DO ARTHROPOD ABUNDANCE AND DIVERSITY DIFFER BETWEEN GRASS HABITATS VARYING IN HEIGHT?

BY

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Abstract

Grassland bird species are known to select breeding sites based on height of vegetation. To determine whether or not such habitat selection may be related to the underlying prey base, this experiment compared arthropod abundance and diversity between replicate grassland plots that differed in height. A total of twelve 100 x 100 m plots were randomly assigned one of two treatments. During the 2003 bird breeding and fledgling season, half of the plots were allowed to grow to their natural height, while the other half were periodically mowed to limit their height to 25 cm. Arthropods were sampled from each plot six times with sweep netting. A total of 4,541 individual arthropods were captured, identified and biomass was determined. A multivariate repeated measures analysis of variance was used to test for significance between grass height treatments at specific sampling dates, and to account for repeated sampling of the same plots over time. An independent samples t-test was used to test for significance between sweep samples of mowed and unmowed plots for *Conocephalus strictus, Melanoplus* and *Athysanus argentarius*. This study did find slight differences between the arthropod abundance in mowed and unmowed plots. The grassland birds that were breeding and raising their young in this old field study site could have diminished the difference to a level where no significant difference was detected.

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Introduction

As early as 1820, the native prairie in Illinois was replaced by a patchwork of small farms that produced livestock, corn, small grains, and forage crops. In the 1900s, forage crops consisted of native vegetation which was entirely replaced by non-native cool-season grasses and legumes introduced from Europe only 20 years later (Warner 1994). Loss and degradation of grassland habitat persisted as diversified farming gave way to intensive cropping (Vickery and Herkert 2001). Thus, as this trend continues, conserving the biological diversity of the grasslands is a serious, even vital concern (Samson and Knopf 1994). Grassland bird populations, for example, have declined in the last three decades more than any other cohort of birds in North America (Herkert, 1995; Peterjohn and Sauer, 1999).

The North American Breeding Bird Survey (BBS) was initiated in eastern North America in 1966. By 1968, survey routes were established across the continental United States and southern Canada. More than 2,800 routes have been surveyed annually since 1980. Recent analysis of BBS data indicate negative population trends for most grassland bird species between 1966 and 1996. Common causes of decline of all grassland bird species are the destruction, fragmentation, and degradation of habitat (Peterjohn and Sauer 1999). The loss and degradation of habitat resulting from intensive farming in Illinois (Warner 1994) has significantly influenced populations of grassland bird species such as the Henslow's sparrow *(Ammodramus henslowii),* savannah sparrow *(Passerculus sandwichensis)*, grasshopper sparrow *(Ammodramus savannarum),* eastern meadowlark *(Sturnella magna)*, and bobolink *(Dolichonyx oryzivorus)*.

In order to stabilize or increase grassland bird populations through conservation and management of grasslands, an understanding of bird habitat preferences is essential (Cody 1985). In 1969 Wiens developed a method to describe habitat preferences within a single grassland bird community. Wiens described environmental components called "recognition stimuli" that contribute to the habitat's structural organization and composition that lead to site selection preferences. The features and measures Wiens considered in the description of avian grassland habitats specifically: "vegetation [type (general form, stem, leaf, height),

distribution (percent cover, dispersion, density)]; light; substrate [topography (slope, direction, type altitude, special features), soil (type, color, composition, moisture), litter (depth, percent cover, composition)]; and special features [water, roads, wires, poles or posts, structures]; are still used today for habitat characterization (Fisher and Davis 2010).

In general the bird species in Wien's study were found to select sites based on "richness" of habitats described and quantified in terms of density and height of vegetation, and cover and depth of litter. The western meadowlark *(Sturnella neglecta),* and vesper sparrow *(Pooecetes gramineus),* preferred lawn-like cover; the savannah sparrow, grasshopper sparrow, and eastern meadowlark selected intermediate vegetation density and height with 45% of the vegetation within their occupied habitat being between 5-12 cm high; and the bobolink and Henslow's sparrow preferred comparatively the greatest vertical vegetation density and litter depth.

In addition to richness of habitat as described by Wiens, a complex combination of ecological elements may be driving the process of habitat selection. Studies suggest that many grassland bird species are area sensitive (Ribic et al. 2009) and respond not only to patch size but to such elements as the total amount and nearness of hedgerows (Ribic and Sample 2001). Landscape composition described in terms of types of edges (Fletcher and Koford 2002) as well as landscape structure at a large scale of 800-ha may also influence habitat use of birds (Murry et al. 2008).

Because many grassland bird species are largely insectivorous during the breeding season (Ehrlich et al. 1988, Kaspari and Joern 1993, McIntyre and Thompson 2003), the abundance and diversity of arthropod prey may affect habitat quality and could play an important role in site selection. In the deciduous forests of the New Jersey Pine Barrens, the density of foliage-gleaning birds was highly correlated with arthropod biomass (Brush and Stiles 1986) as birds shifted to areas where food supply was greater. Although habitat associations of forest birds are often assessed using foliage volume, this, indeed, may be an indirect measure of habitat quality in general and, in particular, of food availability.

The relationship between grassland bird species and habitat richness may be partially explained by arthropods' responses to maturation and senescence of vegetation.
The taxonomic diversity of two Orders of insects, Heteroptera and adult Coleoptera, was found to correlate positively with the increasing structural diversity of plants in sites comprised of young fields, old fields, and woodland in various stages of a secondary succession (Southwood et al. 1979). Arthropods are also known to respond to vegetation structure. The overall abundance of arthropods along with the densities of a number of selected species of arthropods were consistently higher in the structurally complex components of a grassland habitat than in those components that were less structurally complex (Dennis et al 1998). The grasslands of intermediate stature selected by grasshopper sparrows and savannah sparrows, one might hypothesize, contain arthropod prey that appeals to these bird species. As a consequence, the arthropod prey base in short, intermediate, and tall grasslands may well differ sufficiently to contribute to grassland bird habitat selection.

This study compares arthropod abundance (biomass) and diversity between grassland sites of shorter and taller vegetation to determine whether arthropod prey contributes to habitat selection of grasshopper sparrows and savannah sparrows. Because grassland birds are known to respond to plant taxonomic composition (Wiens 1969, Herkert 1993, Sample and Mossman 1997) and seral stage (Fritcher et al. 2004), an old field was selected to provide a site where variables such as floristic characteristics and seral stage were constant and could be factored out. Within a study area, the abundance and diversity of arthropods were measured in a grassland that contained shorter and taller vegetation. Mowing was used to maintain the shorter vegetation.

Materials and Methods

Study site

This study was conducted within the Midewin National Tallgrass Prairie located near Wilmington, in Will County, Illinois. Midewin National Tallgrass Prairie was established in 1996 and is the first national tallgrass prairie in the country. The Illinois Land Conservation

Act Public Law 104-106 created the Midewin National Tall Grass Prairie and designated the transfer of 19,165 acres of land in Illinois from the U.S. Army to the U.S. Department of Agriculture Forest Service. Midewin National Tallgrass Prairie is administered by the U.S. Forest Service, in cooperation with the Illinois Department of Natural Resources.

The study area selected within the Midewin National Tallgrass Prairie is characterized as an old field. Dominant grasses include *Bromus inermis,* a non-native cool-season grass, and a variety of other grass species along with remnant native forb species. During the bird breeding and fledgling season, this field is typically inhabited by such grassland bird species as bobolink; eastern meadowlark; grasshopper sparrow; and upland sand piper *(Bartramia longicauda)*. The field at the study site contains six 100-m radius bird census points (C.J.Whelan, Illinois Natural History Survey, Institute of Natural Resource Sustainability).

Experimental design

In March 2003, a 400 x 300 m rectangular area within the selected grassland of the old field was divided into twelve 100 x 100 m plots (Fig. 1). Each 100 x 100 m plot was randomly assigned to be either mowed or unmowed (control), resulting in six replicate plots of each treatment. Mowing services were provided by Midewin National Tallgrass Prairie. This method of simulating structure was selected because of its affordability and practicality.

During the bird breeding through fledgling season of 2003, 15 May through the end of July, sweep net samples were made on each of seven dates. The selected old field had been mowed to a uniform height of 15 cm the preceding fall. During the study, vegetation in the mowed plots was maintained at a height of 15-25 cm. Control plots were left unmowed during the study. Mowing creates a disturbance of the arthropod community and causes some specimens to emmigrate (Chambers and Samways 1998, Dunwiddie 1991, Haskins and Shaddy 1986). Sweep net samples were taken several days before and after the initial mowing to document the effect of mowing on the arthropod community. To mitigate the potential disturbance caused by mowing, sweep net samples were to be taken no less than five days after mowing thus allowing time for the arthropods to re-establish population equilibria within each plot.

