptera collection data for Racehorse Lake, Johnson County, Missouri. May-September 2010.

Date	5-May-10				24-May-10				8-Jun-10				23-Jun-10				14-Jul-10				29-Jul-10				31-Aug-10				14-Sep-10				
Site	**1**	**2**	**3**	∑	**1**	**2**	**3**	∑	**1**	**2**	**3**	∑	**1**	**2**	**3**	∑	**1**	**2**	**3**	∑	**1**	**2**	**3**	∑	**1**	**2**	**3**	∑	**1**	**2**	**3**	∑	∑
Hymenoptera sp 34	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1	1	0	**2**	0	0	0	**0**	2
Hymenoptera sp 35	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Hymenoptera sp 36	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1	0	0	**1**	0	0	0	**0**	0	0	0	**0**	1
Hymenoptera sp 37	0	0	0	**0**	0	0	0	**0**	1	0	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Hymenoptera sp 38	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1	0	1	**2**	0	0	1	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	3
Hymenoptera sp 39	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	1	1	**2**	0	0	1	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	3
Hymenoptera sp 40	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	1
Hymenoptera sp 41	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	1
Hymenoptera sp 42	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	1
Hymenoptera sp 43	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	1
Hymenoptera sp 44	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1	0	0	**1**	0	0	0	**0**	1
Hymenoptera sp 45	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	1	**1**	0	0	0	**0**	1
Hymenoptera sp 46	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	1	**1**	0	0	0	**0**	0	0	0	**0**	1
Hymenoptera sp 47	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	1	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Hymenoptera sp 48	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Hymenoptera sp 49	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1	0	0	**1**	0	0	0	**0**	1
Hymenoptera sp 50	0	0	0	**0**	0	0	0	**0**	0	0	1	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Hymenoptera sp 51	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	1	**1**	1
Hymenoptera sp 52	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	1	1	**2**	0	0	0	**0**	0	0	0	**0**	2
Hymenoptera sp 53	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1	0	0	**1**	0	0	0	**0**	1
Hymenoptera sp 54	0	0	0	**0**	0	0	0	**0**	0	0	1	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Hymenoptera sp 55	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	1	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Hymenoptera sp 56	0	0	0	**0**	0	0	0	**0**	1	0	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Hymenoptera sp 57	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	1	**1**	0	0	0	**0**	0	0	0	**0**	1
Hymenoptera sp 60	0	0	0	**0**	0	0	0	**0**	1	0	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Hymenoptera sp 61	0	0	0	**0**	0	0	0	**0**	1	0	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1

Appendix C.2 Coleoptera collection data for Racehorse Lake, Johnson County, Missouri. May-September 2010.

Date	**5-May-10**				**24-May-10**				**8-Jun-10**				**23-Jun-10**				**14-Jul-10**				**29-Jul-10**				**31-Aug-10**				**14-Sep-10**				
Site	**1**	**2**	**3**	∑	**1**	**2**	**3**	∑	**1**	**2**	**3**	∑	**1**	**2**	**3**	∑	**1**	**2**	**3**	∑	**1**	**2**	**3**	∑	**1**	**2**	**3**	∑	**1**	**2**	**3**	∑	∑
"Apion" sensu lato	0	3	0	**3**	0	0	0	**0**	0	0	2	**2**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	5
Rhinocyllus conicus Froelicl	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Sitona lepidus Gyllenhal	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Cylindrocopturus adspersus	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Sitona cylindricollis (Fahra	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Tychius meliloti Stephens	0	0	1	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Smicronyx amoenus (Say)	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1	0	0	**1**	0	0	0	**0**	1
Staphylinidae sp 1	9	0	0	**9**	0	0	0	**0**	0	0	1	**1**	0	1	1	**2**	0	1	0	**1**	0	1	0	**1**	0	3	2	**5**	0	0	0	**0**	19
Diabrotica unidecimapuncta	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Disonycha pennsylvannica	2	4	2	**8**	0	0	0	**0**	1	1	0	**2**	0	0	0	**0**	3	2	0	**5**	3	0	1	**4**	3	0	0	**3**	0	0	0	**0**	22
Chrysomelidae sp 4	0	0	0	**0**	0	0	0	**0**	0	0	1	**1**	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	2
Chauliognathus sp 1	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	2
Carabidae sp 1	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Coleoptera sp 12	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	1	1	0	**2**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	3
Coleoptera sp 13	0	0	0	**0**	0	0	0	**0**	0	0	1	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Coleoptera sp 14	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Coleoptera sp 15	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	1	**1**	0	0	0	**0**	0	0	0	**0**	1
Coleoptera sp 16	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	3	0	**3**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	3
Coleoptera sp 17	0	0	1	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Coleoptera sp 18	0	0	0	**0**	1	0	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Coleoptera sp 19	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Coleoptera sp 20	0	0	1	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Coleoptera sp 21	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	1	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Coleoptera sp 22	0	0	0	**0**	0	0	2	**2**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	2
Coleoptera sp 23	0	0	1	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Coleoptera sp 24	0	0	0	**0**	1	0	0	**1**	1	0	0	**1**	0	2	0	**2**	0	0	0	**0**	0	0	0	**0**	0	2	0	**2**	0	0	0	**0**	6
Coleoptera sp 25	0	0	0	**0**	0	0	0	**0**	0	0	1	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1

Appendix C.3 Diptera collection data for Racehorse Lake, Johnson County, Missouri. May-September 2010.

