Transactions of the Illinois State Academy of Science
(2009), Volume 102, #1&2, pp. 107-115

received 7/8/08
accepted 1/10/09

# Abundance and Diversity of Thread-Waisted Wasps (Hymenoptera: Sphecidae: Sphecinae) at Alice L. Kibbe Life Science Station, Hancock County, Illinois USA

Kenneth W. McCravy[1]*, Jeffrey J. Bara[2], Sheri N. Hessler[1], Lauren K. Luxmore[1], Keesa S. Stinebaker[1], and Seán E. Jenkins[1]
[1]Department of Biological Sciences, Western Illinois University
1 University Circle, Macomb, IL 61455
[2]Department of Biology, University of Louisville
Louisville, KY 40292
*Corresponding author email: KW-McCravy@wiu.edu

## ABSTRACT

Sphecid wasps (Hymenoptera: Sphecidae) represent a diverse group of predatory wasps that includes potentially important bioindicators and biological control agents. Thread-waisted wasps (Hymenoptera: Sphecidae: Sphecinae) were surveyed in four habitats (recently burned prairie – burned in spring 2005, previously burned prairie – last burned in spring 2004, recently burned oak-hickory forest – burned in spring 2005, and unburned oak-hickory forest – not burned for 5+ years) in west-central Illinois from May through October 2005 using malaise traps. Ten species, representing six genera, were collected. *Ammophila nigricans* Dahlbom, *Eremnophila aureonotata* (Cameron), and *Sphex nudus* Fernald were the most abundant species, representing over 90% of total captures, with *A. nigricans* alone accounting for almost 75% of all captures. Recently burned prairie produced the greatest overall abundance and species richness, and forest habitats produced the lowest. Relative proportions of sphecine captures in recently burned vs. previously burned prairie decreased late in the season. Greatest numbers of sphecines were captured in July. Seasonal activity patterns were generally similar to those of sphecines further north, but may extend somewhat longer in west-central Illinois for some species. Our results suggest that sphecines are most abundant and active in prairie habitats at our study site, and that three species dominate the sphecine fauna there. Fire and subsequent recovery of prairie may have short-term effects on sphecine abundance and activity patterns.

## INTRODUCTION

The Sphecinae (Hymenoptera: Sphecidae) is a diverse subfamily of large, often brightly colored wasps commonly known as “thread-waisted wasps” because of the distinctive slender petiole of the metasoma. The subfamily consists of 11 genera and 127 species in North America (O’Brien, 1989). Most sphecine genera nest in cavities in the ground,

although some nest aerially and a few are inquilines (Bohart and Menke, 1963). Sphecines are predatory, provisioning the nest with arthropod prey. Sphecines are often prey specialists, with a genus specializing on a particular taxon, size, location (e.g., fossorial vs. arboreal caterpillars), or stage of prey (O'Brien, 1989). While sphecines are generally considered solitary, some display a primitive form of sociality (Bohart and Menke, 1976).

Spheciform wasps have received attention as potential biodiversity indicators and bioindicators of habitat quality and ecological disturbance (Tscharntke et al., 1998; Gayubo et al., 2005), and wasp species richness has been shown to correlate with landscape complexity and habitat diversity (Steffan-Dewenter, 2002). Sphecid wasps can also be important as biological control agents (Frank et al., 1995).

Western Illinois University's Alice L. Kibbe Life Science Station contains a mosaic of forest and restored prairie habitats that are being subjected to long-term management using controlled burning to suppress early successional and non-native plant growth. This landscape heterogeneity provides an excellent opportunity to examine the diversity of west-central Illinois sphecines in relation to habitat diversity and disturbance. The goals of our study were to: 1) characterize the sphecine fauna of prairie and forest habitats at Alice L. Kibbe Life Science Station, 2) examine seasonal activity patterns of the sphecine fauna, and 3) examine variation in sphecine abundance and diversity in relation to habitat.