Because arthropods respond to the floristic characteristics of their habitat (Southwood et al. 1979), plant species composition was established for each of the study plots during the month of July. Along each side of a 25 x 25 m square centered in each of the twelve 100 x 100 m plots, an area of 0.25 m^2 was randomly selected to identify plant species and estimate their percent cover. The percent ground cover at each sample area was determined on a non-overlapping basis *i.e.,* the sum at a sample area could not exceed 100% (McIntyre and Thompson 2003). This modified method of plant sampling was not intended as an accurate way to determine plant composition for statistical comparison but rather to provide an estimate of relative sameness of plots within the old field. Plant composition for all plots in the study consisted of cool season grasses including bluegrass (*Poa pratensis*), bentgrass (*Agrostis alba*), bromegrass (*Broumus inermis*), horsetail (*Equisetum* sp.), Scribner's panic grass (*Panicum scribnerii*), and Timothy grass (*Phleum pratense*). Grasses were the dominant plants within this grassland study area. These grasses made up between 75-95% of the plant ground cover composition within the sample area. Other plant species included: black-eyed susan (*Rudbeckia hirta*), deptford pink (*Dianthus*), goldenrod (*Solidago altissimum* and *S. rigida*), hoary vervain (*Verbena stricta)*, common milkweed (*Asclepias syriaca*), horse nettle (*Solanum carolinense*), wild bergamot (*Monarda fistulosa*), cinquefoil (*Potentilla* sp.), ragweed (*Ambrosia artemisiifolia*), wild carrot (*Dauca carota*), rose (*Rosa* sp.), yarrow (*Achillea millefolium*). Vegetative litter and several unidentified sedges contributed to the plant composition as well.

Mowing Regime

Mowing was conducted twice during the study, on 5 June and 17 July. Mowing took place at least five days prior to arthropod sampling dates.

Sampling the Arthropods

During the 2003 bird breeding and fledgling season, 15 May through the end of July, sweep net sampling of arthropods was conducted on seven dates: 16 May, 12 June, 20 June, 2 July, 12 July, 22 July, and 2 August. To minimize the effect of arthropods migrating vertically within the canopy at different times of day, samples were taken consistently between 10:00 and 13:00, after the dew had evaporated, during days of little or no cloud cover, and when the

wind speed was below 0.5 knots. Plots were sampled in random order on each sampling date.

A sweep net was used in this study to sample the arthropods from each plot. The sweep net technique adequately compares the abundance of all arthropods among locations because the inherent biases of the method are relatively consistent (Cooper and Whitmore 1990). 100 sweeps were made along a line between opposite corners of a 25 x 25 m section centered within each plot. The sweep net had a 38 cm diameter hoop to which a muslin net was attached. Sweep samples were taken at least five days after mowing.

The first study in Illinois to determine food habitats of seven grassland bird species including grasshopper sparrows and savanna sparrows concluded these birds selected insects that were > 10 mm in length (Kobal et al 1997). Therefore, any arthropod less than 5 mm in length was not included in the study. Arthropod samples were stored in 80 percent ethanol and then identified, counted, oven-dried at 65 degrees C, and weighed (Fowler et al 1991). Arthropod abundance was converted into biomass and was then quantified as the average dry weight of each species. The total mass of all species over 5 mm in length was determined for each plot on the specific sampling date.

Absolute abundance (density)

To compare arthropod abundance counts obtained by the sweep net technique with the numbers of specimens of each species that actually occurred in each plot, on July 22 and concurrent with one of the normal sweep net sampling dates, a one-time absolute abundance count was conducted for each plot. A rigidly framed 60 cm cube (BioQuip BugDorm-3) with fine mesh sides and tops was used to first retain all arthropods 5 mm in length and larger, in and then purge from, a 60 cm x 60 cm area in each of the twelve plots. To do this, a cube was abruptly placed over the vegetation within the central 25 m X 25 m of each plot in a random manner, and all visible arthropods on the inside of the cube were removed with an aspirator. The vegetation within the cube was then removed and all specimens >5 mm in length found clinging to the vegetation were collected. Finally, the top centimeter of soil was carefully gone over and the larger (>5 mm) arthropods encountered either on the ground or in

that top centimeter of soil were removed. All arthropods were placed in 80 percent ethanol appropriately labeled as to sampling method, plot number, and date and thereafter dealt with in the same manner as the arthropods from the sweep net samples.

Density is often expressed as numbers of specimens per unit area (Cooper and Whitmore 1990). In this study absolute abundance is expressed as arthropod biomass in grams per square meter (g/m^2) using the following equation:
mass/(0.6 m x 0.6 m)

Arthropod identification

Arthropods were identified to family by using taxonomic keys (Borror et al. 1989) and, when possible, to genus and species with help from taxonomic specialists and reference collections housed at the Illinois Natural History Survey (INHS). Specialists who identified specimens for this study included C. Dietrich and M.E. Irwin (University of Illinois, Champaign-Urbana, Illinois); R. Panzer (Northeastern Illinois University, Chicago, Illinois); and F.H. Pascoe (University of St. Francis, Joliet, Illinois).

Data Analysis

Total biomass by Orders and by species

A multivariate repeated measures analysis of variance was used to test for significance within subjects (dates) and between subjects (mowed vs. unmowed), and to account for repeated sampling of the same plots. An independent samples t-test was used to test for significance between sweep samples of mowed and unmowed plots for *Conocephalus strictus, Melanoplus* and *Athysanus argentarius*.

Absolute abundance

A paired samples t-test was used to test for significance between absolute samples and sweep samples.

Diversity

β diversity measures how similar or different habitats or samples are in terms of the variety of species found in them. To measure the similarity between mowed and unmowed plots in terms of the arthropod species found in each treatment, the Sorenson similarity index was used. This index is one of the oldest and most accepted similarity indexes (Magurran 1988):

$C_s = 2j/(a+b)$

where j = the number of species common to both sites and a = the number of species in Site A with b the number of species in Site B. This index is designed to equal one in cases of complete similarity and zero if the sites have no species in common.

By the use of similarity coefficients, the Sorenson index compares pairs of sites such as the mowed and unmowed sites within the old field. Rare species were not the focus of this study, and the Sorenson index used in this comparison was adjusted to count species equally in the equation regardless of whether they were abundant or rare (A.E. Magurran 1988).

Results

A total of 4,541 individual arthropods were collected on the seven sampling dates. The arthropods were sorted into eleven Orders. Lepidoptera was not sorted beyond Order. A total of 38 families and 9 discrete morphofamilies within ten Orders were identified. Within the 38 families, 48 species were identified, while 46 discrete morphospecies were isolated but not identified (Fig. 2). Upon visual inspection, there was little difference between unmowed and mowed plots based on the number of species (Fig. 3a) and the number of families sampled during the study (Fig. 3b).

Because arthropods numbers are influenced by disturbances such as haying, mowing, grazing and burning (Rambo and Faeth 1999, Swengel 2001, Dennis et al 2008), sampling took place at least five days after mowing. Between the first two sampling dates, 16 May and 12 June, arthropod biomass increased three-fold in the mowed plots while it increased six-fold in the unmowed plots (Fig. 4). A mowing took place during that time interval, on 5 June.

Although there was a decrease in biomass in the unmowed plots by the third sampling date on 20 June, biomass continued to increase steadily thereafter in both mowed and unmowed plots as reflected on the forth and fifth sampling dates, 2 July and 12 July. The second and final mowing took place on 17 July. On the post-mowing 22 July sampling date, arthropod biomass in the mowed plots was 33% lower than it was on the pre-mowing 12 July sampling date. However, on 2 August biomass in the mowed plots had surpassed the pre-mowing amount recorded on 12 July, providing a strong signal that the arthropods in the mowed plots had recovered from treatment.

Life cycles of different species of arthropods do not coincide so assemblages change continuously (Chambers and Samways 1998). This was illustrated by the number of individuals of *Metrioptera roeselli* and *Conocephalus strictus* sampled in unmowed plots (Fig. 5a). In unmowed plots, numbers of *Metrioptera roeselli* were greatest in the 12 June sweep sample. On the 20 June sweep sample, numbers of *Metrioptera roeselli* and *Conocephalus strictus* were similar. By 2 Aug, the highest number of *Conocephalus strictus* were collected while no specimens of *Metrioptera roeselli* had been collected. A comparison between unmowed and mowed counts on 22 July and 2 Aug of *Conocephalus strictus* indicates that the numbers of *Conocephalus strictus* were influenced by mowing (Fig. 5b).

Data analysis

Total biomass

A multivariate repeated measures analysis of variance was used to test for significance within subjects (dates) and between subjects (mowed vs. unmowed), and to account for repeated sampling of the same plots. Total biomass (all Orders combined) differed significantly over time (Pillai's Trace = 0.986; df = 6, 5; P = < 0.001) but was independent of treatment (Pillai's Trace = 0.764; df = 6, 5; P = 0.147). When analyzing each individual Order, Orthoptera biomass differed significantly over time (Pillai's trace = 1; df = 6, 1; P = 0.038) but was independent of treatment (Pillai's Trace = 0.992; df = 6, 1; P = 0.163). For all other Orders, multivariate test statistics could not be produced because of insufficient residual degrees of

freedom. In these cases, biomass for each Order was compared and interpreted on each of the seven dates.

Lepidoptera mass in the unmowed plots was one-and-a-half to five times greater than in the mowed plots. The Lepidoptera was the only arthropod Order having a biomass consistently greater in unmowed than in the mowed plots (Fig. 6a).

The Diptera proved to be the only arthropod Order with a biomass in the mowed plots at least two times greater than in the unmowed plots, and this occurred on three of the seven sampling dates; 16 May, 12 July, and 2 August (Fig. 6b). The biomass in both treatments was nearly equal on two of the sampling dates; 20 June and 22 July. Fly mass in unmowed plots was two-fold greater than mowed plots on one sampling date, 12 June and one-third greater on the 2 July sampling date.

