Conservation Assessment for the Prairie bunchgrass leafhopper (Polyamia herbida DeLong)

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This document is undergoing peer review, comments welcome

TABLE OF CONTENTS

EXECUTIVE SUMMARY 1
ACKNOWLEDGEMENTS 1
NOMENCLATURE AND TAXONOMY 1
DESCRIPTION OF SPECIES 2
Description of Adult Stage 2
Description of Immature Stages 2
LIFE HISTORY 2
Reproduction 2
Ecology 3
Dispersal/Migration 3
Obligate Associations 3
HABITAT 4
National Forests: Hoosier NF (Perry Co., IN) 4
Site Specific 5
Hoosier NF: Boone Creek Special Area 5
Hoosier NF: Cloverlick Special Area 5
Hoosier NF: Harding Flats Special Area 6
DISTRIBUTION AND ABUNDANCE 7
Range-wide Distribution 7
State and National Forest Distribution 7
RANGE WIDE STATUS 9
POPULATION BIOLOGY AND VIABILITY 9
POTENTIAL THREATS 9
Present or Threatened Risks to Habitat 9
Row Crop Agriculture 10
Fire Suppression 10
Fire Management 11
Grazing 12
Pasture Development 12
Competition from Introduced Species 13
Disease or Predation 14
Insect Pest Control Efforts 15
Over utilization 16
Residential Development 16
Inadequacy of Existing Regulatory Mechanisms 16
SUMMARY OF LAND OWNERSHIP & EXISTING HABITAT PROTECTION 17
SUMMARY OF EXISTING MANAGEMENT ACTIVITIES 17
PAST AND CURRENT CONSERVATION ACTIVITIES 18
recommendations 18
RESEARCH AND MONITORING 19
Existing Surveys, Monitoring, and Research 19
Survey Protocol 19
Monitoring Protocol 20

Research Priorities 21
Additional Areas of Potential Prairie Bunchgrass Leafhopper Research 22
Other Rare Species Associated with the Prairie Bunchgrass Leafhopper 22
REFERENCES 22
APPENDIX 36
LIST OF CONTACTS 36
Information Requests 36
Review Requests 36

LIST OF FIGURES

Figure 1. Adult *Polyamia herbida*, dorsal view.

Figure 2. Known Distribution of the Prairie Bunchgrass Leafhopper (*Polyamia herbida*) and its Foodplants in the Eastern United States.

EXECUTIVE SUMMARY

The prairie bunchgrass leafhopper (*Polyamia herbida* DeLong) is a minute, intricately patterned leafhopper associated with high quality, native grassland remnants in the central U. S. It is considered rare and local range-wide, always in close association with its primary food plants, bunch-forming panic grasses (*Panicum* spp.). This leafhopper typically produces a single brood per year, although southern populations (such as those in the Hoosier National Forest) are double brooded. *Polyamia herbida* is never common (except on a very local level) and most records are based on one or a few individuals. The destruction of the nation's grasslands over the past 200 years has greatly reduced the amount and distribution of suitable habitat for this and many other species. Many records for this leafhopper date from 50-75 years ago and come from areas that are now completely urbanized or replaced with large-scale row crop agriculture. The few high quality fragments of suitable habitat that remain for this leafhopper are often small and highly isolated from one another. Numerous invasive species (both plant and animal) also pose imminent threats to the survival of many populations of this rare leafhopper. The adults of *Polyamia herbida* are funtionally flightless and sedentary, rarely stray far from their food plants. They are also sensitive to dormant season fires, beacuse they overwinter as eggs in dried grass stems. Therefore, a concentrated effort to identify populations prior to the initiation of burn management is warranted to avoid accidental extermination. The protection, restoration and expansion of known populations will be needed to ensure the long-term survival of the prairie bunchgrass leafhopper across its range.

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NOMENCLATURE AND TAXONOMY

The genus *Polyamia* was first erected as the subgenus "*Polyamius*" of *Deltocephalus* by Dwight DeLong in 1927. He and J. P. Sleesman later erected *Polyamia* to full generic status (DeLong and Sleesman, 1929). The prairie bunchgrass leafhopper (*Polyamia herbida*) was first described by DeLong in 1935, from specimens collected on sand prairies along the Illinois River in the northwest part of the state. *Polyamia saxosa*, almost identical and described a few years later, is now considered a color form of this species (Sinada, 1993). It is most closely related to the superficially similar *Polyamia compacta* and *P. interrupta.*

DESCRIPTION OF SPECIES

DESCRIPTION OF ADULT STAGE

The prairie bunchgrass leafhopper typically measures 2.5-3 mm (0.2 inches) in length. The top of the head (vertex) is yellow to orange-tan and marked with a series of distinguishing spots and dashes (see Figure 1). These markings vary greatly in size, from almost non-existent (*saxosa*) to large and dark (typical *herbida*). The face is the same color as the vertex, but is nearly covered with a paired series of black arcs, slightly visible from above. The forewings are short and leave the terminal abdominal segments exposed. The wings are dark, chestnut brown, with the veins being lighter tan and sometimes edged with white. The blocky cells, of the forewing are filled with the dark brown to blackish brown shade and may also be highlighted with white (see Figure 1). The hindwings are translucent and somewhat whitish. They are very short and the species is considered flightless.

Large populations of this leafhopper (although extremely rare) are typically variable, with the *saxosa* form being uncommon. The body is mottled chestnut brown and black, with markings of lighter brown and tan. The legs are mottled with dark brown, tan and blackish. *Polyamia herbida* is superficially identical to a number of other *Polyamia* (see DeLong, 1948). It is closely related to *Polyamia compacta* and *interrupta*. Given the extreme similarity between *Polyamia* species, their identification is best left to experts on the group. This species can only be seperated by careful examination of the markings on the vertex and the internal genitalia.

DESCRIPTION OF IMMATURE STAGES

Eggs of *Polyamia herbida* are minute and inserted into tissues of the leaves and culms of their foodplants. The eggs then overwinter in detritus around the base of the foodplants. The young nymphs are greenish white, and feed by sucking fluids from xylem tissue on the developing grass culms. As they grow, the nymphs become tan and brown dorsally, with a series of longitudinal stripes. They lack well-developed wings until the final instar and are comepletely flightless at all stages.

LIFE HISTORY

REPRODUCTION

Leafhoppers are hemimetabolous, meaning they pass through a gradual metamorphosis in which each stage resembles a small adult. The wings are at first minute and subsequently grow larger, with the adult stage being reached following the final moult (skin shedding event). In the north, adults appear in late summer (mid-August through September). They feed, mate and females lay eggs over a protracted period of a few weeks to a month or more. Adults of the genus *Polyamia* appear and lay eggs when *Panicum* grasses are beginning to set seed.

ECOLOGY

The food plants of *Polyamia herbida* in the Hoosier National Forest are small, clump-forming, panic grasses and this leafhoppers is only found in dry prairie and barrens remnants where these grasses are abundant and diverse (Bess, 2004a). Vegetation in these habitats is typically short in height (0.3-1 meters: ~1-3 feet) and dominated by little bluestem (*Schizachyrium scoparium*), panic grasses and forbs in the plant families Asteraceae and Fabaceae.

The adult brood period can last up to three months, during which they mate and females lay eggs in tissues of the larval food plant. The adults feed by sucking fluids from the phloem tubes in leave veins of their foodplants. Given their size, these leafhoppers are extremely long-lived and can survive for three months or more, but typically die with the onset of repeated hard frosts. In the extreme southern part of its range (Arkansas, Oklahoma and Texas), *Polyamia* adults may pass through the winter alive and resume feeding and egg laying in the spring (February-March). Therefore, some individual populations could live for eight months or more. In the Hoosier National Forest, adults are typically gone by mid-November (Bess, 2004a). The eggs hatch in the spring following re-newed growth of *Panicum*. It is presumed that the newly emerged nymphs immediately begin feeding.

DISPERSAL/MIGRATION

Polyamia herbida is generally regarded as rare and highly local in occurrence (see Figure 2). Given its specific foodplant requirements, this leafhopper rarely (if ever) leaves the dry native grasslands and their panic grasses. The adults are flightless and rather sedentary, typically moving carefully among plants, oftentimes crawling, rather than running or hopping and are inactive during the hottest parts of the day (Bess, pers. obs.). On hot, humid days, this species can be locally abundant in the upper layers of the *Panicum* vegetation around dusk. This may be preparation for mating flights as documented in other leafhopper taxa. The females lay numerous small eggs and probably disperse over a very small area during the course of their lives (~100 square feet). This leafhopper is not known to migrate.