## MATERIALS AND METHODS

Sampling occurred May through October 2005 at Alice L. Kibbe Life Science Station near Warsaw in Hancock Co., Illinois USA. Habitats sampled included a restored prairie burned in spring 2005 (40° 22.0' N, 91° 24.3' W), a restored prairie last burned in spring 2004 (40° 21.8' N, 91° 24.3' W), an oak-hickory forest stand burned in spring 2005 (40° 22.0' N, 91° 24.5' W), and an oak-hickory forest stand unburned for 5+ years (40° 21.8' N, 91° 24.1' W). These habitats will be referred to as recently burned prairie, previously burned prairie, recently burned forest, and unburned forest, respectively. The prairie habitats were former agricultural fields that were restored to prairie in the late 1970s. The recently burned prairie was ca. 3.0 ha and linear, with a length of ca. 500 m and width of ca. 60 m. The previously burned prairie was irregular in shape and ca. 2.5 ha. Abundant plants in the prairie habitats included warm season bunch grasses such as Indian grass, *Sorghastrum nutans* (L.) Nash, big bluestem, *Andropogon gerardii* Vitman, little bluestem, *Schizachyrium scoparium* (Michx.) Nash, and switchgrass, *Panicum virgatum* L., as well as many forb species from the families Asteraceae and Fabaceae. Woody species included rough-leaved dogwood, *Cornus drummondii* C. A. Mey, and smooth sumac, *Rhus glabra* L. (Willand, 2006). Mean percent ground cover (± SE), as measured by visual estimation of 20 0.5-$m^2$ plots in mid-July 2005, was 55.5 ± 3.73 and 80.5 ± 3.80 in the recently burned prairie and previously burned prairie, respectively. In mid-Sept 2005, these measures were 71.0 ± 2.98 and 76.5 ± 2.54, respectively.

The forest habitats were old growth, dry-mesic upland oak-hickory forests. These stands were open woodland-savanna with a history of grazing until the 1950s-60s. Fire suppression allowed the emergence of a dense understory after this time. The recently burned forest had undergone prescribed burning every 2-3 years since the mid 1990s to suppress

understory vegetation, but the unburned forest had a history of more infrequent and inconsistent fire, and hadn't been burned in 5+ years (Willand, 2006). Total contiguous forest area was at least 200 ha, with burn units of ca. 3.0 ha each. Dominant overstory tree species included white oak, *Quercus alba* L., northern red oak, *Quercus rubra* L., and shagbark hickory, *Carya ovata* (Miller) K. Koch (Willand, 2006). Few invasive plant species were present. Mean percent ground cover (± SE) in the forest habitats was also measured by visual estimation of 20 0.5-$m^2$ plots. In mid-July 2005 these values were 29.0 ± 3.24 and 59.5 ± 3.36 in the recently burned forest and unburned forest, respectively. In mid-Sept 2005, these measures were 23.5 ± 2.84 and 38.0 ± 3.88, respectively. Plant nomenclature follows that of Gleason and Cronquist (1991).

Three malaise traps (Townes, 1972) were placed in each of the four habitats, for a total of 12 traps. Malaise traps are flight interception traps that are effective in capturing active flying insects such as Hymenoptera (Darling and Packer, 1988). Traps within a given habitat were placed a minimum of 75 m apart. Traps in prairie habitats were located 15 m to 30 m from the nearest forest/prairie interface, and traps in forest habitats were located 25 m to 50 m from the nearest forest/prairie interface. Trap collection bottles were filled with 70% EtOH. Traps were operated continuously from 16 May to 24 October. Samples were collected twice weekly, every three or four days, and the previous bottle was replaced with one containing fresh EtOH. Sphecine wasps were collected from the samples, pinned, and labeled with collection information. A representative sample of collected sphecines was identified by Dr. Wojciech Pulawski, of the California Academy of Science. We identified the remaining sphecines using this reference collection and Bohart and Menke (1963).

Sphecine species richness and Simpson's diversity indices (Simpson, 1949) were calculated for each habitat. Species richness is associated with sample size, so rarefaction was used in comparing species richness of different habitats. Rarefaction provides an estimate of the expected number of species for a given sample size (Krebs, 1999). The University of Alberta Department of Biology online rarefaction calculator (http://www.biology.ualberta.ca/jbrzusto/rarefact.php#Calculator) was used in these analyses. Simpson's index considers the number of species captured (species richness) but also the relative proportions of individuals that occur in each species. A collection of species that is dominated by one or a few species will have lower diversity than one in which individuals are apportioned equally among all species (Brower et al., 1998). Simpson's index ranges from 0 (low diversity) to near 1. Comparisons between Simpson's indices were done using *t*-tests following the methods of Keefe and Bergerson (1977). Relative abundances of sphecines in prairie habitats in relation to season (early vs. late) were analyzed using the *G*-test, with Yates' continuity correction.