Overall, arachnid mass in the unmowed plots was nearly equal to four times greater than in the mowed plots (Fig. 7a), and the Coleoptera mass was half to eleven times greater in unmowed than in mowed plots (Fig. 7b). The mass of the Hemiptera was two-thirds to five times greater in unmowed than in mowed plots (Fig. 8a). The Homoptera mass in unmowed was nearly equal to three times greater than in the mowed plots (Fig. 8b), and the Hymenoptera mass was one-third to three times greater in unmowed than in mowed plots (Fig. 9a.). The mass of the Orthoptera was four-fifths of to seven times greater in unmowed than in mowed plots (Fig. 9b).

Diversity

For each of the seven sampling dates, the Sorenson index was calculated based on the number of species found in unmowed compared to mowed plots (Fig. 10). The unmowed and mowed plots were slightly more similar than they were dissimilar.

Absolute abundance

On 22 July, samples were taken in all twelve plots to estimate absolute abundance in terms of grams per square meter (Fig 11).

Five species made up 85% of the total biomass of arthropods (Fig. 12a): *Melanoplus*, *Conocephalus strictus (Scudder)*, *Gryllus* sp., isopod, *Athysanus argentarius (Metcalf)*. These same five species made up 68% of the total number of individuals the only difference being *Conocephalus strictus (Scudder)* numbers superceded *Melanoplus* (Fig. 12b).

A paired samples t-test was used to test for significance between absolute samples and sweep net samples of the four most abundant species (Fig. 13). Although the Order Isopoda was among the top five species in the absolute samples, it was never found in sweep net samples and therefore was not considered for further statistical comparisons. Sweep net samples of *Melanoplus* closely reflected the absolute samples with no significant difference ($t = 1.677$; $df = 11$; $P = 0.122$). This was true also for *Athysanus argentarius* ($t = 0.753$; $df = 11$; $P = 0.468$) where no significant difference between the sweep net samples and the absolute samples was reported. *Conocephalus strictus* ($t = 4.680$; $df = 11$; $P = < 0.001$) was significantly over represented in the sweep net samples while *Gryllus* sp. was significantly under represented in the sweep net samples ($t = 4.465$; $df = 11$; $P = < 0.001$).

Species comparison of total biomass

An independent samples t-test was used to test for significance between sweep samples of mowed and unmowed plots for *Conocephalus strictus, Melanoplus* and *Athysanus argentarius*. In all cases, Levene's test was used to verify the assumption of equal variances. The statistical comparison was made between 12 July mowed and unmowed plots when the grass height difference was relatively small; and also between 22 July mowed and unmowed plots, five days after the final mowing, when the effect of grass height was the greatest. There were no significant differences between mowed and unmowed plots for *Conocephalus strictus* on either 12 July ($t = 0.938$; $df = 10$; $p = 0.370$) or 22 July ($t = 0.235$; $df = 10$; $p = 0.819$). There were no significant differences between mowed and unmowed plots for *Melanoplus* on either 12 July ($t = 0.056$; $df = 10$; $p = 0.957$) or 22 July ($t = 0.807$; $df = 10$; $p = 0.438$). In the case of *Athysanus argentarius* there was a significant difference between mowed and unmowed plots on 12 July ($t = 2.396$; $df = 10$; $p = 0.038$) but on 22 July there was no significant difference ($t = 2.085$; $df = 10$; $p = 0.064$).

Discussion

This study examined arthropod abundance and diversity in a grassland of shorter and taller vegetated plots to determine whether arthropod prey could be a contributing factor to habitat selection by grasshopper sparrows and savannah sparrows. Total biomass differed significantly over time within both shorter and taller vegetated plots in this study. This was also true for one order, Orthoptera. The Sorenson Index measured more similarity than dissimilarity of arthropod species between treatments. This study found no significant difference in total biomass between treatments, nor did it find any significant difference between treatments in biomass within the Order Orthoptera. A statistical comparison of three of the five most abundant species *Conocephalus strictus, Melanoplus* and *Athysanus argentarius* was made when grass height difference was relatively small between mowed and unmowed plots and also when effect of grass height was greatest, five days after mowing. In five out of six cases, there was no significant difference between treatment.

This study did find slight differences between the arthropod abundance in mowed and unmowed plots. The grassland birds that were breeding and raising their young in this old field study site could have diminished the difference to a level where no significant difference was detected. Even though Wien's energetic models (Weins 1973, Weins and Rotenberry 1979) suggest grassland birds do not have significant effects on insect populations, this may be misleading (Fower et al. 1991). Studies on the effects of avian predation on grasshopper densities use avian exclosures (birds excluded areas) to compare grasshopper densities to control areas. When grasshopper densities are $>6/m^2$, avian predation does not consistently reduce overall grasshopper numbers (Branson 2005). But at low densities, specifically 3 individuals/m^2 (Fowler et al. 1991), and <2.5 individuals/m^2 (Bock et al 1992), avian predation does have significant negative impacts on grasshopper population.

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Figure 1. Study area within an old field 400 x 300 meters divided into twelve 100 x 100 meter plots. Each 100 x 100 meter plot was randomly assigned to a mowed or unmowed (control) resulting in six replicates of both the mowed and unmowed treatments.

300 meters

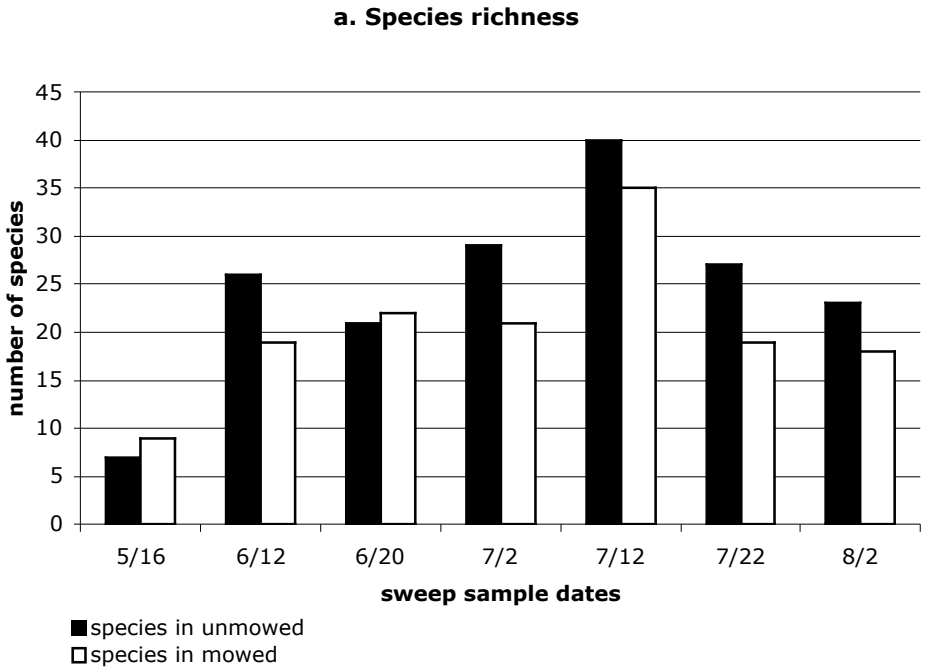
Unmowed Plot 2	Mowed Plot 2	Unmowed Plot 1
Mowed Plot 1	Unmowed Plot 3	Mowed Plot 3
Mowed Plot 4	Unmowed Plot 4	Unmowed Plot 5
Mowed Plot 5	Mowed Plot 6	Unmowed Plot 6

400 meters

Figure 2. Arthropods sampled from the old field at Midewin National Tallgrass Prairie, Wilmington, Illinois during seven dates of the study.

ARTHROPODS			
Class	**order**	**family**	**species**
Arachnida	Araneae	Araneidae	*Argiope midae, morphospecies 1, 2, 3*
		Jumping spider	*Marpissa pikei, Phi claris, Sarinda hentzi*
		Philodromidae	*Tibellus oblongatus*
		Tetragnathidae	*Tetragnathidae laboriosa*
		Thomisidae	*Misumenaides formosipes, Philodromus alascensis, Xysticus triguttatus*
	Opiliones	morphofamily 1	*morphospecies 1*
Crustacea	Isopoda	morphofamily 1	*morphospecies 1*
Insecta	Coleoptera	Cantharidae	*Cantharis bilineatus (Say), Chauliognathus marginatus*
		Chrysomelidae	*Colaspis brunnea (Fabricius)*
		Cleridae	*Cymatodera inornata (Say)*
		Coccinellidae	*morphospecies 1*
		Curculionidae	*morphospecies 2, 3*
		morphofamily 1	*morphospecies 4*
		morphofamily 2	*morphospecies 5*
		morphofamily 3	*morphospecies 6*
		Lampyridae	*morphospecies 7*
		Mordellidae	*morphospecies 8*
		Scarabaeidae	*Popillia Japonica, morphospecies 9*
	Diptera	Anthomyidae	*morphospecies 1*
		Asilidae	*Leptogaster sp.*
		Muscidae	*morphospecies 2, 3, 4, 5, 6*
		Sciomyzidae	*Limnia sp.*
		Syrphidae	*Paragus sp., Playcheirus sp., Toxomerus marginatus, morphospecies 7*
		Tipulidae	*morphospecies 8*
		morphofamily 4	*morphospecies 9*
	Ephemeroptera	morphofamily 1	*morphospecies 1*
	Hemiptera	Alydidae	*Alydus eurinus*
		Cicadellidae	*Draeculaceph*
		morphofamily 5	*morphospecies 1*
		morphofamily 6	*morphospecies 2*
		Membracidae	*Campylenchia latipes (Say)*
		Miridae	*morphospecies 3, 4, 5, 6*
		Nabidae	*Nabicula subcoleoptrata (Kirby), morphospecies 7, 8*
		Pentatomidae	*Euschistus variolarius, morphospecies 9, 10*
		Scutelleridae	*Homaemus aeneifrons*
		Miridae	*morphospecies 11*
	Homoptera	Cercopidae	*Philaenus spumarius (L.), A argentari, morphospecies 1, 2*
		Cicadellidae	*Athysanus argentarius (Metcalf), Aphrodes bicincta (Say), Chlorotettix unicolor (Fitch), Dorycephalus platyrhynchus, Draeculaceph, P spumarius*
		Membracidae	*S lutea*
	Hymenoptera	Braconidae	*Cardiochiles sp.*
		Formicidae	*Formica, Formica Fusca group, Formica NeoFormica, Murmica, Aphaenogaster*
		Helictidae	*morphospecies 3, 4, 5*
		Ichneumonidae	*morphospecies 6, 7, 8, 9, 10*
		Tiphiidae	*morphospecies 11*
	Lepidoptera	multiple families	*multiple species*
	Orthoptera	Acrididae	*Dissosteira Carolina, Metrioptera roeselli, Melanoplus*
		Gryllidae	*Oecanthus, Gryllus sp.*
		Tettigoniidae	*Amblycorpha, Conocephalus strictus, Neoconoceph*

