Conservation Assessment for the Reflexed Indiangrass Leafhopper (Flexamia reflexa (Osborn and Ball))

USDA Forest Service, Eastern Region

October 18, 2005

James Bess
OTIS Enterprises
13501 south 750 west
Wanatah, Indiana 46390

This document is undergoing peer review, comments welcome

TABLE OF CONTENTS

LIST OF FIGURES

EXECUTIVE SUMMARY

The reflexed Indiangrass leafhopper (*Flexamia reflexa* Osborn and Ball) is a small, grayish insect associated with high quality, native grassland remnants in the Upper Midwest. It is considered rare and local range-wide, always in close association with its primary food plant, Indiangrass (*Sorghastrum nutans* and prob. also *S. elliottii* and *S. secundum*). This leafhopper typically produces a single brood per year, although southern populations (such as those in the Hoosier National Forest) are double brooded. *Flexamia reflexa* 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. Roughly half of the 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 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 *Flexamia reflexa* are rather sedentary and 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 reflexed Indiangrass leafhopper across its range.

ACKNOWLEDGEMENTS

I would first like to thank Steve Olson, Kelle Reynolds and Kirk Larson (US Forest Service) for initiating this project and providing valuable support throughout. Steve Olson (US Forest Service) provided information on the vegetation of the Hoosier National Forest and introduced me to the Boone Creek, Cloverlick and Harding Flats Barrens Special Areas, where I eventually discovered healthy populations of *Flexamia reflexa*. Ron Panzer (Northeastern Illinois University) provided valuable information regarding the current known distribution and biology of the reflexed Indiangrass leafhopper in Illinois. Richard Henderson and Scott Sauer (Wisconsin DNR) were also very helpful in providing information from their exhaustive surveys of the insects occurring on Wisconsin prairies. Dave Cuthrell, Michigan Natural Features Inventory) forwarded valuable information on *Flexamia reflexa* gathered from his work on Michigan prairies. Finally, I would like to thank K. G. A. (Andy) Hamilton at Agriculture Canada in Ottawa, Ontario. Dr. Hamilton is a world authority on the Homoptera and Cicadellidae and provided information on *Flexamia reflexa* records housed in the Canadian National Insect Collection. Over the past 15 years, Dr. Hamilton has lent much valuable assistance during my studies of the leafhopper fauna of North America.

NOMENCLATURE AND TAXONOMY

The reflexed Indiangrass leafhopper (*Flexamia reflexa*) was first described by Herbert Osborn and Elmer Ball in 1897 as *Deltocephalus reflexus*. When he described the genus *Deltocephalus* in 1838, Burmeister failed to designate a type species, which was based upon those species in which the vertex (top of head) is well produced, acutely triangular, distinctly margined and the surface flat (see Delong, 1926, page vi). Burmeister's failure to designate a type species, coupled with his rather general description, led to the inclusion of a wide variety of leafhoppers in the genus *Deltocephalus*. These were subsequently split into a number of distinct subgenera by DeLong in his 1926 PhD dissertation, subsequently published in the Ohio State University Studies Series. In his treatment of the genus *Deltocephalus*, DeLong placed *Flexamia reflexa* and related species in the subgenus *Flexamius*, often referred to as the "*reflexus*-group".

Flexamia was first elevated to generic status by DeLong and Sleesman in 1929, with *Flexamia reflexa* designated as the type species. Unfortunately, DeLong later used both *Flexamia* and *Flexamius* interchangeably (DeLong, 1935, 1948; DeLong, 1937; DeLong and Knull, 1945; DeLong and Hershberger, 1947). Since about 1950, however, the generic name *Flexamia* has been consistently used by subsequent researchers and revisionists (Oman, 1949; Young and Bierne, 1957; Whitcomb and Hicks, 1988). There are 60 species of *Flexamia* currently named, all from North America (see Dietrich et al., 1997; Whitcomb and Hicks, 1988).

DESCRIPTION OF SPECIES

DESCRIPTION OF ADULT STAGE

The reflexed Indiangrass leafhopper typically measures 3-4 mm (0.2 inches) in length and is named for the whitish, reflexed veinlets margined with dark brown around the terminal portion of the forewing (see Figure 1). The forewings (also called "elytra") are light grayish, with the terminal portion of the forewing having large, blocky cells, which are filled with a dark brown to blackish brown shade. The hindwings are translucent and somewhat whitish. Populations do not appear variable, being amazingly consistent across a farily large geographic area. The body is ivory white to light tan ventrally, with the dorsal abdomen being darker brown and tan. The upper half of the face is blackish, with the lower half, ivory white. Some individuals may have the face infuscated, obscuring the whitish coloration. The legs are tan, dark brown and grey.