## RESULTS AND DISCUSSION

A total of 1981 sphecines (12.3/trap/day), representing 10 species and 6 genera, were collected over the course of the study (Table 1). Mean numbers of sphecines captured per trap (± SEM) were 472.3 ± 207.9 in the recently burned prairie (min = 222, max = 885), 175.3 ± 18.2 in the previously burned prairie (min = 144, max = 207), 10.0 ± 4.5 in the recently burned forest (min = 5, max = 19), and 2.67 ± 2.67 in the unburned forest (min = 0, max = 8). The first sphecine, *Chalybion californicum* (de Saussure), was collected on

30 May, and the last, *Ammophila urnaria* Dahlbom, on 10 October. Greatest numbers of sphecines were collected during July (1053 specimens), with a peak collection date of 11 July (263 specimens). Three species (*Ammophila nigricans* Dahlbom, *Eremnophila aureonotata* (Cameron), and *Sphex nudus* Fernald) comprised 91.5% of total captures, with *A. nigricans* alone accounting for almost 75% of all captures (Table 1).

Each sphecine species was more abundant in prairie than in forest habitats, with the exception of *Podium luctuosum* F. Smith (Table 1). This is an uncommonly collected species that inhabits mesic woodlands, constructing cells under bark flaps or in tree holes (Krombein, 1979; O'Brien, 1989). Cells are provisioned with cockroaches. *Parcoblatta uhleriana* (de Saussure) and *Parcoblatta virginica* (Brunner) have been recorded as prey (Pate, 1949; Krombein, 1967), and both, as well as several other species of *Parcoblatta*, occur in Illinois (Hebard, 1917). However, this species will move into more open habitats as evidenced by our capture of three specimens in two different traps in the recently burned prairie. Among species other than *P. luctuosum*, *E. aureonotata* produced the greatest proportion of captures in forest traps (7.1%), suggesting that this species may tend to range more widely into different habitats than other open-habitat sphecines. Among the remaining eight species, only 1.1% (19 of 1763 individuals) was collected in forest traps (Table 1).

Among prairie captures, greater numbers of each sphecine species were collected in the recently burned than in the previously burned prairie (Table 1).The recently burned prairie produced the greatest sphecine numbers and species richness, and both prairie habitats combined comprised 98.1% of all sphecines collected. Observed species richness was within one standard deviation of the expected richness based on rarefaction for all habitats except the previously burned prairie, which had substantially lower species richness than expected (Table 1). Diversity was significantly greater in recently burned than in previously burned prairie (0.47 vs. 0.30; $t = 5.714$, df = $\infty$, $P < 0.001$), but was lower overall in prairie than in forest habitats, due primarily to the dominance of *A. nigricans* in the prairie habitats (Table 1).

It is possible that the reduced vegetation and more open habitat produced by burning created more favorable conditions for sphecine prey location or nesting activities. Of the six genera collected in this study, three (*Ammophila*, *Eremnophila*, and *Sphex*) are fossorial nesters (O'Brien, 1989), and the three most abundant species were in these genera (Table 1). There was also a temporal pattern with regard to relative abundances of these three species in the two prairie habitats. For *A. nigricans*, 70.9% of early season (through July) captures occurred in the recently burned prairie, whereas only 34.0% of late season (after July) captures occurred in the recently burned prairie ($G = 26.46$, df = 1, $P < 0.0001$). Similar reductions in late season proportions of recently burned prairie captures occurred for *E. aureonotata* (from 96.6% to 52.5%; $G = 55.02$, df = 1, $P < 0.0001$) and *S. nudus* (from 98.6% to 76.1%; $G = 16.21$, df = 1, $P < 0.0001$). This relative decrease in proportion of recently burned prairie captures later in the season may reflect the recovery of the vegetation in this habitat from very sparse post-burn levels to a level similar to the previously burned prairie, with concomitant effects on wasp hunting, nesting, or flight behavior.