Figure 3. The number of a. species sampled in unmowed and mowed plots, on each sampling date and b. families sampled in unmowed and mowed plots, on each sampling date.



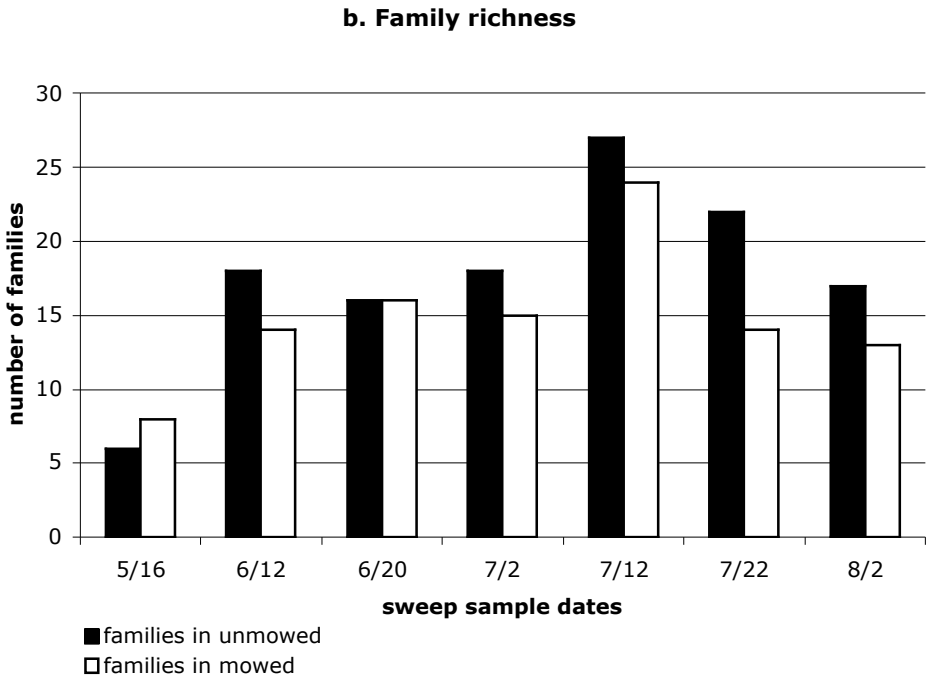


Figure 4. During the 2003 bird breeding and fledgling season, 15 May through the end of July, sweep net sampling of arthropods was conducted seven times: 16 May, 12 June, 20 June, 2 July, 12 July, 22 July, and 2 August. Samples were taken between 10:00 and 13:00, when there was little or no cloud cover and when the wind speed was less than 0.5 knots. Plots were sampled in random order on each date. Mowing was conducted twice during the study: 5 June and 17 July. Mowing took place not less than 5 days before collection dates.

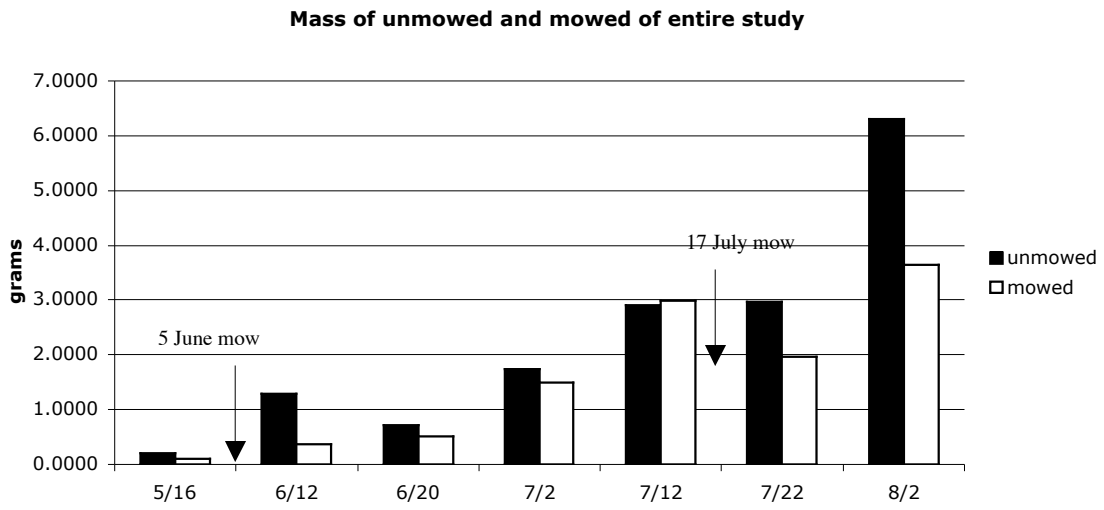
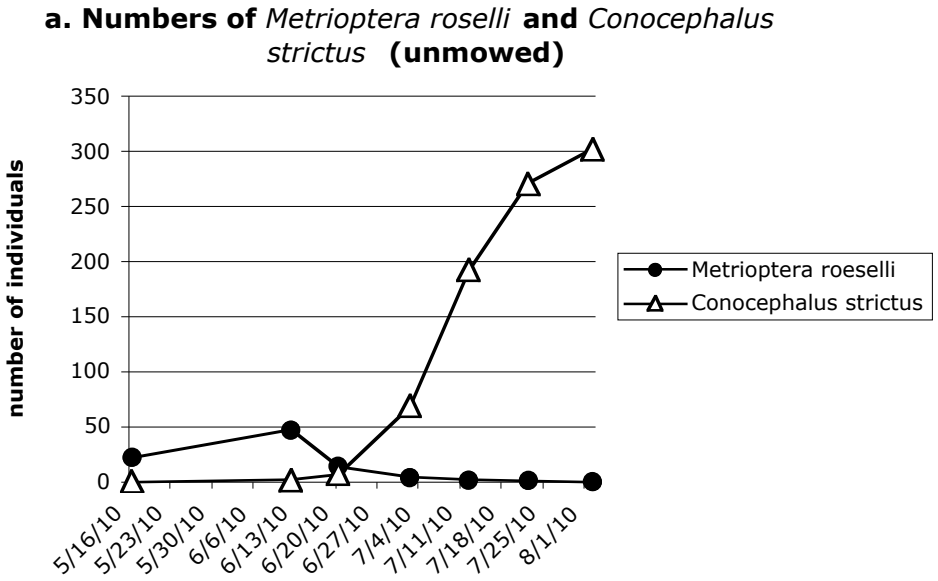


Figure 5 a. Number of individuals of *Metrioptera roeselli* and *Conocephalus strictus* sampled in unmowed plots. Abundance of *Metrioptera roeselli* was greatest in the 12 June sweep sample. On the 20 June sweep sample, numbers of *Metrioptera roeselli* and *Conocephalus strictus* were similar. By 2 Aug, the highest number of *Conocephalus strictus* were collected while no specimens of *Metrioptera roeselli* had been collected. **b.** Number of individuals of *Metrioptera roeselli* and *Conocephalus strictus* sampled in mowed plots. A comparison between unmowed and mowed counts on 22 July and 2 Aug of *Conocephalus strictus* indicates that the numbers of *Conocephalus strictus* were influenced by mowing.