OBLIGATE ASSOCIATIONS

The obligate habitat for the prairie bunchgrass leafhopper is high quality, dry native grassland containing an abundance of panic grasses. In the Hoosier National Forest, *Polyamia herbida* is associated with *Panicum* in dry prairie and barrens remnants on limestone (Bess, 2004a). This leafhopper rarely (if ever) occurs far from stands of the larval food plant(s). The prairie bunchgrass leafhopper also shares its habitat with a number of regionally and globally imperiled insect, plant and vertebrate species (see Bess, 1996, 2000, 2004a-b; Panzer et al., 1995).

HABITAT

Polyamia herbida occurs in a variety of grassland types, including glaciated, dry sand prairie-barrens, and unglaciated barrens and hill prairie. In the extensve sand dunes around southern Lake Michigan and the Kankakee River Valley, this leafhopper primarily occurs in dry sand barrens and sand prairie remnants where it is associated with *Panicum auburne, P. columbianum, P. depauperatum, P. oligosanthes, P. leibergii, P. lindheimeri, P. lineariifolium* and *P. villosisimum.* The herbaceous vegetation in these habitats is typically dominated by several sedges (*Carex longii, C. muhlenbergii, C. pennsylvanicum,* etc.) and short grasses. Typical grasses include three-awn (*Aristida intermedia* and *A. purpurascens*), poverty oatgrass (*Danthonia spicata*), Junegrass (*Kohleria cristata*) and little bluestem. Tall grasses like big bluestem and panic grasses are more local, typically in depressions or along waterways. Butterfly weed (*Asclepias tuberosa*), green milkweeds (*A. hirtella* and *A.viridiflora*), false indigo's (*Baptisia leucantha, B. alba, B. tinctoria*), bastard toadflax (*Commandra umbellata*), flowering spurge, wild strawberry (*Fragaria virginica*), prairie sunflowers (*Helianthus mollis, H. occidentalis*), bushclover (*Lespedeza capitata*), puccoon (*Lithospermum canescens*), rough blazingstar (*Liatris aspera*), cylindric blazingstar (*Liatris cylindrica*), lupine (*Lupinus perennis*), downy phlox (*Phlox pilosa*), bracken fern (*Pteridium aquilinum*), old-field goldenrod (*Solidago nemoralis*), showy goldenrod (*S. speciosa*), goat's rue (*Tephrosia virginica*), blueberries (*Vaccinium* spp.) and violets (*Viola lanceolata, V. sagitatta, V. pedata*) are characteristic forbs.

In the Flint Hills of east-central Kansas, *Polyamia herbida* is found in dry tallgrass prairie, being most frequent on ridgetops where *Panicum lindheimeri* and *P. oligosanthes* are often locally dominant. In Arkansas, this leafhopper occurs in high quality, sandy barrens very similar to those of northwest Indiana. *Panicum* species make up the most diverse (and often most abundant) genus of grasses in these habitats, especially on rocky, xeric sites. High quality barrens/dry prairie remnants in the Upper Coastal Plain and Ouachita Mts of Arkansas were found to support very large and diverse *Polyamia* fauna's (Bess, 1997a-b, 1998, 2000).

NATIONAL FORESTS: HOOSIER NF (PERRY CO., IN)

In extreme southern Indiana, *Polyamia herbida* is found on unglaciated limestone barrens feeding on *Panicum* in barrens and habitats similar to tallgrass prairie. In the Hoosier National Forest (HNF) of Indiana, the habitat for this leafhopper is considered exemplary for high quality remnants in the Ohio River Valley and is as described below. Here, populations of the prairie bunchgrass leafhopper are associated with eight or more species of panic grass (*Panicum anceps, P. boscii, P. depauperatum, P. dichotomum, P. latifolium, P. laxiflorum, P. lineariifolium* and/or *P. polyanthes*). These grasses are patchy in distribution within the Hoosier National Forest, being found primarily in isolated colonies on small roadside prairies, powerline rights-of-way and scattered throughout high quality, fire-maintained barrens. In barrens remnants, *Panicum* occurs on rock outcrops, steep slopes and areas of compacted or formerly eroded soils that are beginning to re-vegetate. They also form a subcanopy in the dry prairie, typically under a canopy of little bluestem.

SITE SPECIFIC

Hoosier NF: Boone Creek Special Area

The canopy is near 100 percent throughout much of the SA, but recent fire management has eliminated much of the subcanopy woody growth. This has allowed the herbaceous layer to flourish in a rich carpet of sedges (e.g. *Carex albicans, C. cephalophora, C. complanata, C. frankii, C. glaucodea* and *C. granularis*) and grasses such as big bluestem, wood oats (*Chasmanthium latifolium*), poverty oatgrass, rye grasses (*Elymus* spp.), little bluestem and panic grasses. Several of the panic grasses listed above are common to locally abundant throughout the SA. However, the leafhopper is only found in areas of minimal or no canopy, with extensive sun exposure throughout the day.

Characteristic forbs include agave (*Agave virginica*), pussytoes (*Antennaria plantaginifolia*), smooth blue aster, butterfly weed, pale Indian plantain (*Cacalia atriplicifolia*), bluebells (*Campanula americana*), New Jersey tea (*Ceanothus americanus*), tall tickseed (*Coreopsis tripteris*), partridge pea (*Cassia fasciculata*), sticktights (*Desmodium* spp.), purple coneflower (*Echinacea purpurea*), rattlesnake master, flowering spurge, woodland sunflower (*Helianthus divaricatus*), bush clovers, blazingstars (*L. aspera, L. spicata, L. squarrosa*), puccoon, bergamot (*Monarda fistulosa*), Sampson's snakeweed (*Orbexilum pedunculatum*), prairie phlox (*Phlox glaberrima*), downy phlox, narrow-leaved mountainmint (*Pycnanthemum tenuifolium*), gray coneflower (*Ratibida pinnata*), wild roses (*Rosa carolina* and *R. setigera*), prairie dock, three-leaved rosinweed (*Silphium trifoliatum*), American columbo (*Swertia caroliniensis*), goat's rue and tall ironweed (*Vernonia altissima*). There is approximately 20 acres of high quality *Polyamia herbida* habitat at Boone Creek, with another 200 acres of marginal habitat. Another very high quality "prairie-like" remnant of barrens occurs immediately across the road and to the north of the SA, to the west of where the gas pipeline crosses. This is where most *Polyamia herbida* were collected (Bess, 2004a).

Hoosier NF: Cloverlick Special Area

The Cloverlick Special Area is a ca. 1,300 acre complex of open and closed canopy oak and oak-pine barrens. This entire site was formerly open barrens and prairie, with old, widely spaced blackjack oaks, post oaks and hard pines in the canopy layer. Historically, a farm was developed here and part of the site was planted for soft pine timber production. Along with these activities came fire suppression, further degrading the barrens. Currently, much of the site is closed in with young oaks, maples (*Acer* spp.) and hickories (*Carya* spp.). However, recent restoration activities (including removal of the pine plantation) have opened approximately 200 acres of "prairie-like" barrens. The barrens grasslands at Cloverlick have been managed with manual cutting of brush and prescribed fire. This has resulted in a high quality, complex, with many open, "prairie-like" areas having local dominance by panic grasses. This site contains roughly 200 acres of high quality habitat for *Polyamia herbida*, with an additional 100-200 acres of marginal habitat.

In occupied *Polyamia herbida* habitat, the herbaceous vegetation is dominated by panic grasses and little bluestem. *Panicum* species grow profusely on the edges of these open, grassy barrens and tthroughout some of the smaller grasslands or "prairies". Additional common grasses include bluestems (*Andropogon glomerata A. elliottii* and *A. virginicus*), poverty oat grass (*Danthonia spicata*) and rye grasses (*Elymus hystrix, E. virginicus*). Sedges are also common

and often locally abundant, including *Carex albicans, C. cephalophora, C. complanata, C. glaucodea* and *C. rosea*. The nodding bulrush (*Scirpus pendulus*) and nutsedge (*Scleria oligantha*) are also common.