Flexamia reflexa is superficially identical to a number of other *Flexamia* and many published records for this leafhopper are actually misidentified specimens of other species (see DeLong, 1948; Whitcomb and Hicks, 1988). *Flexamia reflexa* is closely related to *Flexamia prairiana*, which was described as a separate species by DeLong in 1937. The two can only be seperated by examination of the internal genitalia, with characters associated with the male aedeagus being diagnostic. This determination is best left to specialists on the group. Females are exceedingly difficult to separate, impossible in many cases.

DESCRIPTION OF IMMATURE STAGES

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

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 several weeks to three months or more.

ECOLOGY

The primary food plant of *Flexamia reflexa* in the Hoosier National Forest is Indiangrass (Bess, 2004). *Flexamia reflexa* is always found in high quality mesic prairie remnants where Indiangrass is a dominant species (Bess, 2004). Vegetation in these habitats is typically tall in height (1-3 meters: ~3-9 feet) and dominated by perennial grasses and forbs in the plant families Asteraceae and Fabaceae. Adults feed by sucking fluids from the phloem tissue in major veins on Indiangrass leaves.

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 Xylem 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), *Flexamia* adults can pass through the winter alive and resume feeding and egg laying in the spring (February-March; Bess, 1999b). Therefore, some individual populations may live for eight months or more. In the Hoosier National Forest, adults are typically gone by mid-November (Bess, pers. obs.). The eggs hatch in the spring following first greenup of *Sorghastrum*. It is presumed that the newly emerged nymphs actively seek out fresh *Sorghastrum* sprouts, where they immediately begin to feed.

DISPERSAL/MIGRATION

Flexamia reflexa 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 mesic native grasslands where Indiangrass abounds. The adults are rather sedentary, typically moving carefully among plants, oftentimes crawling, running or hopping rather than flying. The females lay numerous small eggs and probably disperse over a fairly small area during the course of their

lives (~400 square feet). This leafhopper is not known to migrate and females are functionally flightless because of their extended, egg-filled abdomens.

However, a number of leafhoppers are known to become active at and just before dusk, often rising into the upper herbaceous layer and undergoing mass flights above the vegetation (Lessio and Alberto, 2004; Larson and Whalon, 1987). This is thought to either aid dispersal to new habitats or increase mating success. Males are predominately the sex involved in these flights. Hoy, et al. (1996) found that mated females of *Macrosteles quadrilineatus*, a crepsucular flying species, were very sedentary and rarely even moved between plants. On hot, humid days, *Flexamia reflexa* can be locally common in the upper layers of vegetation around dusk (Bess, numerous pers. obs.). This may be preparation for mating flights as documented in other leafhopper taxa.

OBLIGATE ASSOCIATIONS

The obligate habitat for the reflexed Indiangrass leafhopper is high quality, mesic native grassland containing an abundance of Indiangrass. In the Hoosier National Forest, *Flexamia reflexa* is associated with *Sorghastrum* in dry to mesic prairie and barrens remnants on limestone (Bess, 2004a). This leafhopper rarely (if ever) occurs far from stands of the larval food plant(s). The reflexed Indiangrass leafhopper also shares its habitat with a number of regionally and globally imperiled insect, plant and vertebrate species (see Bess, 1990-2004; Panzer et al., 1995).

HABITAT

Flexamia reflexa occurs in a variety of grassland types, including glaciated wet-mesic silt loam prairie, wet-mesic sand prairie, interdunal grasslands and unglaciated barrens, glades and prairie. In northeastern Illinois, this leafhopper primarily occurs in mesic lakeplain siltloam prairie remnants where it is primarily associated with *Sorghastrum nutans*. On the Atlantic Coastal Plain, populations are also apparently associated with *Sorghastrum elliottii* and *S. secundum*. In Indiana, this species is found primarily in mesic to wet sand prairie, silt loam prairie and high quality barrens-prairie remnants on limestone.