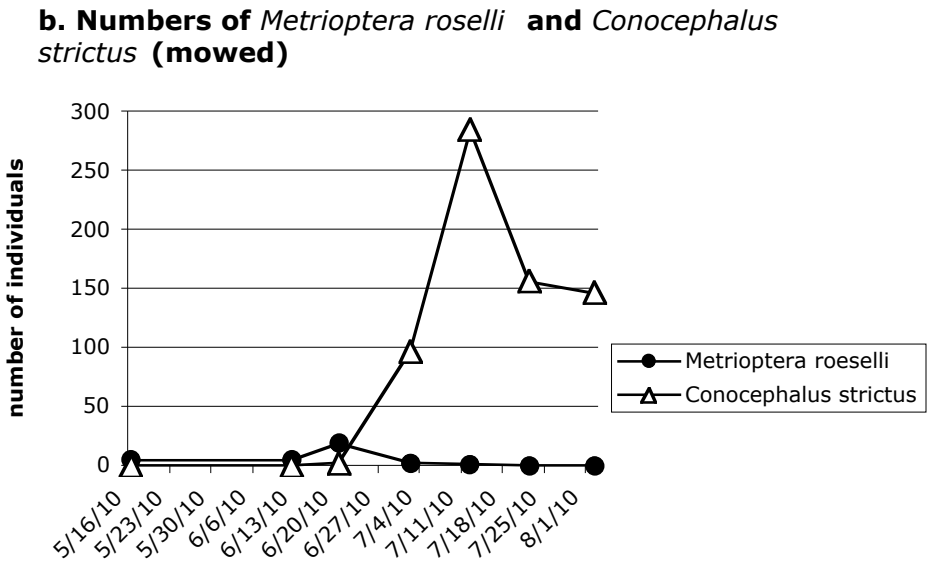
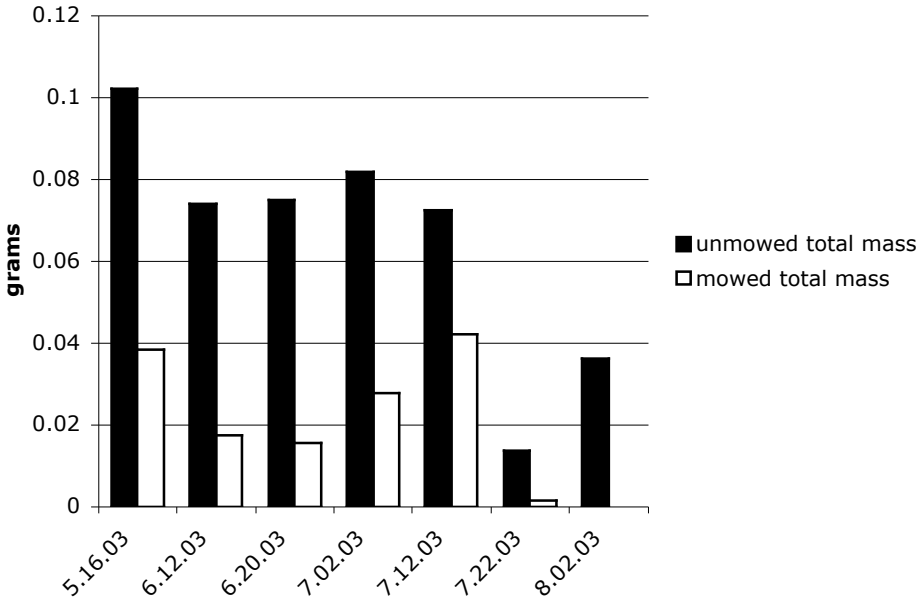


Figure 6. Mass for a. Lepidoptera and b. Diptera in control and treatment during the entire study.

a. Lepidoptera total mass



b. Diptera total mass

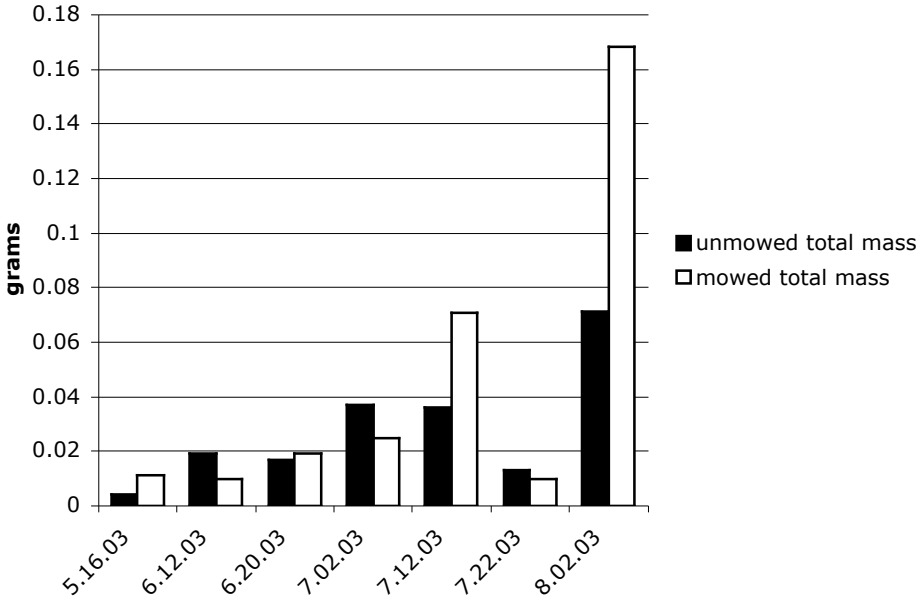
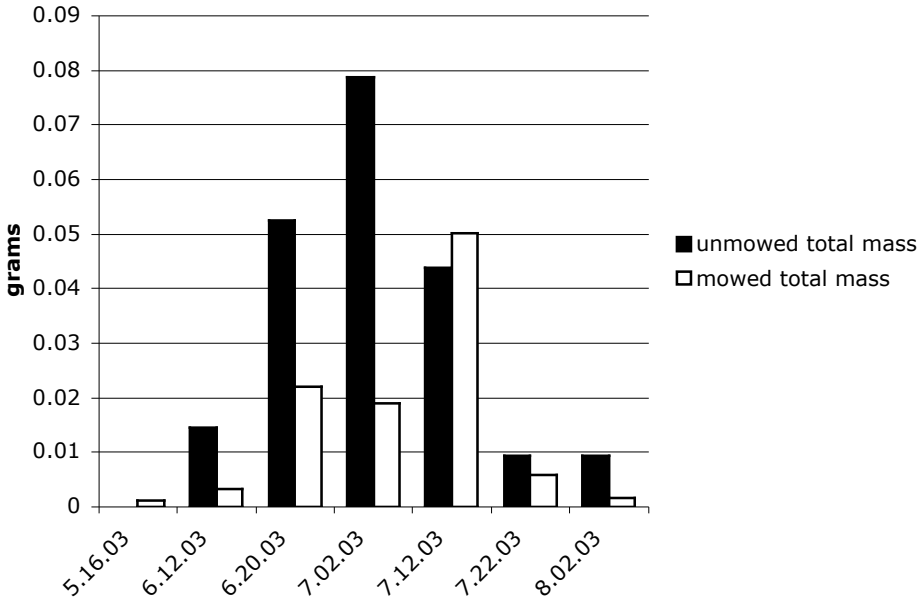


Figure 7. Mass for a. Arachnid and b. Coleoptera in control and treatment during the entire study.

a. Arachnid total mass



b. Coleoptera total mass

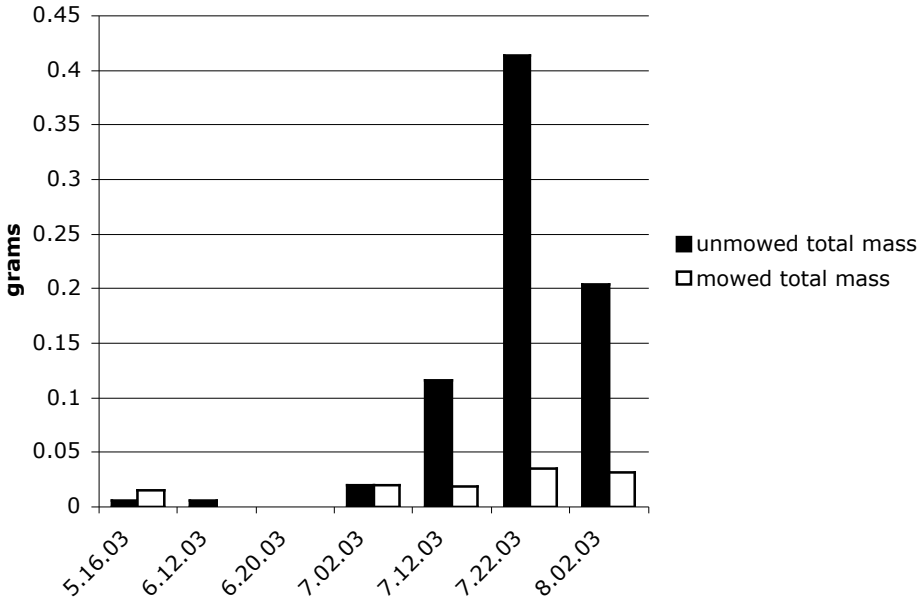
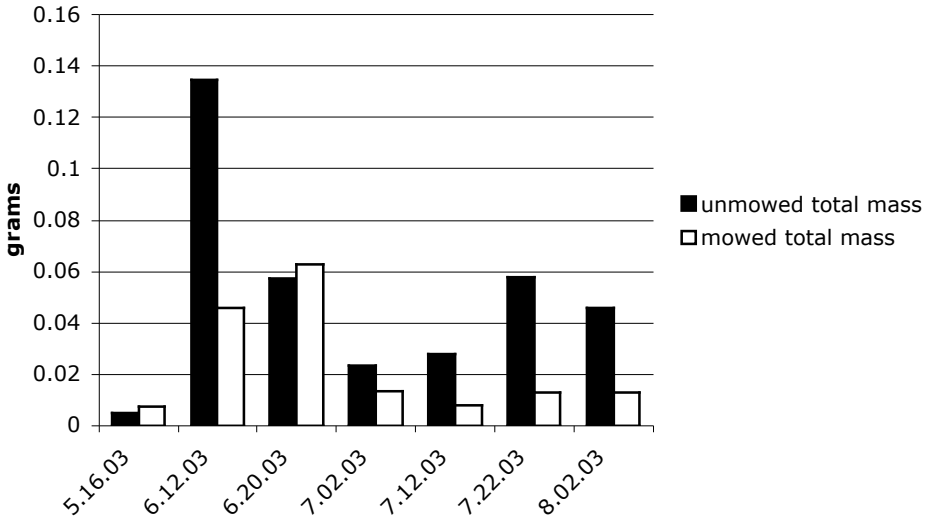