Characteristic forbs include; wild onion (*Allium canadense*), smooth blue aster (*Aster laevis*), white wild indigo (*Baptisia leucantha*), blue hearts (*Buchnera americana*), tall tickseed (*Coreopsis tripteris*), fuzzy sticktight (*Desmodium canescens*), shootingstar (*Dodecatheon media*), rattlesnake master (*Eryngium yuccifolium*), flowering spurge (*Euphorbia corollata*), cream gentian (*Gentiana alba*), downy sunflower (*Helianthus mollis*), bushclovers (*Lespedeza* spp.), blazingstars (*Liatris aspera, L. spicata* and *L. squarrosa*), bergamot (*Monarda fistulosa*), panic grasses (*Panicum spp.*), obedient plant (*Physostegia virginiana*), mountainmint (*Pycnanthemum pycnanthemoides, P. virginianum*), black-eyed susan (*Rudbeckia hirta*), wild petunia (*Ruellia humilis*), rose gentian (*Sabatia angularis*), three-leaved rosinweed (*Silphium trifolium*), prairie dock (*Silphium terebinthenaceum*), stiff goldenrod (*Solidago rigida*) and goat's rue (*Tephrosia virginiana*).

The community surrounding the grass and forb dominated openings is typically dry oak woodland or barrens, dominated by post oak (*Quercus stellata*), blackjack oak (*Q. marilandica*), white oak (*Q. alba*) and black oak (*Q. velutina*). Tuliptree (*Liriodendron tulipifera*), black gum (*Nyssa sylvatica*), sycamore (*Platanus occidentalis*) and red elm (*Ulmus rubra*) are also common, especially on fire suppressed remnants. Shrubs are diverse and can quickly dominate sites that are not periodically burned. Common shrubs include paw paw (*Asimina triloba*), redbud (*Cercis canadensis*), flowering dogwood (*Cornus florida*), hazelnut (*Corylus americana*), huckleberry (*Gaylusaccia baccata*), witch hazel (*Hamamelis virginiana*), Carolina buckthorn (*Rhamnus caroliniana*), raspberries (*Rubus alleghaniensis, R. occidentalis*), coralberry (*Symphoricarpos*), sassafras (*Sassafras albidum*), blueberries (*Vaccinium* spp.) and possum haw (*Viburnum rufidulum*). Closed canopy oak woodland and forest are generally inhospitable to both *Panicum* spp. and the prairie bunchgrass leafhopper.

Hoosier NF: Harding Flats Special Area

Harding Flats Barrens is another large barrens complex Special Area in the Hoosier NF. Here, *Panicum* is found in localized colonies occurring in roadside prairies and more open barrens, especially on the upper portions of south and southwest facing slopes. The canopy is near 100 percent throughout much of the SA, but recent fire management has eliminated much of the subcanopy woody growth in some areas. This has allowed the herbaceous layer to flourish in a rich carpet of sedges and grasses, as listed for other barrens sites within the HNF.

Characteristic forbs include agave (*Agave virginica*), pussytoes (*Antennaria plantaginifolia*), smooth blue aster, butterfly weed, pale Indian plantain (*Cacalia atriplicifolia*), bluebells (*Campanula americana*), New Jersey tea (*Ceanothus americanus*), tall tickseed (*Coreopsis tripteris*), partridge pea (*Cassia fasciculata*), sticktights (*Desmodium* spp.), purple coneflower (*Echinacea purpurea*), rattlesnake master, flowering spurge, woodland sunflower (*Helianthus divaricatus*), bush clovers, blazingstars (*L. aspera, L. spicata, L. squarrosa*), puccoon, bergamot (*Monarda fistulosa*), Sampson's snakeweed (*Orbexilum pedunculatum*), prairie phlox (*Phlox glaberrima*), downy phlox, narrow-leaved mountainmint (*Pycnanthemum tenuifolium*), gray coneflower (*Ratibida pinnata*), wild roses (*Rosa carolina* and *R. setigera*), prairie dock, three-

leaved rosinweed (*Silphium trifoliatum*), American columbo (*Swertia caroliniensis*), goat's rue and tall ironweed (*Vernonia altissima*). There is approximately 10 acres of known, high quality *Polyamia herbida* habitat at Harding Flats, with another 60-100 acres of marginal habitat.

DISTRIBUTION AND ABUNDANCE

RANGE-WIDE DISTRIBUTION

Polyamia herbida has a fairly limited range in eastern North America, being known from relatively few sites (see Figure 2). Most known records are from prairies and barrens in the Midwest, Ouachita Mountains and edges of the eastern Great Plains. Throughout its range, this leafhopper is considered rare and extremely local in occurrence. Many records consist of one or only a few individuals. Historically (prior to 1989), the species was known from only two sites, in central Illinois (DeLong, 1948).

Polyamia herbida is rarely observed and Sinada (1993) could locate only the original type series of specimens for her revision of the genus. All of these came from sand prairies along the Mississippi River in northwest Illinois. All other records from Illinois, Indiana, Kentucky and Minnesota are new to science. Dietrich (1997) stated that Andy Hamilton (a North American leafdhopper specialist with Agriculture Canada, Ottawa, Ontario) has also found this species in Michigan, Missouri, New York and Ontario. In the U. S., the only places where *Polyamia herbida* currently occurs in large numbers are 1.) Hoosier National Forest of southern Indiana; 2.) Barrens and prairie remnants of central and western Kentucky; and 3.) Dunes and sand plains of NW Indiana (see Bess, 1991; 2000; 2004). Panzer and associates have also reported this leafhopper in the Chicago region of Illinois, with records from ~8 high quality prairies, most on sand near Lake Michigan or the Kankakee River (Panzer, 2005 pers. comm.).

STATE AND NATIONAL FOREST DISTRIBUTION

The following state-level distribution information for the prairie bunchgrass leafhopper is gathered from Bess (1991, 1996, 2001, 2004, 2005), Blocker and Reed (1976); DeLong (1948); Panzer (2005 pers. comm.). National Forest information is provided for the Hoosier National Forest in Indiana. When known, county-level comparisons with National Forest boundaries were also made for each additional state occupied by the leafhopper. Known or potential occurrences for military installations and other federal landholdings have been included when relevant.

Arkansas

A single record for this species is known from the Pine Bluff Arsenal in Jefferson County (Bess, 1998). This Department of Defense (USDoD) facility contains robust populations of several globally imperiled species (see Bess, 1997, 1998). Suitable habitat for this leafhopper occurs elsewhere in the state, especially in the Ouachita and Ozark National Forests. *Polyamia herbida* was also collected from high quality alkaline prairie on the Rick Evers Grandview Prairie Fish and Wildlife Area in Hempstead County (see Bess, 2000).

Illinois
There are roughly 13 populations in the northern part of the state (Panzer 2005, pers. comm.). There are no known National Forest occurrences. Suitable habitat for this species likely occurs in the Shawnee National Forest, but no surveys have been undertaken to date. *Polyamia herbida* is currently known from a number of fire-maintained prairie preserves, including the Savanna Army Depot (USDoD). This species was originally described by Dwight DeLong from specimens collected in Illinois (DeLong, 1935).

Indiana
Polyamia herbida is known from 9 sites in the state, 6 of which are in the NW corner (see Figure 2). Most of these are small and occur on Nature Preserves owned and managed by the State of Indiana, The Nature Conservancy or private, not-for-profit organizations such as The Shirley Heinze Land Trust. A few scattered populations occur in the Indiana Dunes National Lakeshore. A number of small, scattered populations occur on Nature Preserves in or near the Kanakakee Sands Restoration managed by The Nature Conservancy. A large metapopulation occurs within the Hoosier National Forest.

Kansas
There are records for *Polyamia herbida* from the Flint Hills of Kansas, all in the eastern half of the state. No National Forests occur in eastern Kansas.

Kentucky
Known from a few high quality barrens sites in the central and western portion of the state. There is additional potential habitat for this species in the Daniel Boone National Forest, the Fort Knox Military Reservation and at Mammoth Cave National Park.

Michigan
A single population is known from Michigan, on a small prairie remnant in the west-central part of the state. Additional potential habitat for this species occurs in the Huron-Manistee National Forest and the Allegan and Barry State Game Areas. Very limited leafhopper sampling has been undertaken in the state.

Minnesota
Recorded for the first time in the state in 2005, from two bluff prairies in the SE part of the state.

Wisconsin
Populations occur on dry native prairie remnants in several counties scattered across the southern two-thirds of the state. There are no known National Forests occurrences.