Date	5-May-10				24-May-10				8-Jun-10				23-Jun-10				14-Jul-10				29-Jul-10				31-Aug-10				14-Sep-10				
Site	**1**	**2**	**3**	∑	**1**	**2**	**3**	∑	**1**	**2**	**3**	∑	**1**	**2**	**3**	∑	**1**	**2**	**3**	∑	**1**	**2**	**3**	∑	**1**	**2**	**3**	∑	**1**	**2**	**3**	∑	∑
Diptera sp 38	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	1
Diptera sp 39	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1	0	0	**1**	1
Diptera sp 40	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1	1	0	**2**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	2
Diptera sp 41	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	1
Diptera sp 42	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	2
Diptera sp 43	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	1	**1**	0	0	0	**0**	0	1	0	**1**	2
Diptera sp 44	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1	0	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Diptera sp 45	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1	1	0	**2**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	3
Diptera sp 46	0	0	0	**0**	0	0	0	**0**	6	0	0	**6**	0	0	0	**0**	1	0	0	**1**	0	0	0	**0**	1	0	0	**1**	0	0	0	**0**	8
Diptera sp 47	0	0	0	**0**	1	0	0	**1**	0	0	0	**0**	1	0	0	**1**	0	0	0	**0**	0	0	0	**0**	1	0	0	**1**	0	0	0	**0**	3
Diptera sp 48	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	1
Diptera sp 49	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Diptera sp 50	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	3	0	**3**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	3
Diptera sp 51	0	0	0	**0**	0	0	0	**0**	2	23	11	**36**	0	2	16	**18**	0	15	0	**15**	1	66	54	**121**	0	2	0	**2**	1	1	0	**2**	194
Diptera sp 52	1	0	0	**1**	0	0	0	**0**	0	1	0	**1**	2	1	0	**3**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	5
Diptera sp 53	0	0	1	**1**	0	1	1	**2**	0	0	0	**0**	0	1	0	**1**	1	0	0	**1**	0	0	0	**0**	0	0	1	**1**	1	1	2	**4**	10
Diptera sp 54	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Diptera sp 55	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Diptera sp 56	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Diptera sp 57	1	0	0	**1**	0	0	1	**1**	1	0	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1	0	0	**1**	0	0	0	**0**	4
Diptera sp 58	0	0	0	**0**	1	0	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Diptera sp 59	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	1	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Diptera sp 60	0	0	0	**0**	0	0	0	**0**	1	0	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Diptera sp 61	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	1
Diptera sp 62	0	0	1	**1**	0	0	0	**0**	0	0	1	**1**	0	7	0	**7**	0	0	1	**1**	0	3	0	**3**	2	2	2	**6**	1	0	0	**1**	20
Diptera sp 63	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	2	0	**2**	0	0	0	**0**	0	0	0	**0**	2
Diptera sp 64	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	2	0	**2**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	2

Appendix C.3 Cont'd Diptera collection data for Racehorse Lake, Johnson County, Missouri. May-September 2010.

Date	**5-May-10**				**24-May-10**				**8-Jun-10**				**23-Jun-10**				**14-Jul-10**				**29-Jul-10**				**31-Aug-10**				**14-Sep-10**				
Site	**1**	**2**	**3**	**∑**	**1**	**2**	**3**	**∑**	**1**	**2**	**3**	**∑**	**1**	**2**	**3**	**∑**	**1**	**2**	**3**	**∑**	**1**	**2**	**3**	**∑**	**1**	**2**	**3**	**∑**	**1**	**2**	**3**	**∑**	**∑**
Diptera sp 65	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Diptera sp 66	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1	0	0	**1**	0	0	1	**1**	0	0	0	**0**	0	0	0	**0**	2
Diptera sp 67	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	1	**1**	0	0	0	**0**	0	0	0	**0**	1
Diptera sp 68	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	1
Diptera sp 69	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	1	**1**	0	0	0	**0**	0	0	0	**0**	1
Diptera sp 70	0	0	0	**0**	0	0	0	**0**	0	0	1	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Diptera sp 71	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	1	0	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	2
Diptera sp 72	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1	0	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Diptera sp 73	0	0	0	**0**	0	0	0	**0**	1	0	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Diptera sp 74	0	0	1	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Diptera sp 75	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	1
Diptera sp 76	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	1
Diptera sp 77	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Diptera sp 78	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	1
Diptera sp 79	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1	0	0	**1**	0	0	0	**0**	1
Diptera sp 80	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	1	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Diptera sp 81	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	1	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Diptera sp 82	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Diptera sp 83	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Diptera sp 84	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Diptera sp 85	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	1	**1**	0	0	0	**0**	0	0	0	**0**	1
Diptera sp 86	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	1	**1**	0	0	0	**0**	0	0	0	**0**	1
Diptera sp 87	0	0	0	**0**	0	0	0	**0**	1	0	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Diptera sp 88	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Diptera sp 89	0	0	0	**0**	0	5	37	**42**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	42
Diptera sp 90	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	1	**1**	0	0	0	**0**	0	0	0	**0**	1
Diptera sp 91	0	0	0	**0**	0	0	0	**0**	1	0	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Diptera sp 92	0	0	0	**0**	0	0	0	**0**	1	0	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Diptera sp 93	0	0	0	**0**	0	0	0	**0**	0	0	1	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Diptera sp 94	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1	0	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Diptera sp 95	0	0	0	**0**	0	1	1	**2**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	2
Diptera sp 96	0	0	0	**0**	0	0	0	**0**	1	0	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Diptera sp 97	0	0	0	**0**	0	0	0	**0**	1	0	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Diptera sp 98	1	0	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Diptera sp 99	0	0	0	**0**	0	0	0	**0**	0	6	0	**6**	2	0	0	**2**	1	0	0	**1**	0	0	0	**0**	0	0	0	**0**	1	0	0	**1**	10