Figure 8. Mass for a. Hemiptera and b. Homoptera in control and treatment during the entire study.

a. Hemiptera total mass



b. Homoptera total mass

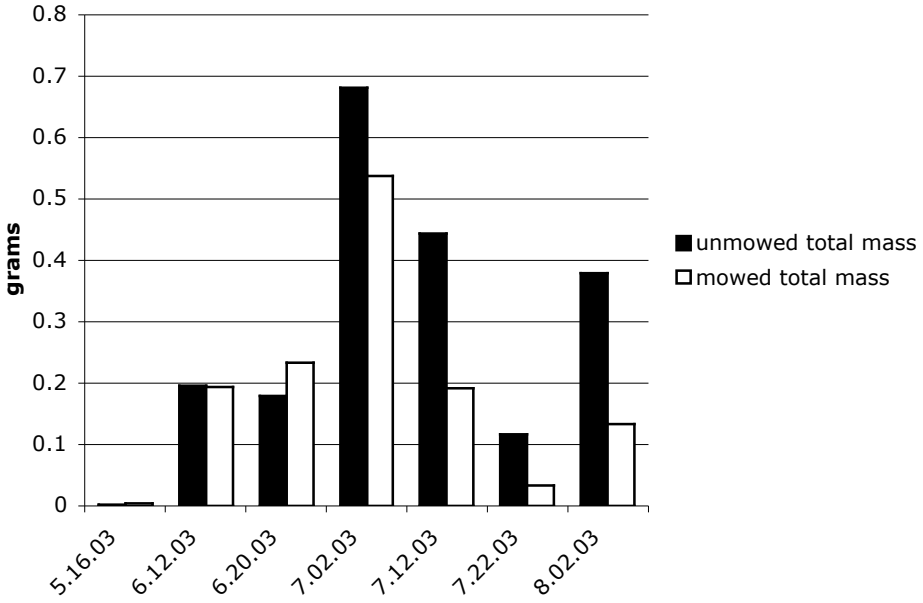
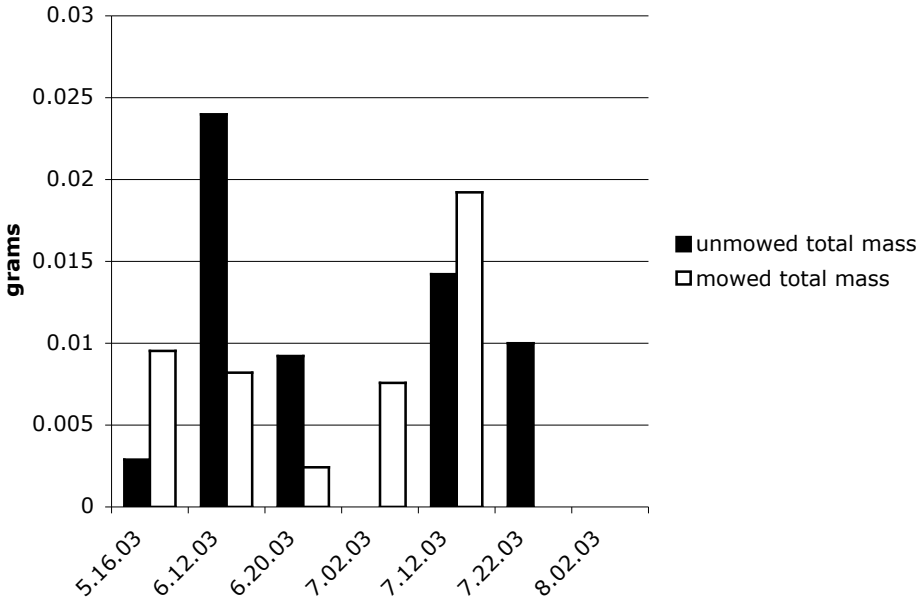


Figure 9. Mass for a. Hymenoptera and b. Orthoptera in control and treatment during the entire study.

a. Hymenoptera total mass



b. Orthoptera total mass

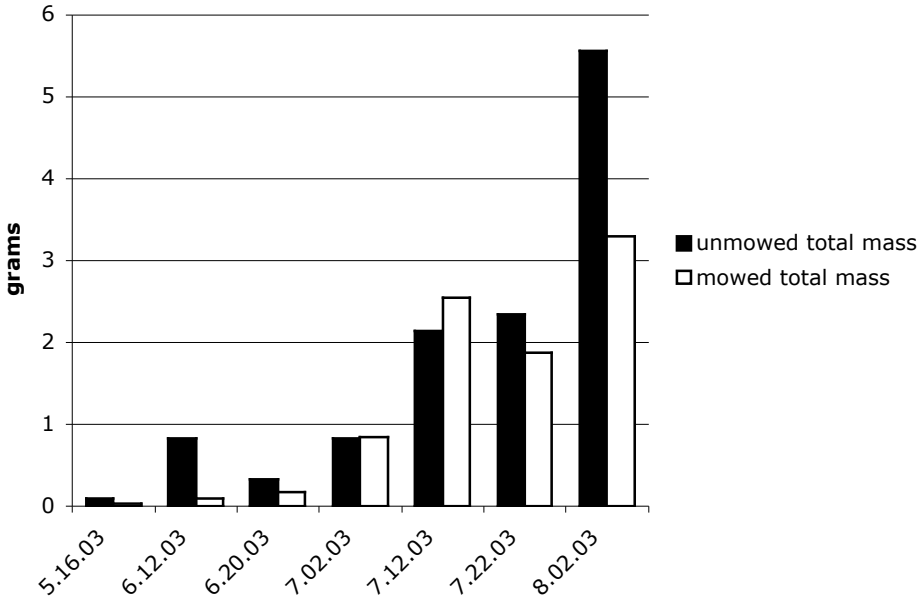


Figure 10. The Sorenson index was calculated to measure the similarity between mowed and unmowed plots in terms of the arthropod species found in each treatment. This index is designed to equal one in cases of complete similarity and zero if the sites are dissimilar and have no species in common.

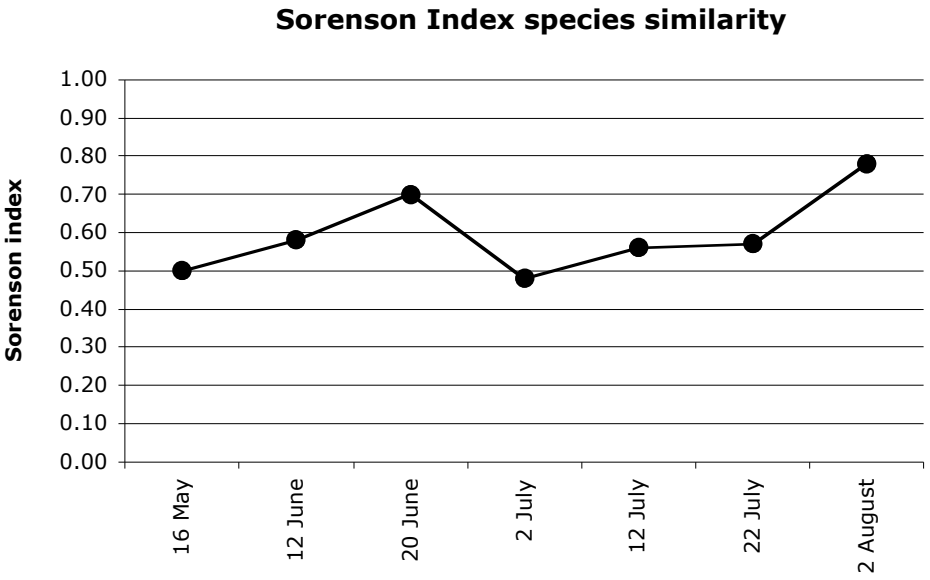
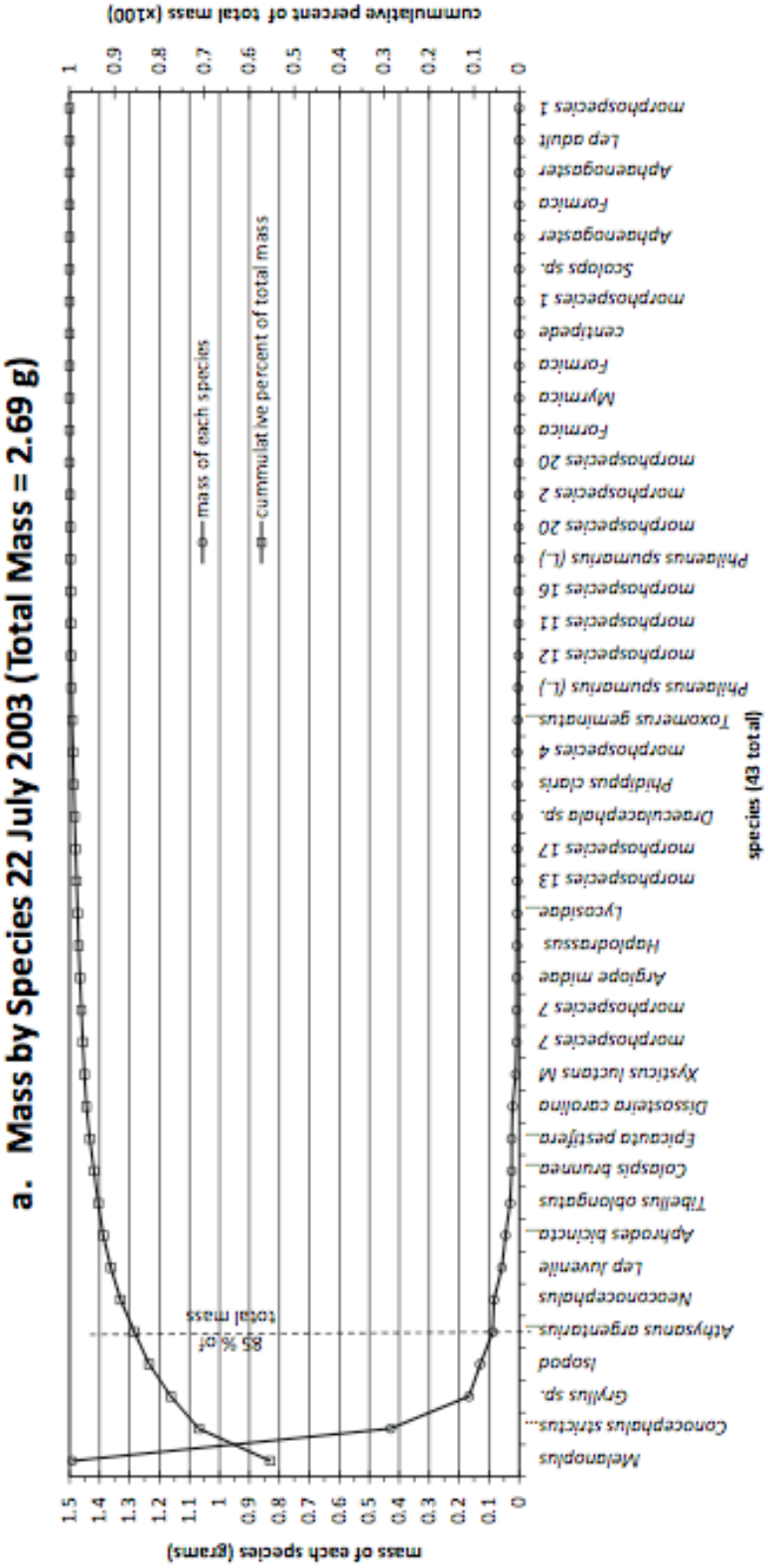