RANGE WIDE STATUS

Polyamia herbida is considered imperiled by most states in which it occurs (NatureServe, 2005). Even in its supposed stronghold (Illinois, Indiana and Wisconsin) there is strong evidence to conclude that the prairie bunchgrass leafhopper is imperiled. This is especially true with regards to its preferred habitats; high quality dry prairie and barrens having a diverse and abundant assemblage of clump-forming panic grasses. The following information was gathered (in part) from the NatureServe.org Website in October of 2005. Global and National ranks in ( ) are herein proposed for this species.

Global Status: GNR (G2G3)
Global Status Last Reviewed: - (October, 2005)
Global Status Last Changed: GNR
Rounded Global Status: GNR (G2)
National Status: GNR (N2)
Status and Ranking by: J. A. Bess

State-level Status (S-Ranks)
The NatureServe Website contains no information on this species other than a few state ranks (IN: S1S3, KY: SNR). It would easily rank as an S2 or S1S3 in all states from which it is known. All other states have the species either listed as Not Ranked or Unrecorded. Indiana has listed *Polyamia herbida* as a state threatened species (INDNR, 2005). Illinois and Wisconsin have this leafhopper listed as a "Species of Conservation Concern". Missouri, Iowa, Kansas and Tennessee all contain fairly extensive amounts of potential habitat for this species but are poorly sampled for leafhoppers, especially the *Polyamia*.

POPULATION BIOLOGY AND VIABILITY

Prior to European settlement of the continent, *Polyamia herbida* and it food plants probably occurred on native grasslands from eastern Minnesota and Iowa east to Ohio and south to Louisiana and Texas. The rapid transformation of the eastern Great Plains from native pasture to intensive row crop agriculture following World War II led to a reduction in habitat acreage for this and other grassland species. Fire suppression in the barrens of the Ohio Valley and Ozark regions from the mid-1800's on also greatly reduced available habitat for this species and isolated the remaining populations. Today, this leafhopper exists as a collection of isolated subpopulations varying greatly in size, many of which may no longer exist.

POTENTIAL THREATS

PRESENT OR THREATENED RISKS TO HABITAT

The prairie bunchgrass leafhopper's historic habitats were once extensive prairies, savannas or barrens, maintained by periodic fire (Anderson et al., 1999; Delcourt and Delcourt, 1997; Dorney and Dorney, 1984; Grimm, 1984; Henderson and Long, 1984; Higgins, 1986; Komarek, 1971, 1985; Lynch, 1941; Nuzzo, 1986; Tester, 1989, White, 1983). Currently however, the amount of available habitat for this species has been greatly reduced through fire suppression, overgrazing,

the conversion of prairies and fens to row crop agriculture, road construction, hydrologic manipulation and other human activities.

The remaining suitable habitat for *Polyamia herbida* typically occurs as small (10 acres or less), highly isolated grasslands, separated from one another on the landscape by vast expanses of either dense forest or agricultural lands, urban/suburban sprawl and other man-made habitats. In addition, the environmental forces that once created and regulated these grasslands (e.g. fire, bison herds, prairie dog towns) are no longer functioning. Invasive, non-native plants have also colonized these degraded habitats and are currently invading many remnant natural areas. The prairie bunchgrass leafhopper is also susceptible to depredation by a variety of insect predators and parasites. Because of its overwintering characteristics, this leafhopper is highly susceptible to immolation during dormant season fires and small, isolated populations can be easily eradicated when fire consumes their habitat completely. Real and potential threats to this species and its habitat are outlined below.

Row Crop Agriculture

The conversion of much of the Great Plains and central Midwest to large scale row crop agriculture following World War II coincided with a precipitous loss of prairie habitat (see Hutchinson, 1996). Up until this time, most U.S. farms were small and diverse, geared towards self-sustenance and supplying small local economies. Often, wetter parts of the land were placed under pasture or ignored and fencerows were common. Marginal areas of farmland often contained a diverse assemblage of prairie plants, associated insects and other organisms. These conditions were rapidly changed with the development of hybrid seeds, insecticides, herbicides and the entrance of the U.S. into the global food economy. Fencerows and pastures were knocked out to make way for large-scale machinery to till and plant vast stretches of corn, rice, cotton and soybean monocultures. Center-pivot irrigation allowed many formerly unfarmable acres to be tilled, especially in the drier, sandy prairies and barrens of the Midwest and Great Plains.

Fire Suppression

The suppression of wildfires in eastern North America following European colonization is among the more profound changes to the North American environment in the past 5,000 years (see Heinselman, 1981; Nuzzo, 1996). Fire is known to regulate vegetation structure, which has a reciprocal influence on fire frequency (Anderson et al., 1970; Anderson and Brown, 1986; Anderson et al., 1999; Auclair, et al., 1973; Bancroft, 1977; Cohen et al., 1984; Daubenmire, 1968; Duever, et al., 1986; Forman, 1979; Glasser, 1985; Henderson and Long, 1984; Kozlowski and Ahlgrens, 1974; Schwaegman and Anderson, 1984; Tester, 1989; Wade, et al., 1980; Weaver, 1954; Weaver and Fitzpatrick, 1934; Wells and Boyce, 1953; Wright and Bailey, 1982). In the absence of fire, many formerly open, grass-dominated plant communities have quickly succeeded to shrublands and closed canopy forests.

It has been well documented that many North American grass dominated plant communities burned with relative frequency in the past (Bayley and Odum, 1976; Bancroft, 1977; Cohen, 1974; Cohen, et al. 1984; Cypert, 1961; Duever, et al. 1986; Forman, 1979; Foster and Glaser, 1986; Garren, 1943; Glasser, 1985; Henderson and Long, 1984; Higgins, 1986; Kirby, et al., 1988; Komarek, 1971: Lotan, 1981; Loveless, 1959; Penfound, 1952; Schwegman and

Anderson, 1984; Thompson, 1959; Weaver and Alderson, 1956; Wells, 1931, 1942). Many of the plants occurring in these communities are also "fire-dependent", meaning they require periodic fire for their long-term survival (Anderson et al., 1970; Arend and Scholtz, 1969; Daubenmire, 1968; Hulbert, 1969, 1981; Knapp and Seastadt, 1986; Peet et al., 1975; Thor and Nichols, 1973; Tilman, 1987; Weaver, 1954; Weaver and Fitzpatrick, 1934; Whitford and Whitford, 1978; Wright and Bailey, 1982).

In degraded remnants of these habitat-types, prescribed burning relaxes competition from invading, non-fire adapted plants, allowing fire-adapted species to proliferate and expand into newly opened areas (Allan and Anderson, 1955; Anderson and Brown, 1986; Britton, et al., 1980; Daubenmire, 1968; Dorney and Dorney, 1989; Grimm, 1984; Henderson and Long, 1984; Kozlowski and Ahlgren, 1974; Kline, 1984; Lotan et al., 1981; Miller, 1963; Schwartz and Heim, 1996; Schwaegman and Anderson, 1984; Tester, 1989; Tester and Marshall, 1962; Uhler, 1944; White, 1983; Wright and Bailey, 1982). Fire also reduces canopy cover of woody species and removes accumulated detritus (Gresham, C. A. 1985; Linde, 1969; Linduska, 1960; Miller, 1963; Van Lear and Johnson, 1983; Witford and Whitford, 1978). This allows more sunlight to reach the soil surface, resulting in increased photosynthetic productivity in the herbaceous flora (Allan and Anderson, 1955; Auclair, et al. 1973; Cohen, 1974; Dorney and Dorney, 1981; Lorimer, 1985; Smith and Kadlec, 1985; Thor and Nichols, 1973; U.S. Fish and Wildlife Service, 1964). Burning also releases nutrients, although their availability is often limited temporally (Bancroft, 1977; Bayley and Odum, 1976; Faulkner and de la Cruz, 1982)

Severe fires during drought periods can also alter the physical characteristics of grasslands by burning deep into mineral soil (Allan and Anderson. 1955; Bancroft, 1977; Cohen, 1974; Lynch, 1941; Miller, 1963; Wein and Maclean, 1983). Changes to the vegetative structure of grasslands can have profound effects on the local fauna. Frequent fires typically favor species that require grass, sedge and herb dominated vegetation as habitat for feeding, resting, mating, breeding or other activities. The reduction in woody cover and detritus accumulation further improves habitat for some species, while removing habitat for others. For example, in times of extreme fire or erosion, in which the organic layers are lost from the soil profile, the resulting conditions are often hostile to many plant species. However, in certain barrens communities, where *Panicum* species are frequent, they are often observed as some of the first colonizers on these infertile, and often acidic, soils. This favors *Polyamia* species over other leafhoppers and often these leafhoppers and their foodplants will occupy a site for some time before additional grasses begin to compete.