Collection dates for the seven most abundant species are shown in Figs. 1 and 2. Data are presented based on weekly rather than biweekly trapping totals for clarity. Collections of *E. aureonotata* occurred during a two-month period from 11 July to 12 Sept, with peak collections in mid- to late July and early August. This is similar to the seasonal activity patterns of this species in Michigan (O'Brien, 1989). *Sphex nudus* showed activity patterns similar to *E. aureonotat*a in our study, with peak collections in late July and early August (Fig. 1). *Ammophila nigricans* was first collected on 6 June, with peak abundance on 11 July. The latest collection of this species occurred on 5 September (Fig. 1). This species was collected 11 days earlier and 8 days later in our study than in Michigan, where 49 specimens were collected from 17 June to 28 August (O'Brien, 1989). This potential difference in seasonal activity could reflect the more extended warm weather season in west-central Illinois or the much greater sample size of this species in our study. Like its congeneric *A. nigricans*, *A. urnaria* was first collected on 6 June, but its activity was more prolonged than that of *A. nigricans*, extending to 10 October (Fig. 2). This is consistent with activity patterns of these two species in Michigan, where *A. nigricans* was not collected beyond late August, but *A. urnaria* has been collected as late as early October (O'Brien, 1989). Again, our latest collection of this species was 9 days later than was found in Michigan (O'Brien, 1989). *Ammophila urnaria* is the most commonly collected species of the genus in Michigan and probably the most common *Ammophila* in North America (O'Brien, 1989), but it was much less common than *A. nigricans* in our study (Table 1). Although greater sample sizes would be needed for clarification, our collection data are consistent with O'Brien's (1989) suggestion that *A. urnaria* may be bivoltine (Fig. 2). The first collection of *C. californicum* occurred on 30 May, with greatest numbers in mid to late June (Fig. 2). This blue mud dauber uses abandoned nests of the black and yellow mud dauber *Sceliphron caementarium* (Drury) (Rau, 1928), which was not collected in our study. Perhaps this latter species is less abundant in the vicinity of our study site, or is less susceptible to capture in malaise traps. Both *Isodontia mexicana* (de Saussure) and *Isodontia apicalis* (F. Smith) were first collected on 6 June, but *I. apicalis* was not collected again until July, whereas *I. mexicana* was consistently collected throughout June and July (Fig. 2).

In summary, *A. nigricans*, *E. aureonotata*, and *S. nudus* were the most abundant species of sphecines collected in our study. Sphecine abundance and diversity varied widely within a relatively small geographic area. Disturbance by fire appeared to affect sphecine abundance, activity, and diversity, but these effects were short-lived. In general, sphecine seasonal activity patterns at our study site were similar to those found further north, but may extend somewhat longer for some species.

## ACKNOWLEDGMENTS

We thank Dr. Wojciech Pulawski (California Academy of Science) for invaluable assistance with wasp identification. Naomi Borth and Christie Seagren (both of Western Illinois University) provided assistance with wasp collection and pinning. We thank two anonymous reviewers for helpful suggestions that improved the manuscript. Generous funding was provided by the Western Illinois University College of Arts and Sciences through the Undergraduate Research and Scholarly Activity Grants Program.

## LITERATURE CITED

Bohart, R. M., and A. S. Menke. 1963. A reclassification of the sphecinae, with a revision of the Nearctic species of the tribes Sceliphronini and Sphecini (Hymenoptera, Sphecidae). University of California Publications in Entomology 30: 91-181.

Bohart, R. M., and A. S. Menke. 1976. Sphecid Wasps of the World: a Generic Revision. University of California Press, Berkeley.

Brower, J. E., J. H. Zar, and C. N. von Ende. 1998. Field and Laboratory Methods for General Ecology, 4th ed. McGraw-Hill, Boston.

Darling, D. C., and L. Packer. 1988. Effectiveness of malaise traps in collecting Hymenoptera: the influence of trap design, mesh size, and location. Canadian Entomologist 120: 787-796.