Additional characteristic plants in the more mesic habitats include grasses such as bluestems (*Andropogon elliottii, A. gerardi, A. glomerata*), Canada bluejoint (*Calamagrostis canadensis*), Junegrass (*Kohleria cristata*), panic grasses (*Panicum* spp.), little bluestem (*Schizachyrium scoparium*), and cordgrass (*Spartina pectinata*). Characteristic forbs include heath aster (*Aster ericoides*), smooth blue aster (*Aster laevis*), wild indigo (*Baptisia leucantha*), tickseeds (*Coreopsis* spp.), rattlesnake master (*Eryngium yuccifolium*), flowering spurge (*Euphorbia corollata*), downy sunflower (*Helianthus mollis*), marsh blazing star (*Liatris spicata*), mountain mint (*Pycanathemum virginicum*), rosinweed (*Silphium integrifolium*), compassplant (*Silphium laciniatum*), prairie dock (*Silphium terebinthenaceum*), stiff goldenrod (*Solidago rigida*) and culver's root (*Veronicastrum virginicum*).

Some of these prairie habitats, especially those associated with Lake Michigan or streams, are quite marly and trend towards prairie fen or panne. Characteristic plants of these calcium and

magnesium rich habitats include many of those found in tallgrass prairie, but with a greater representation by calciphilic sedges (e.g. *Carex sterilis, C. buxbaumii, C. lasiocarpa, C. pellita*), rushes (*Eleocharis, Juncus, Rhynchospora, Scleria* and *Scirpus* spp.) and wetland grasses like manna grass (*Glyceria* spp.) and marsh timothy (*Muhlenbergia glomerata*). In sites containing *Flexamia reflexa*, big bluestem and little bluestem are also important. Characteristic forbs include Indian plantain (*Cacalia tuberosa*), swamp thistle (*Cirsium muticum*), poison hemlock (*Cicuta maculata*), fringed gentian's (*Gentiana crinita* and *G. procera*), giant sunflower (*Helianthus giganteus*), giant St. Johnswort (*Hypericum pyramidatum*), Kalm's lobelia (*Lobelia kalmii*), shrubby cinquifoil (*Potentilla fruticosa*), Riddell's goldenrod (*Solidago riddellii*) and valerian (*Valeriana ciliata*).

On sandy sites, the herbaceous vegetation is typically dominated by several sedges (*Carex longii, C. muhlenbergii, C. pennsylvanicum*, etc.) and short grasses such as three-awn (*Aristida* spp.), poverty oatgrass (*Danthonia spicata*), Junegrass, numerous panic grasses and little bluestem. Tall grasses like big bluestem and Indiangrass are somewhat more local, but still frequent, especially in depressions. 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*), rough blazingstar (*Liatris aspera*), 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.

It should be noted that Fattig (1955) reported *Flexamia reflexa* as "abundant on Johnsongrass (*Sorghum halapense*) " at a site in north central Georgia. However, this has not been substantiated by additional collections. Fattig made several other unusual claims concerning leafhoppers in his otherwise excellent treatment of the Cicadellidae of Georgia. I have never found *Flexamia reflexa* on Johnson grass, although *Deltocephalus flavicostus* and *Stirellus bicolor* are often swept in large numbers from this pest plant. Johnson grass and Indiangrass are fairly closely related so it is possible that, under certain circumstances, *F. reflexa* might feed on this species when adjacent to barrens containing abundant Indiangrass.

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

In extreme southern Indiana, *Flexamia reflexa* is found on unglaciated limestone barrens feeding on *Sorghastrum* 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. On the Hoosier, populations of the reflexed Indiangrass leafhopper are associated with *Sorghastrum nutans*. This plant is local in the Hoosier National Forest, found primarily in isolated colonies occurring on small roadside prairies, powerline rights-of-way and scattered throughout high quality, fire-maintained barrens. In high quality barrens remnants, *Sorghastrum* occurs on toe slopes or decomposing rock outcrops and in areas having thicker soils on the tops of ridges. Most of the roadside populations

of this plant are small, highly isolated and do not support populations of the reflexed Indiangrass leafhopper.

SITE SPECIFIC

Hoosier NF: Boone Creek Barrens Special Area

Boone Creek Barrens SA is a formerly fire suppressed barrens complex that has recently undergone intensive fire management, with very positive results. Here, *Sorghastrum nutans* is found in scattered patches in the more open barrens, especially on the upper portions of south and southwest facing slopes and along the roadside on the north boundary of the 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, especially on upper slopes. Removal of detritus and competing woody plants has allowed the herbaceous layer to flourish. In many areas there is a fairly thick cover of sedges, grasses and forbs. Characteristic sedges include *Carex albicans, C. cephalophora, C. complanata, C. frankii, C. glaucodea* and *C. granularis*. Warm season grasses dominated in open areas and along roadsides, with big bluestem, little bluestem and Indiangrass being most frequent. In more shaded areas, wood oats (*Chasmanthium latifolium*), poverty oatgrass and rye grasses (*Elymus* spp.) typically dominated the graminoid component..