Fire Management

In the case of *Polyamia herbida*, fire causes direct mortality of its overwintering stages, given their location in the previous year's detritus on the soil surface. Conversely, the primary food plant, *Panicum spp.*, responds favorably to burn management through an increase in above-ground biomass, number of flowering stalks and increased seed production (Dokken and Hulbert, 1978; Hulbert, 1969, 1981). However, under frequent fire management and on certain soils, panic grasses will decrease in abundance, often being replaced by little bluestem (Oregon State, 2005). Therefore, although fire is essential to the long-term survival of *Polyamia herbida* habitat, some precautions are necessary to ensure that the entire population of leafhoppers (or panic grasses) is not contained in a single burn unit. Both species respond favorably to burn rotations (per unit) of 2 to 4 years (see Dokken and Hulbert, 1978; Panzer, 1998). In the southern part of its range, *Polyamia*

herbida is double brooded and the second generation of adults is typically larger than the earlier one. These adults can move into recently burned habitat, allowing them to more rapidly colonize new habitat than more northern populations. The increased production in panic grasses following fire greatly favors the leafhopper and the species typically responds to pre-burn population levels in 2 years following burning of an occupied burn unit (Panzer, 1988).

Grazing

Domesticated cattle will eat panic grasses, but they typically grow low to the ground and are not preferred forage. Horses can crop grass much lower to the ground and will eat *Panicum*. Goats, sheep, and pigs will remove all edible green foliage from a pasture. Although direct mortality would be of prime concern, continued grazing would also stress or eliminate individual plants, reducing the amount of food available to subsequent generations of the leafhopper. Grazing would also reduce or eliminate flower and seed production, further limiting the amount of *Panicum* that will re-colonize previously disturbed areas.

Extensive livestock grazing also reduces the cover of native grasses and forbs on which the adult prairie bunchgrass leafhopper depends for resting places and shade. Repeated heavy grazing degrades native plant communities, disturbs and compacts the soil and can kill the original flora; providing germination sites for invasive weeds, shrubs and young trees (Tester and Marshall, 1962). It can also lead to rapid soil erosion, especially on hilly and/or rocky sites. Particularly in the Ohio Valley grasslands inhabited by *Polyamia herbida*, the thin underlying soils are easily disturbed and overgrazing often leads to destruction of the vegetation and widespread erosion of topsoil. For example, in Perry County, Indiana, it is reported that all upland soils have been stripped of their original A and B soil horizons through severe erosion (USDA Soil Conservation Service, 1969). These factors have undoubtedly combined to make many sites formerly suitable for this species currently unfit as habitat.

Pasture Development

Intimately associated with grazing is the development and maintenance of sustainable pastures. In prehistoric times (and locally in our recent history) pastures have been developed, maintained and enhanced through the use of fire (Allan and Anderson, 1955; Anderson, 1996; Britton, et al., 1980; Anderson et al., 1970; Cohen, 1974; Heinselman, 1981; Henderson and Long, 1984; Komareck, 1971; Lynch, 1941; Miller, 1963; Nuzzo, 1986; Uhler, 1944; Sipple, 1978, 1979; USFWS, 1964; Wells, 1931, 1942). Fire removes the accumulated duff, kills seedlings and saplings of woody species and provides germination sites for the seeds of fire adapted grassland plants (see Anderson et al., 1970, 1984; Daubenmire, 1968; Dorney and Dorney, 1989; Grimm, 1984; Henderson and Long, 1984; Knapp and Seastedt, 1986; Packard, 1988; Peet et al., 1975; Schwaegman and Anderson, 1984; Tester, 1989; Thor and Nichols, 1973; Tilman, 1987; White, 1983; Whitford and Whitford, 1978; Wright and Bailey, 1982). Prehistoric Native Americans were typically concerned with providing feeding grounds for game animals and the production of native plant crops (Anderson et al., 1999; Delcourt and Delcourt, 1997). European immigrants initially used fire to clear brush and enhance the growth of grasses and other plants that provided forage for their domesticated livestock. Unfortunately, excessive numbers of animals were often placed on grasslands with marginal amounts of available forage, leading to the destruction of the native vegetation and erosion of topsoil.

In the early 1800's, when America experienced its first great wave of westward expansion by Europeans, most formal training on the subject of pasturage was based in Europe. Therefore, nearly all American pasture development, enhancement or maintenance projects at that time were based on experience with the cool-season grasses native to northwestern Europe. Many overgrazed pastures formerly dominated by warm-season native grasses were subsequently replanted with cool-season, Eurasian grasses. These grasses were thought to be superior because they remained green throughout much of the growing season. Extensive pasture replanting and "enhancement" efforts further limited and fragmented the amount of available habitat for organisms dependent on native grasslands. This isolation of often small populations can lead to inbreeding and extinction (see Wilson and MacArthur, 1967).

Species typically used in dry pasture "enhancement" or "restoration" include redtop (*Agrostis alba*), smooth brome (*Bromus inermis*), fescue (*Festuca elatior* and others), reed canary grass (*Phalaris arundinacea*) and Kentucky bluegrass (*Poa pratensis*). On less saturated soils, legumes such as clovers (*Melilotus* and *Trifolium* spp.), alfalfa (*Medicago sativa*) or black medic (*Medicago lupulina*) are often placed in the grass mix to provide nitrogen fixation in the soil and fodder for livestock. On drier sites (especially in sand), grasses such as smooth brome, crested wheatgrass *(Agropyron cristatum*), bluegrasses and greasegrass (*Tridens flava*) are often planted as pasture enhancers. Non-native clovers and alfalfa are often included in the pasture mix.

These methods have become indoctrinated into our system of land reclamation and persist to this day. By producing large amounts of seed that germinate under cool temperatures, these European grasses and clovers can quickly dominate areas of exposed soil and move into adjacent native habitats. They compete with native species for resources and can exclude many of them from sites where they were formerly common, especially following disturbance of the original vegetation. Farmers and ranchers often spray herbicides to remove unwanted broadleaf species (such as panic grasses) from grass pastures. These factors eliminate potential habitat for the prairie bunchgrass leafhopper, particularly along fencerows, ditches and roadsides.

Only in the past 20 years have native species been actively marketed as alternatives for use in erosion control, bank stabilization and pasture or range enhancement. Recent research has found that, despite their widespread use, non-native pasture grasses and legumes often harbor large populations of pest leafhopper species (typically 10 times those found on adjacent native pastures), with many of them also being non-native (Bess, et al., 2004). The inclusion of alfala and sweet clovers in the pasture greatly increases the abundance of non-native pest species. Native grass and forb species provide much better sustainable forage over the course of the growing season and support fewer agricultural pest insects.

Competition from Introduced Species

In addition to the pasture species mentioned above, a number of other introduced plants threaten the quality and long-term survival of habitat for the prairie bunchgrass leafhopper. It is estimated that the U. S. government spends 138 billion dollars each year in damage from introduced species and their control efforts (BASF, 2005). In the Great Plains, these include downy brome (*Bromus tectorum*), musk thistle (*Carduus nutans*), spotted knapweed (*Centaurea maculatum* and others), Canada thistle (*Cirsium arvense*), leafy spurge (*Euphorbia esula*), St.

Johnswort (*Hypericum perforatum*), whitetop (*Lepidium draba*) and many others (see McKnight, 1993; Miller, 2003; Swearingen, 2004).

In more dry prairies of the Midwest, non-native pasture species such as bluegrasses, smooth brome and fescue often dominate what were once native grasslands. Sweet clovers (*Melilotus* spp.) and perennial clovers (*Trifolium* spp.) are also frequently planted in pastures, with the former occurring as weeds across much of North America, often to the exclusion of the native flora. Canada thistle and spotted knapweed are also noxious weeds in these habitats, with the latter being a particular nuisance on open sandy sites. Japanese honeysuckle (*Lonicera japonica*), bush honeysuckle (*Lonicera mackii* and *S. tartarica*), glossy buckthorn (*Rhamnus cathartica*) and multiflora rose (*Rosa multiflora*) are frequent invaders on fire suppressed native grassland remnants. Many native trees and shrubs such as junipers (*Juniperus* spp.), oaks (*Quercus* spp.), pines (*Pinus* spp.), cherries (*Prunus* spp.), sumacs (*Rhus* spp.) and snowberry (*Symphoricarpos*) can also overtake fire suppressed or otherwise disturbed grasslands.