Frank, J. H., J. P. Parkman, and F. D. Bennett. 1995. *Larra bicolor* (Hymenoptera: Sphecidae), a biological control agent of *Scapteriscus* mole crickets (Orthoptera: Gryllotalpidae), established in Northern Florida. Florida Entomologist 78: 619-623.

Gayubo, S. F., J. A. González, J. D. Asís, and J. Tormos. 2005. Conservation of European environments: the Spheciformes wasps as biodiversity indicators (Hymenoptera: Apoidea: Ampulicidae, Sphecidae and Crabronidae). Journal of Natural History 39: 2705-2714.

Gleason, H. A., and A. Cronquist. 1991. Manual of Vascular Plants of Northeastern United States and Adjacent Canada, 2nd ed. New York Botanical Garden, New York.

Hebard, M. 1917. The Blattidae of North America, north of the Mexican boundary. Memoirs of the American Entomological Society 2: 1-284.

Keefe, T. J., and E. P. Bergersen. 1977. A simple diversity index based on the theory of runs. Water Research 11: 689-691.

Krebs, C. J. 1999. Ecological Methodology, 2nd ed. Benjamin/Cummings, Menlo Park, CA.

Krombein, K. V. 1967. Trap-nesting wasps and bees: life histories, nests, and associates. Smithsonian Press, Washington, DC.

Krombein, K. V. 1979. Superfamily Sphecoidea, pp. 1573-1740. In Krombein, K. V., P. D. Hurd, Jr., D. R. Smith, and B. D. Burks, eds. Catalog of Hymenoptera in America North of Mexico, Vol. 2. Smithsonian Inst. Press, Washington, DC.

O'Brien, M. F. 1989. Distribution and biology of the sphecine wasps of Michigan (Hymenoptera: Sphecidae: Sphecinae). Great Lakes Entomologist 22: 199-217.

Pate, V. S. L. 1949. A minute on *Podium luctuosum*. Entomological News 60: 174.

Rau, P. 1928. The nesting habits of the wasp, *Chalybion caeruleum*. Annals of the Entomological Society of America 21: 25-34.

Simpson, E. H. 1949. Measurement of diversity. Nature 163: 688.

Steffan-Dewenter, I. 2002. Landscape context affects trap-nesting bees, wasps, and their natural enemies. Ecological Entomology 27: 631-637.

Townes, H. 1972. A lightweight malaise trap. Entomological News 83: 239-247.

Tscharntke, T., A. Gathmann, and I. Steffan-Dewenter. 1998. Bioindication using trap-nesting bees and wasps and their natural enemies: community structure and interactions. Journal of Applied Ecology 35: 708-719.

Willand, J. E. 2006. Diversity of ground beetles (Coleoptera: Carabidae) in relation to habitat characteristics and prescribed burning. M.S. Thesis, Western Illinois University, Macomb, Illinois, 34 pp.

Table 1. Numbers, species richness, rarefaction estimates of species richness (± SD), and species diversity of sphecine wasps captured in malaise traps in four habitats: prairie burned in spring 2005 (RBP – recently burned prairie), prairie last burned in spring 2004 (PBP – previously burned prairie), oak-hickory forest burned in spring 2005 (RBF – recently burned forest), and oak-hickory forest unburned for 5+ years (UF – unburned forest). Traps were operated continuously from 16 May to 24 October 2005 in Hancock Co., Illinois USA. Percentages do not sum to 100.0 due to rounding error.