Appendix C.4 Hemiptera collection data for Racehorse Lake, Johnson County, Missouri. May-September 2010.

Date	5-May-10				24-May-10				8-Jun-10				23-Jun-10				14-Jul-10				29-Jul-10				31-Aug-10				14-Sep-10				
Site	**1**	**2**	**3**	**∑**	**1**	**2**	**3**	**∑**	**1**	**2**	**3**	**∑**	**1**	**2**	**3**	**∑**	**1**	**2**	**3**	**∑**	**1**	**2**	**3**	**∑**	**1**	**2**	**3**	**∑**	**1**	**2**	**3**	**∑**	**∑**
Cicadellidae sp 1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	2	2	0	1	0	1	0	0	0	0	0	1	0	1	5
Cicadellidae sp 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2	0	0	0	0	0	0	0	0	2
Cicadellidae sp 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	2	1	0	3	0	0	0	0	0	0	0	0	4
Cicadellidae sp 4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	2	0	0	0	0	0	0	0	0	2
Cicadellidae sp 5	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Cicadellidae sp 6	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Cicadellidae sp 7	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Cicadellidae sp 8	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Cicadellidae sp 9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1
Cicadellidae sp 10	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Cicadellidae sp 11	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Cicadellidae sp 12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
Cicadellidae sp 32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Cicadellidae sp 33	0	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	3
Agallia sp 1	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Draeculacephala mollipes	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Belastoma sp 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
Hydrometra sp 1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	2
Corimelanas sp 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	1
Oedancala sp 1	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2	0	4	0	4	0	0	0	0	0	0	0	0	0	0	0	0	6
Ozophora sp 1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	1	1	2	7	6	15	0	0	0	0	0	0	0	0	17
Miridae sp 1	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Isodelphax basivitta	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	2
Pissonotus piceus	0	1	0	1	0	1	0	1	1	1	0	2	0	3	0	3	6	3	1	10	2	3	2	7	16	0	7	23	12	1	0	13	60

Appendix C.5 Arachnid collection data for Racehorse Lake, Johnson County, Missouri. May-September 2010.

Date	**5-May-10**				**24-May-10**				**8-Jun-10**				**23-Jun-10**				**14-Jul-10**				**29-Jul-10**				**31-Aug-10**				**14-Sep-10**				
Site	**1**	**2**	**3**	∑	**1**	**2**	**3**	∑	**1**	**2**	**3**	∑	**1**	**2**	**3**	∑	**1**	**2**	**3**	∑	**1**	**2**	**3**	∑	**1**	**2**	**3**	∑	**1**	**2**	**3**	∑	∑
Spider sp 13	3	2	3	**8**	2	0	0	**2**	0	0	2	**2**	0	3	0	**3**	0	2	0	**2**	0	1	1	**2**	0	0	0	**0**	1	2	0	**3**	22
Spider sp 14	2	0	0	**2**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	2
Spider sp 15	3	5	7	**15**	0	0	0	**0**	0	3	3	**6**	9	0	3	**12**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	33
Spider sp 16	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Spider sp 17	0	0	0	**0**	0	0	0	**0**	4	1	0	**5**	8	9	3	**20**	1	12	11	**24**	4	0	5	**9**	5	10	7	**22**	10	4	7	**21**	101
Spider sp 18	0	0	0	**0**	0	0	0	**0**	3	0	0	**3**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	3
Spider sp 19	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	0	1	0	**1**	1	0	0	**1**	2	0	0	**2**	0	0	1	**1**	6
Spider sp 20	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	1	**1**	0	0	0	**0**	2
Spider sp 21	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1
Spider sp 22	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	1	**1**	0	0	1	**1**	1	1	0	**2**	0	0	0	**0**	0	0	0	**0**	4
Spider sp 23	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	2	0	0	**2**	1	0	1	**2**	0	0	0	**0**	0	0	0	**0**	4
Spider sp 24	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	1
Spider sp 25	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	1	0	0	**1**	1