Autumn olive (*Eleagnus umbellatus*), Japanese honeysuckle, bush honeysuckles and glossy buckthorn have long been used for landscape and wildlife plantings. These shrubs produce large numbers of berries, which are readily eaten by birds and redistributed across our woodlands and open areas. They are now a common (often dominant) component of many former natural areas. Both *Lonicera* and *Rhamnus* species can become so abundant as to exclude nearly all other flora from the ground and shrub layers. They are especially abundant in woodlands and barrens that have experienced a history of grazing that reduced the native vegetative cover and can move into formerly open, grass dominated areas with great speed. Some, such as Japanese honeysuckle, can be controlled with fire management. All can be controlled with manual cutting and herbicide application, although re-infestations are often inevitable (Luken et al., 1997). Multiple year, intensive control programs must be implemented to effectively eliminate these species even on the smallest natural areas.

Disease or Predation

A number of insectivorous animals feed on leafhoppers (Perkins, 1905; Waloff, 1980). These include; dragonflies (Odonata), robber flies (order Diptera: family Asilidae), bullet-head flies (Diptera: family Pipunculidae), twisted-wing parasites (order Strepsiptera), spiders (numerous families) and a variety of parasitic wasps (primarily families Dryinidae, Mymaridae and Trichogrammatidae). The effect of these depredations can be devestating on small, isolated populations of these leafhoppers. Mymaridae and Trichogrammatidae lay their eggs inside leafhopper eggs. Typically these single wasp eggs immediately divide into dozens or hundreds of clones, which each then develop into larvae and adults. The leafhopper egg is always killed in the process. Bullet-head flies typically catch leafhoppers in the air or resting on plant spems and lay their eggs directly on them. The hatching larvae burrow into the leafhopper's skin and feeds on the internal organs. Typically, the leafhopper dies when the fully developed larva leaves the leafhopper, pupates and emerges as an adult.

Twisted-wing parasites go one step further, causing infected leafhoppers to undergo physical changes in which the genitalia do not fully develop, thus rendering these individuals sterile. In Montana, 25 percent or more of various leafhopper species were infected with Dryinid wasp parasites (Bess, unpub. data). Although these particular parasites do not typically kill their hosts

until late in life, they must certainly have a negative effect on their development and likely reduce fecundity. Dryinid wasp females will typically sting numerous leafhoppers, feed on hemolymph (bodily fluids) that exude from the wound and then do not lay an egg. These stung leafhoppers rarely recover (see Guglielmino and Olmi, 1997; Perkins, 1905; Waloff, 1980).

Insect Pest Control Efforts

Numerous species of leafhoppers are known vectors of plant diseases, causing millions or billions of dollars in crop losses and reduced yields around the world. Therefore, a large part of the annual insect control effort in this country is aimed at eliminating these insects. Although *Polyamia herbida* and related species are not known to be vectors of any plant diseases, they can be negatively impacted by control efforts aimed at pest species. A number of insect pest species can also occur in wooded areas adjacent to *Polyamia herbida* habitat, particularly in barrens. These include the gypsy moth (*Lymantria dispar*), emerald ash borer beetle, pine shoot tip moth and many others. Control efforts aimed at these species have potential to negatively affect *Polyamia herbida* populations in the event of direct contact during broadcast spraying of insecticides or drift of these pesticides from adjacent control areas.

For example, attempts to eradicate the gypsy moth in the middle of the 20th century involved the use of broad scale organophosphate insecticides such as DDT and Carbaryl. These spraying campaigns covered over 12 million acres in the northern and central Appalachians and affected a wide array of organisms, insects and non-insects alike (Schweitzer, 2004b). Chemicals such as DDT also accumulate in successive trophic levels as they pass through an ecosystem. Organisms at the top of food chains (such as insectivores and their predators) develop ever-increasing levels of toxins, causing death and/or reduced fecundity. Given the widespread, catastrophic effects of DDT and Carbaryl spraying, these pesticides have been banned in the United States.

In 1976, the insect growth inhibitor Diflurobenzuron (trade name Dimilin or Vigilante) was registered to control pest insects, while eliminating the indiscriminate poisoning of other organisms (see Schweitzer, 2004). Diflurobenzuron inhibits the formation of chitin, a protein that is the principal component of most arthropod exoskeletons. It only affects young insects, killing them when they go through their next moult ("skin shedding event"). Many fungi also contain chitin in their cell walls, and may also be affected (Dubey et al., 1995). Like the earlier pesticides, Dimilin kills insects (and most other Arthropods) indiscriminately across all orders (see Uniroyal Corp., 1983). The chemical also has a long-lasting residual effect by becoming bound to leaves (particularly conifers) and remaining active even after leaf fall (Martinat et al., 1987; 1988a-b; Mutanen et al., 1988; Whimmer et al., 1993). Both aquatic leaf shredders and terrestrial detritivores that feed on these fallen leaves are highly susceptible to this chemical (Bradt and Williams, 1998). Widespread mortality has been documented in the field and laboratory, in both aquatic and terrestrial ecosystems (Bradt and Williams, 1990; Butler et al., 1997; Dubey et al., 1995; Hansen and Garten, 1982; Lih et al., 1995; Martinat et al., 1987, 1988a-b; 1993; McCasland et al., 1998; Mutanen, et al., 1988; Reardon, 1995; Swift et al., 1988).

In addition to indirect threats, leafhoppers face many direct ones as well. Researchers (e.g. Bethke, et al., 2001) are constantly testing the use of several kinds of insecticides and different application methods for the control of leafhopper pests. To minimize negative effects on non-target species, applied entomologists have endeavoured to find or design new control methods

that more closely target the pest species. Researchers are continuously assessing a variety of predatory and parasitic species for this purpose. All of the above-mentioned parasitic insect groups are potential biocontrol agents for pest leafhopper species. Therefore, buildups in local populations of these parasites in agricultural lands would certainly have potential for negatively affecting populations of *Polyamia herbida* in adjacent habitats.

Research is also underway to promote the use of insect pathogens such as *Hirsutella* sp., a fungus that is known to affect leafhoppers in the southeastern United States. All of these control methods have great potential to negatively affect *Polyamia herbida* through mortality from increased rates of parasitism and disease infection, when applied in adjacent or occupied habitats. Depending on how widely and frequently these agents are used they could begin to affect our ecosystems as a whole.

Over utilization

The prairie bunchgrass leafhopper's small size and secretive habits make it relatively difficult to collect on a large scale. There is currently no market for rare leafhoppers and little chance that it will be over-utilized. However, activities that reduce standing crop of Indiangrass on occupied sites should be seen as detrimental to the leafhopper. These activities include heavy grazing, ATV or horse traffic, heavy foot traffic, mowing, salt runoff, fire, tree plantings in prairie or barrens, etc.

Residential Development

Residential Development can negatively affect habitat for *Polyamia herbida* in a variety of ways. The clearing of sites for houses and associated roadways eliminates habitat and divides what remains into highly isolated islands, separated by paved streets, parking lots, lawns and other habitats inhospitable to the butterfly. Lawn development and maintenance eliminates the native flora, and drift of herbicides and insecticides has a cumulative effect in deteriorating what remains in adjacent natural areas. Fertilizer and pesticide runoff can also contaminate adjacent natural areas, enter streams and rivers and can degrade local and regional water quality (Medina, 1990).

In southern Indiana and Kentucky barrens, high-end and exclusive residential developments are currently being located directly in high quality remnants of these habitats, typically in rural areas within a short drive of nearby metropolitan hubs such as Louisville or Paducah, Kentucky. The entire town of Louisville, KY occupies a huge open, former barrens area colonized in the early 1800's. Infrastructure to maintain and service these developments includes roadways, ditches and utility rights-of-way, whose construction often has extremely deleterious effects on occupied and potential habitat for the leafhopper and its foodplants.