Figure 11. Absolute abundance of arthropods in grams per square meter.

	Plot 1	**Plot 2**	**Plot 3**	**Plot 4**	**Plot 5**	**Plot 6**
Unmowed	0.76 g/m^2	0.73 g/m^2	0.28 g/m^2	0.80 g/m^2	1.02 g/m^2	0.30 g/m^2
Mowed	0.68 g/m^2	0.32 g/m^2	0.96 g/m^2	0.90 g/m^2	0.25 g/m^2	0.46 g/m^2

Figure 12. Absolute samples mass a. by species and b. mass by individuals



b. Number of Individuals by Species 22 July 2003
(Total Number of Individuals = 344)

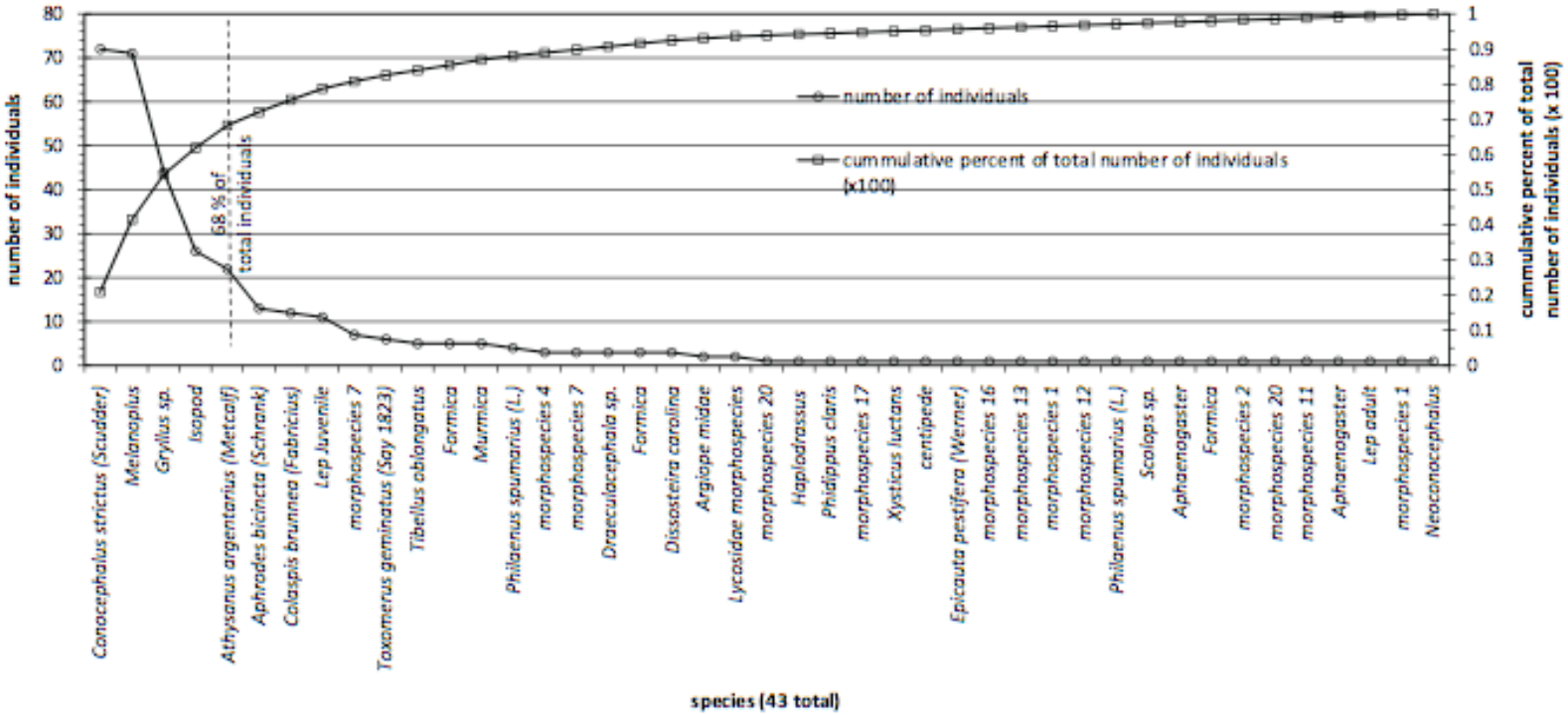


Figure 13. Paired samples t-test was used to test for significance between 22 July absolute samples and sweep net samples of the four most abundand species. *Species biomass significantly different (p=< 0.005) between absolute samples and sweep net samples.