| Species | RBP | PBP | RBF | UF | Total | % of Total Wasps |
|---|---|---|---|---|---|---|
| *Ammophila nigricans* Dahlbom | 1008 | 439 | 15 | 1 | 1463 | 73.9 |
| *Ammophila urnaria* Dahlbom | 42 | 11 | 1 | 0 | 54 | 2.7 |
| *Chalybion californicum* (de Saussure) | 20 | 7 | 1 | 0 | 28 | 1.4 |
| *Eremnophila aureonotata* (Cameron) | 154 | 42 | 12 | 3 | 211 | 10.7 |
| *Isodontia apicalis* (F. Smith) | 25 | 2 | 0 | 0 | 27 | 1.4 |
| *Isodontia mexicana* (de Saussure) | 22 | 8 | 1 | 0 | 31 | 1.6 |
| *Podium luctuosum* F. Smith | 3 | 0 | 0 | 4 | 7 | 0.4 |
| *Sphex ichneumoneus* (L.) | 6 | 0 | 0 | 0 | 6 | 0.3 |
| *Sphex nudus* Fernald | 122 | 17 | 0 | 0 | 139 | 7.0 |
| *Sphex pensylvanicus* L. | 15 | 0 | 0 | 0 | 15 | 0.8 |
| Total Wasps Captured | 1417 | 526 | 30 | 8 | 1981 | 100.2 |
| Species Richness | 10 | 7 | 5 | 3 | | |
| Rarefaction Estimate | 10.0 ± 0.03 | 9.72 ± 0.49 | 4.89 ± 1.14 | 2.68 ± 0.93 | | |
| Simpson's Diversity | 0.47 | 0.30 | 0.61 | 0.68 | | |

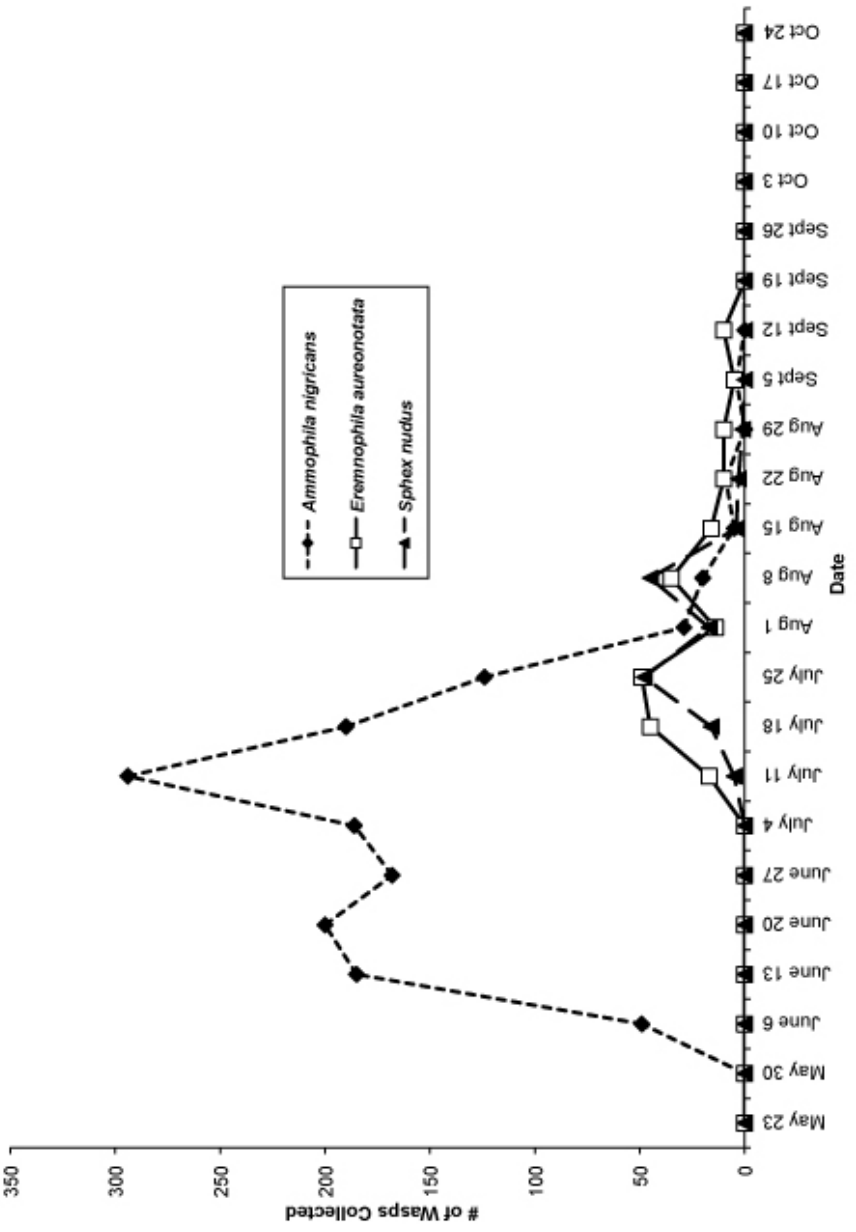


Figure 1. Weekly collections of three species of sphecine wasps captured in malaise traps from May-October 2005 at Alice L. Kibbe Life Science Station, Hancock Co., Illinois USA.