Inadequacy of Existing Regulatory Mechanisms

The lack of any long-standing national program to protect and restore the nation's grasslands has led to the degradation of millions of acres of former native pasturage. In addition, the current, species-based approach to federal laws regarding the protection of imperiled organisms does not currently afford legal protection to the prairie bunchgrass leafhopper. This is despite the fact that its global rarity would make it a candidate for listing as a federally threatened species. A system for environmental protection and restoration based on the conservation of ecological associations

or plant communities would be more appropriate for protecting many of the Nation's natural resources. Many organisms are endangered simply because their habitats are becoming increasingly fragmented and degraded by human activity. This is especially true for those requiring dry prairie or open barrens, which were some of the first habitats colonized by early European settlers and targeted for building homesites and towns. Federally mandated efforts to restore our Nation's prairies and barrens would not only protect hundreds of species from impending doom, but also provide our human population with expanded opportunities for jobs, hunting, fishing, gathering of natural products, education, research, observation and enlightenment.

SUMMARY OF LAND OWNERSHIP & EXISTING HABITAT PROTECTION

The U. S. Forest Service owns occupied prairie bunchgrass leafhopper habitat in Indiana and possibly other states (e.g. AR, IL, KY, MI, MO). Additional U. S. landholdings with occupied or potential habitat for the species are also known. State and privately managed lands (e.g. Wildlife Refuges, Nature Preserves, Conservation Areas, etc.) are also known to contain occupied or potential habitat for this species. State-level efforts at the conservation, restoration and management of high quality grassland and wetland remnants continue to protect populations of this and other rare species.

Federal congressional efforts have included grassland and wetland protection and restoration as important platforms in the most recent National Farm Bills. Iowa and Indiana have been key players in this effort to restore some of our native grasslands and wetlands. The state of Iowa is also undertaking an ambitious project to create or restore grassland all along Interstate 80 and other major highways. In Indiana, the Hoosier National Forest continues to acquire, protect and manage barrens remanants for the conservation and enhancement of native biodiversity. The State of Illinois is actively managing several known populations of this species on Nature Preserves under their stewardship. Minnesota and Wisconsin are also actively inventorying and managing native grassland remnants containing occupied and potential habitat for this species.

SUMMARY OF EXISTING MANAGEMENT ACTIVITIES

Little or no management is currently being directed at prairie bunchgrass leafhopper habitat based solely on the species' presence or absence. However, the preferred habitat for *Polyamia herbida* happen to include globally imperiled plant communities; dry silt loam prairie, dry-mesic sand prairie, clay soil prairie/barrens and oak-pine barrens complexes. Therefore, *Polyamia herbida* habitat has received some management, given ongoing efforts to protect and restore these rare plant communities. Programs to manually remove exotic and native invasive plants (as mentioned in previous sections) have benefited this species, by opening the canopy and reducing competition with its foodplants.

In most areas, grassland restoration and management has depended on prescribed fire as a primary tool. Given that panic grasses respond favorably to fire, *Polyamia herbida* is found more commonly in fire maintained areas than in those that have been fire suppressed. This is true elsewhere in its range and many historic sites are currently overgrown with shrubs because of fire suppression and other alterations of the environment. However, the species is extremely

sensitive to eradication during dormant season burns because the eggs overwinter in the previous years' detritus, which is highly combustable.

Therefore, on occupied sites, efforts must be undertaken to delineate the population boundaries prior to a prescribed burn and divide the population between burn units (at least two, preferrably four). By ensuring that at least half of the population remains unburned during a given prescription, individuals will survive to re-populate the newly restored habitat. In the case of sites having two burn units, at least two growing seasons should pass before the adjacent unit is burned. On sites containing four or more units, a given, occupied burn unit should receive fire on a three year or greater rotation (depending on site characteristics and burn prescription). In a single year, no more than 25 percent of occupied *Polyamia herbida* habitat should be burned at a given site.

PAST AND CURRENT CONSERVATION ACTIVITIES

The prairie bunchgrass leafhopper has always been reported as rare and local, though not usually from a conservation standpoint. Conservation of this species has typically been an incidental by-product of efforts to protect and restore remnants of our native grassland flora. Only recently have researchers begun to suggest that the prairie bunchgrass leafhopper is indeed imperiled and that efforts should be undertaken to identify known and active populations, and begin to assess their health and needs for continued survival. Currently, the prairie bunchgrass leafhopper is considered State Threatened in Indiana (INDNR 2005) and proposed as a "Species of Conservation Concern" in Illinois and Wisconsin (IL DNR, 2005; WI DNR, 2005).

RECOMMENDATIONS

In most areas, grassland restoration and management has depended on prescribed fire as a primary tool. Given that panic grasses generally respond favorably to periodic fire, *Polyamia herbida* is found more commonly in fire maintained areas than in those that have been fire suppressed. This is true elsewhere in its range and many historic sites are currently overgrown with shrubs because of fire suppression and other alterations of the environment. However, this leafhopper is extremely sensitive to eradication during dormant season burns because the eggs overwinter in the previous years' detritus, which is highly combustable.

Therefore, on occupied sites, efforts should be undertaken to delineate the boundaries of known population prior to a prescribed burn, and to divide the population between burn units (at least two on large (>100 acre sites) and four on small (<100 acres) sites). By ensuring that at least half of the population remains unburned during a given prescription, individuals will survive to re-populate the newly restored habitat. In the case of sites having two burn units, at least two growing seasons should pass before the adjacent unit is burned. On sites containing four or more units, a given, occupied burn unit should receive fire on a three year or greater rotation (depending on site characteristics and burn prescription). That is, two full growing seasons should occur within a given burn unit, between burns. In a single year, no more than 25 percent of occupied *Polyamia herbida* habitat should be burned on small sites (<20 acres).

RESEARCH AND MONITORING

Currently, little research is being conducted regarding *Polyamia herbida* except for general surveys (see Bess, 1996, 2001, 2004; Panzer et al., 1995) and some fire studies (Panzer and Schwartz, 1998). Much is still unknown about this species, particularly regarding its ability to move between areas of suitable habitat. It is recommended that (whenever feasible) restoration projects involving native grasslands track the effects of restoration techniques on fire-sensitive, globally imperiled species (such as *Polyamia herbida*) when they are present or known to occur nearby. As with many things, the ability of regional land managers to undertake such studies is limited by funding and availability of expertise. To this end, long-term monitoring of the insect fauna occurring in grassland restorations would address the fundamental question of whether such projects actually provide habitat for rare and imperiled organisms or are merely glorified "flower gardens". Once available, such information would allow land managers to measure the effectiveness of a variety of techniques, ultimately leading to more effective restoration of these ecosystems and protection of the rare species they contain.

The food plants of this leafhopper are attractive species and serve as food plants for a number of very rare grassland insects. They also produce seeds that are food for a variety of songbirds. The preferred habitats of the prairie bunchgrass leafhopper are visually attractive, although sometimes too attractive. These features make our barrens and dry prairies excellent candidates for raising public awareness of (and funding for) grassland protection, management, restoration and creation.

EXISTING SURVEYS, MONITORING, AND RESEARCH

Many of the historic sites for this species in Kentucky have not been visited in nearly 15 years. Verification of all historic occurrences and accompanying population estimates should be an early priority for research on this species. At the present time, little to no monitoring or survey work is being focused on this species in Kentucky, despite its general rarity and the number of major sites for this species in that state. However, recent surveys for rare insects on the Hoosier National Forest uncovered new populations of *Polyamia herbida* in southern Indiana (Bess, 2004). On-going surveys are being conducted for this and other rare prairie insects, statewide (Bess, 1999, 2000, 2001, 2004, 2005). Dr. Ronald Panzer (Northeastern Illinois University) has been surveying for and monitoring this species in Illinois and Indiana for 20 years. Dr. Panzer has also conducted numerous fire effects studies on sites containing *Polyamia,* in addition to exhaustive surveys of the grassland insect fauna occurring in the greater Chicago region (Panzer, 1998; Panzer et al., 1995).

SURVEY PROTOCOL

Surveys should initially be focused around known historic populations of the reflexed Panic grasses leafhopper. As a rule of thumb, surveys should concentrate on prairie and barrens remnants with large populations of panic grasses. Timing of surveys should occur when the adults are present, as these are the easiest life stages to locate and obtain accurate counts. Adults should be searched for with sweep nets, although panic grasses are difficult to sweep and can be easily damages when in light, sandy soils. A vacuum collector may also be used to sample for

these leafhoppers. The adults are fairly minute, cryptically colored, fairly sedentary and sometimes difficult to locate. Vegetation in this species' habitat is typically short and patchy, making collecting fairly easy.