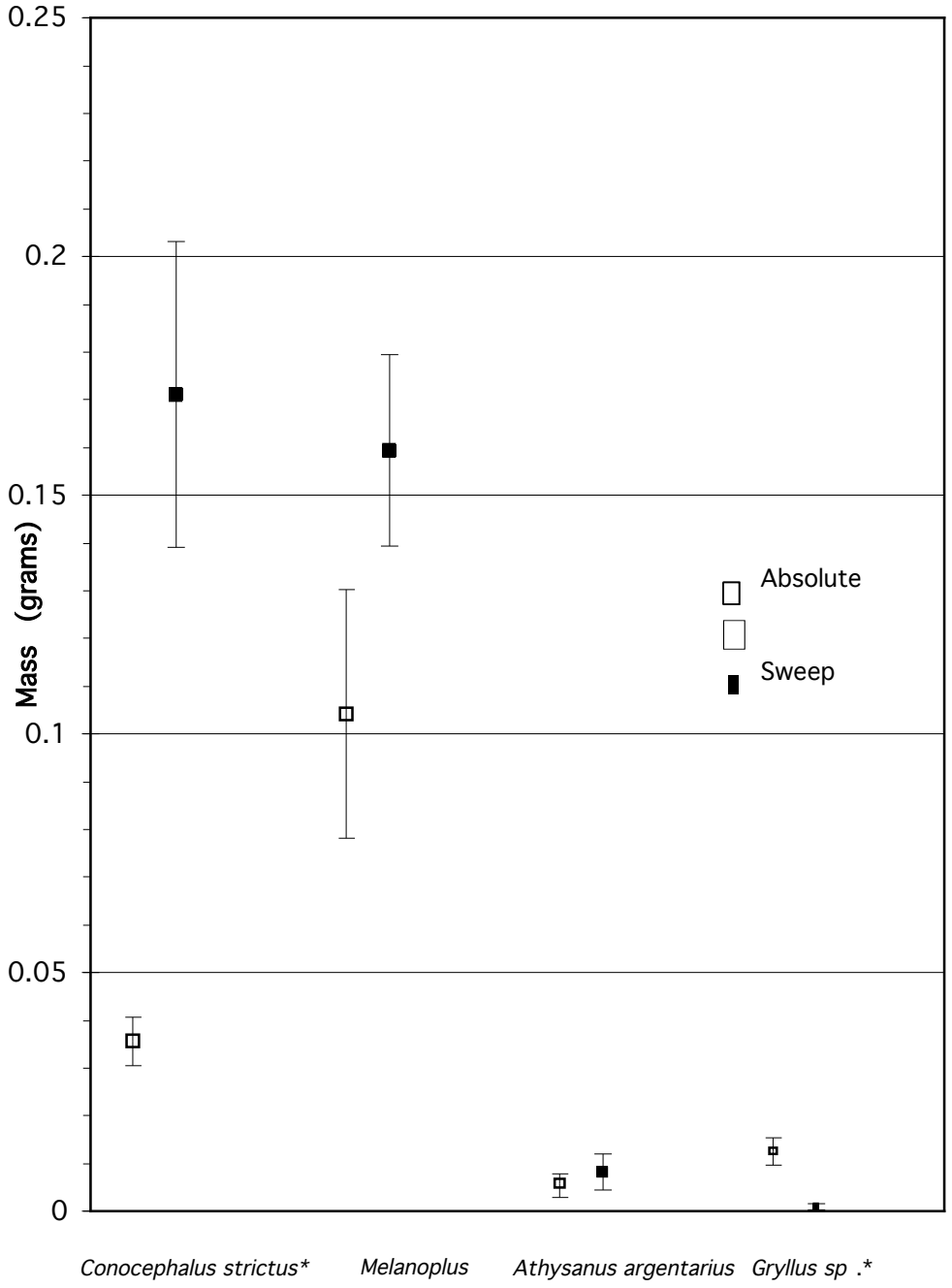


Figure 14. Independent samples t-test was used to test for significance between sweep samples of mowed an unmowed plots for *Conocephalus strictus*. The statistical comparison was made between 12 July mowed and unmowed plots when the grass height difference was relatively small; and also between 22 July mowed and unmowed plots, five days after the final mowing, when the effect of grass height was the greatest.

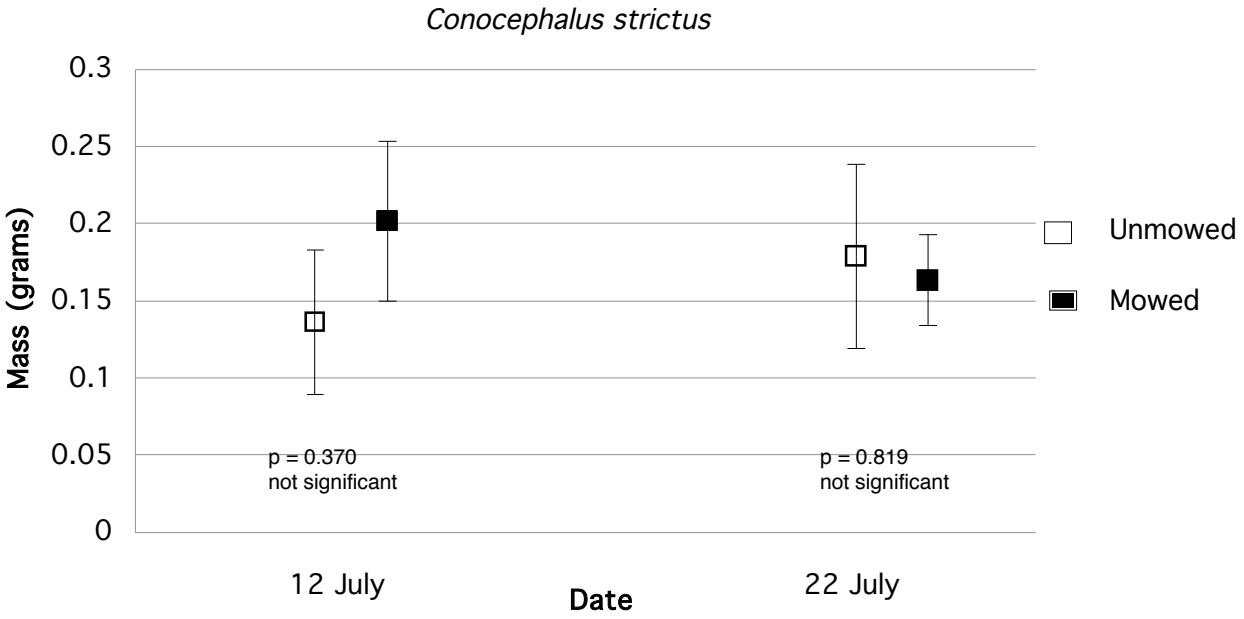


Figure 15. Independent samples t-test was used to test for significance between sweep samples of mowed an unmowed plots for *Melanoplus*. The statistical comparison was made between 12 July mowed and unmowed plots when the grass height difference was relatively small; and also between 22 July mowed and unmowed plots, five days after the final mowing, when the effect of grass height was the greatest.

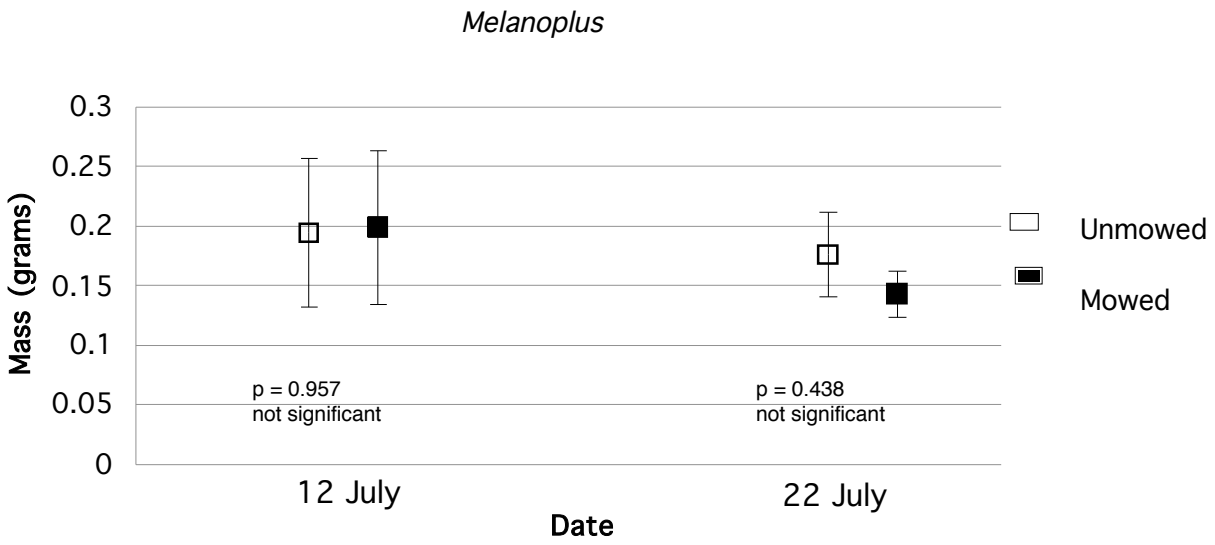
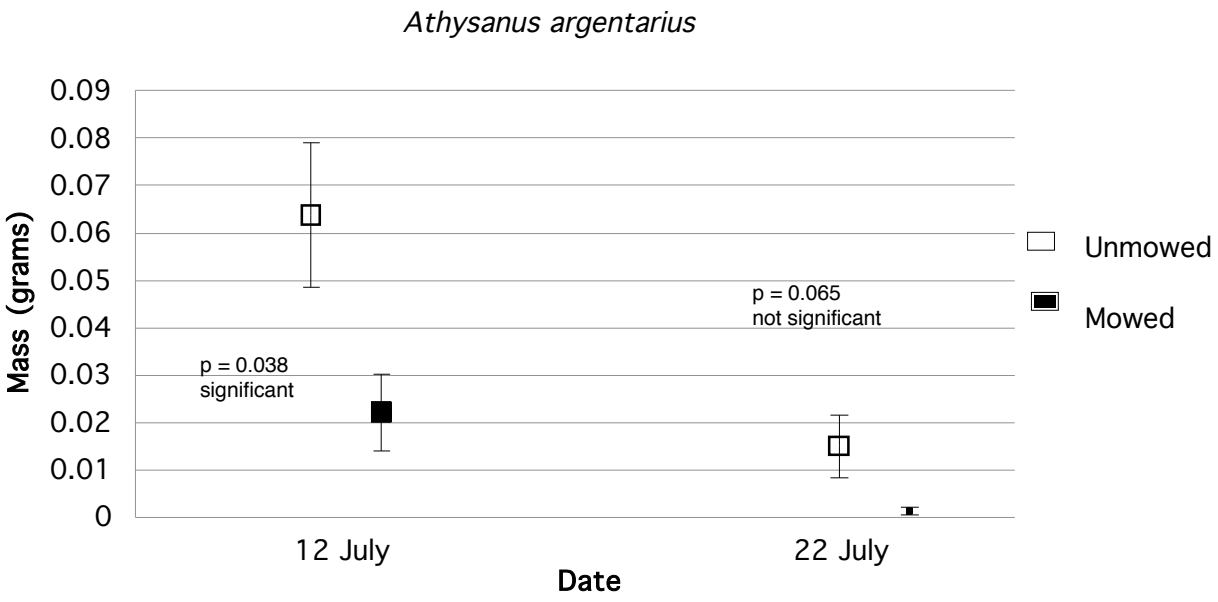



Figure 16. Independent samples t-test was used to test for significance between sweep samples of mowed an unmowed plots for *Athysanus argentarius*. The statistical comparison was made between 12 July mowed and unmowed plots when the grass height difference was relatively small; and also between 22 July mowed and unmowed plots, five days after the final mowing, when the effect of grass height was the greatest.