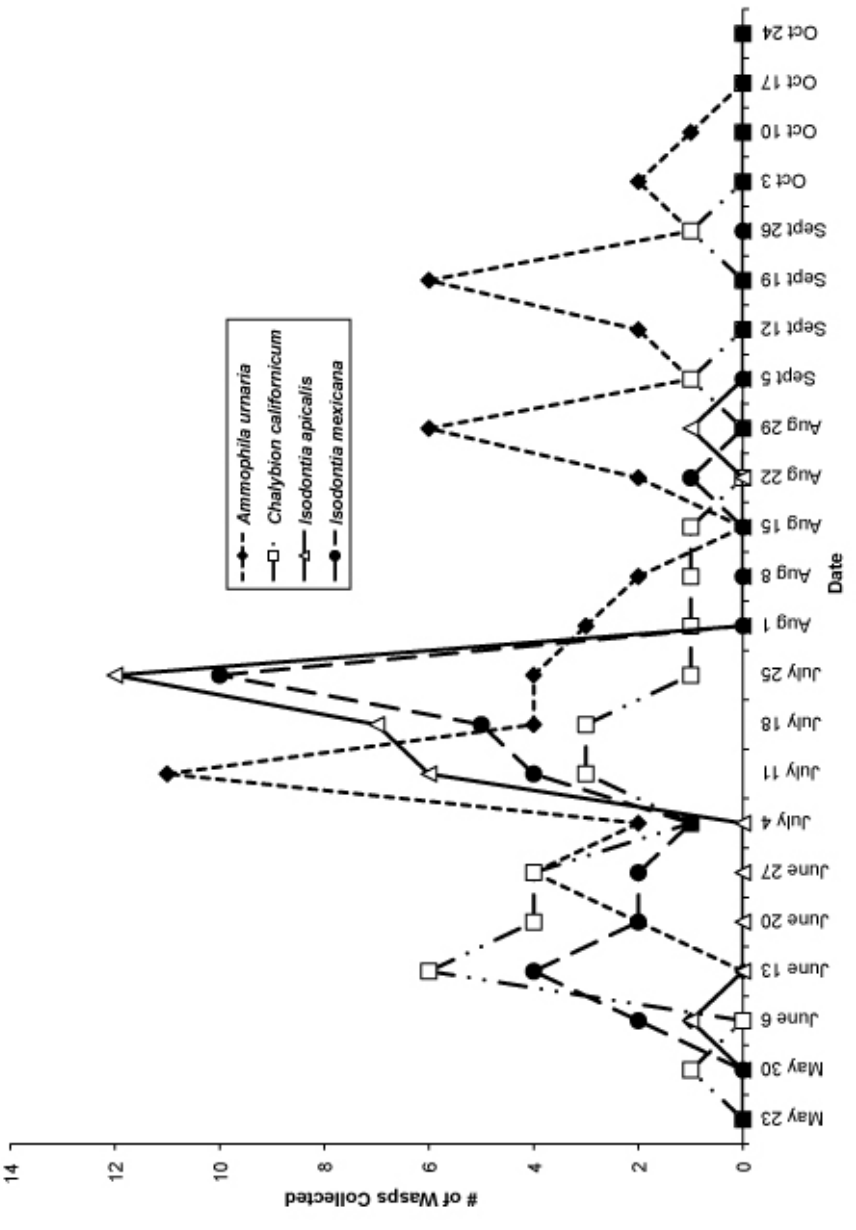


Figure 2. Weekly collections of four species of sphecine wasps captured in malaise traps from May-October 2005 at Alice L. Kibbe Life Science Station, Hancock Co., Illinois USA.