If sweeping, the net should be swung vigorously back and forth in a 180 degree arc, through the vegetation at waist height to near ground level, while walking at a moderate pace. The open face of the net bag should be perpendicular to the direction of the sweeper at all times. Sweep net sampling should occur on warm to hot, humid days, either between 10:00 am and noon or 4:00 pm and dusk. The entire sweep sample may be placed into a ziploc bag and immediately frozen, or individual specimens aspirated into a vial. This last technique is best left to experienced individuals.

Given the similarity of this to other more common species, a specimen from any new locality should be collected as a voucher. In an emergency situation, collected adults can be pinched firmly on the thorax and placed in a glassine envelope or similar protective sleeve. If a killing jar is at your disposal, this may be used instead. Specimens can also be placed live into jars or glassine envelopes and frozen. Collected adults should be either kept in a glassine envelope and dried or frozen, or pinned and affixed with a label bearing the following information:

1. State, County or Parish, Town, Range, Section and Quarter Section (or nearest reference point) of origin;
2. Date of Collection
3. Name of Collector
4. Type of habitat and any associated plants.

MONITORING PROTOCOL

To conduct long-term monitoring programs, a permanent monitoring transect will need to be developed (see Bess et al., 2004). Monitoring programs will naturally vary from site to site and depend greatly on the resources available to conduct such programs. At a minimum, a long-term monitoring program for *Polyamia herbida* should involve the designation of at least one, permanent monitoring transect per occupied site. Monitoring transects should pass through all representative habitats within a site or management unit, with emphasis placed on areas with dense concentrations of Panic grasses. Canopy closure should vary along the transect as much as is representative of the site being surveyed.

The monitoring transect should be of a length that 100-200 sweeps with a 15 inch diameter, muslin sweep net can be taken while walking at a moderate pace. Sweeps should be taken as close to ground level as possible, and extend in a 180 degree arc in front of the surveyor. The net must be held with the face perpendicular to the direction of walking at all times, with care being taken to not spill the net's contents or allow them to escape between sweeps. Each back and forth movement is two sweeps. All the *Flexamia* leafhoppers collected in a 100 or 200-sweep sample should be sorted from the detritus, counted, preserved and identified. Potential *Polyamia herbida* specimens should then be segregated and counted.

Information on the habitat characteristics should also be recorded, such as frequency and cover of Panic grasses, degree of canopy closure, amount of exposed soil, dominant vegetation, soil moisture, etc. At a minimum; transect name, location, date, time, temperature and cloud cover should be noted on each survey form. Information on plant phenology, species in bloom, canopy cover, invasive species, predation, etc. is also useful. Surveys should be conducted in late August or September, when the summer brood of adults are present. This will give more accurate adult population estimates for the next flight season. These surveys provide a wealth of data for use in tracking long-term trends in population size, phenology, distribution and resource utilization.

The monitoring transect should be of a length that can be covered by one or two observers in one to two hours, while walking at a moderate pace. All prairie bunchgrass leafhoppers observed within 30 feet of the transect line should be counted and mapped (preferrably using GIS). Information on the habitat characteristics should also be recorded, such as nectar sources, degree of canopy closure, dominant vegetation, soil moisture, etc. Standardized survey forms can easily be developed and a sample is attached as Figure 2. At a minimum; transect name, location, date, time, temperature and cloud cover should be noted on each survey form. Information on plant phenology, species in bloom, canopy cover, invasive species, predation, etc. is also useful. Surveys should be conducted in late August, when larvae are mature and near pupation. This will give more accurate adult population estimates for the next flight season. These surveys provide a wealth of data for use in tracking long-term trends in population size, phenology, distribution and resource utilization.

RESEARCH PRIORITIES

To date, no research has been conducted regarding the impacts of potential dispersal barriers such as cultivated fields, roads, thick brush or waterways on this species. Determining the maximum distance that individuals will move between remnants and the proper size, composition and location of dispersal corridors necessary for continued survival are key areas of future research on this and other rare *Papaipema* species. Although Panzer and associates (1995, 1998) have conducted research on fire effects and recolonization rates, much additional research on this species is needed. Further research should address at least some of the following:

1. Optimal canopy cover,
2. Minimum patch size of habitat and food plants,
3. Maximum adult travel distance between patches,
4. Percent cover and frequency of panic grasses necessary for long-term survival,
5. Optimal density of associated vegetation (especially adult nectar sources),
6. Fire effects and optimal fire regime,
7. Effectiveness of prairie restorations as habitat,
8. Effects of invasive plants (and efforts to control them) on panic grasses, the leafhopper and associated vegetation, and
9. Effects of silvicultural activities such as pine plantations, pesticide application, harvesting, etc on the leafhopper, its food plants and habitat(s).

Additional Areas of Potential Prairie Bunchgrass Leafhopper Research

Additional areas of research center on developing optimal habitat restoration procedures and re-introduction methodology for the leafhopper. It is also quite probable that there are undetected populations of *Polyamia herbida* in the central United States. Regional and state level efforts are needed to survey for (and protect) this and many other rare insect species.

Other Rare Species Associated with the Prairie Bunchgrass Leafhopper

Historically, the prairie bunchgrass leafhopper shared its habitat with an impressive collection of species, many of which are now globally imperiled through loss of habitat and, in some cases, active extermination programs. Imperiled vertebrate species with which the flower leafhopper once shared its habitat include the original Human Beings, American Bison, Greater Prairie Chicken, Henslow's sparrow and Peregrine Falcon. In addition to these somewhat more charismatic megafuana, a large number of rare insects are also known to occur with *Polyamia herbida* (Bess, 2004; Hall, 1999). These include the albarufan dagger moth (*Acronycta albarufa*: G3), Bell's roadside skipper (*Amblyscirtes belli*: G3), swamp metalmark butterfly (*Calephelis mutica*: G3), reflexed Indiangrass leafhopper (*Flexamia reflexa*) (G2), Great Plains mole cricket (*Gryllotalpa major*: G2), American Burying Beetle (*Nicrophorus americanus*: G1G2 and federally endangered), Rattlesnake Master Borer moth (*Papaipema eryngii*: G1), stinging rose caterpillar (*Parasa indetermina*: G2G3) and the Regal Fritillary (*Speyeria idalia*: G2).

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APPENDIX

LIST OF CONTACTS

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REVIEW REQUESTS

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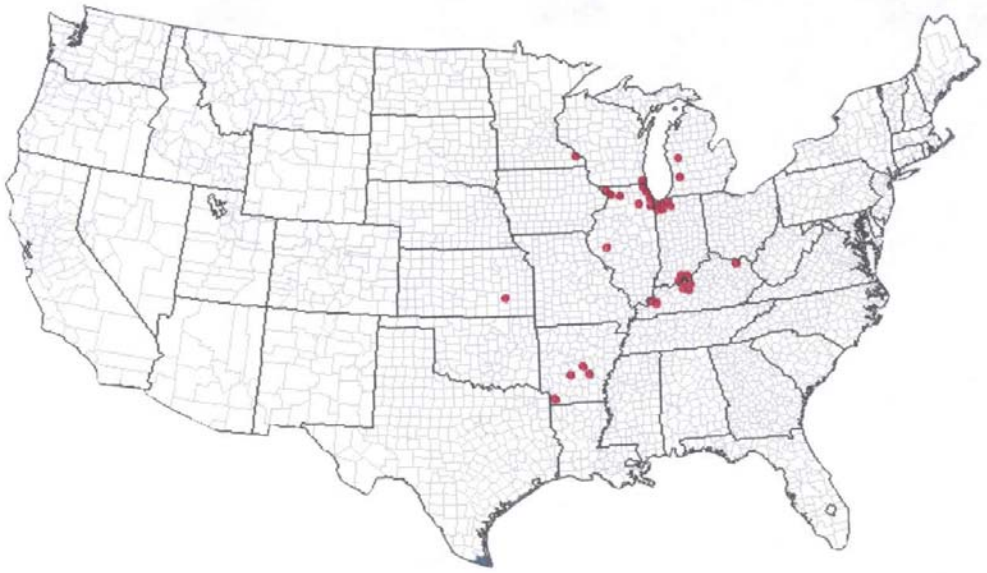
FIGURES

Figure 1. Adult *Polyamia herbida*, dorsal view

Figure 2. Known Distribution of the Prairie Bunchgrass Leafhopper (*Polyamia herbida*) in the Eastern United States.



● = Known Occurrence of *Polyamia herbida*

✳ = Approximated State Occurrence