In the more diverse portions of the Special Area, 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 *Flexamia reflexa* habitat at Boone Creek, with another 100 to 200 acres of fair to marginal habitat.

Hoosier NF: Cloverlick Barrens Special Area

The Cloverlick Barrens 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. *Sorghastrum* grows profusely in these open, grassy barrens and in the more mesic prairie along the floodplain of Cloverlick Creek. These barrens and grasslands have been managed with manual cutting of brush and prescribed fire, resulting in a high quality dry-mesic grassland complex, with the more mesic end dominated by big bluestem and

Indiangrass. This site contains roughly 100 acres of high quality habitat for *Flexamia reflexa*, with an additional 200-300 acres of fair to marginal habitat.

In occupied *Flexamia reflexa* habitat, the herbaceous vegetation is dominated by warm season, bunchgrasses like big bluestem, bushy bluestem (*Andropogon glomerata*), broomsedge (*A. virginica*), little bluestem and Indiangrass. Additional common grasses include wood oats (*Chasmanthium latifolium*), rye grasses (*Elymus hystrix, E. virginicus*) and panic grasses (particularly *Panicum anceps* and species of the subgenus *Dichanthemium*). Sedges are also common and often locally dominant, 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*), swamp aster (*Aster puniceus*), white wild indigo (*Baptisia leucantha*), blue hearts (*Buchnera americana*), Indian plantain (*Cacalia atriplicifolia*), tall thistle (*Cirsium altissimum*), Carolina thistle (*C. carolinianum*), 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*), rough Indiangrass (*Sorghastrum nutans*), scaly blazingstar (*Liatris squarrosa*), rough blazingstar, marsh blazingstar, bushclovers (*Lespedeza* spp.), bergamot (*Monarda fistulosa*), marsh phlox (*Phlox glaberrima*), obedient plant (*Physostegia virginiana*), Indiangrass (*Sorghastrum*), 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, stiff goldenrod (*Solidago rigida*), goats rue (*Tephrosia virginiana*), meadowsweet (*Thalictrum* sp.), spiderwort (*Tradescantia virginiana*) and early wingstem (*Verbesina helianthoides*).

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 *Sorghastrum* and the reflexed Indiangrass leafhopper.

Hoosier NF: Harding Flats Special Area

Harding Flats Barrens is another large barrens complex Special Area in the Hoosier NF. Here, *Sorghastrum* 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 (e.g. *Carex albicans, C. cephalophora, C. complanata, C. frankii, C. glaucodea* and *C. granularis*), grasses (such as Indiangrass) and forbs.

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 *Flexamia reflexa* habitat at Harding Flats, with another 40-60 acres of marginal habitat.

DISTRIBUTION AND ABUNDANCE

RANGE-WIDE DISTRIBUTION

Flexamia reflexa has a fairly broad range in eastern North America, but was historically known from relatively few sites (~28, fide Fattig, 1954; Lathrop, 1917; Whitcomb and Hicks, 1988). It is considered uncommon or rare and extremely local in occurrence. Many of the known records consist of a single individual or specimen and few observers have noted more than a few individuals on a given survey. Historically reported as being common, Whitcomb and Hicks (1988) showed the vast majority of these historic records were misidentifications and could locate only 61 specimens for their revision of the genus. Contrast this with 1,044 specimens of the closely related *Flexamia prairiana* at their disposal. Other *Flexamia* species typically associated with *F. reflexa* were similarly represented in the major insect collections by much greater numbers of specimens (e.g. *F. picta*: 841, *F. clayi*: 325, *F. sandersi*: 265, *F. areolata*: 269).

Since 1989, Bess and Panzer have identified (at least) an additional 35 populations of this species from prairie and barrens remnants in Arkansas, Illinois, Indiana and Kentucky (see Figure 2; Bess, 1990-2004; Panzer et al., 1995 and 2005 pers. comm.). Exhaustive surveys for prairie associated insects in Wisconsin have identified only 5 populations in that state (Scott Sauer, Wisconsin DNR, 2005 pers. comm.). Limited collecting in Michigan has identified at least six additional populations (Dave Cuthrell, Michigan Natural Features Inventory (MNFI), 2005 pers. comm.; K. Hamilton, Agriculture Canada, Ottawa, ON, 2005 pers. comm.). This provides a total of roughly 64 known populations. To date, most of these records for *Flexamia reflexa* are from high quality, remnant prairies and prairie fens in the Midwest, the Great Plains and southeastern Atlantic Coast. It is also known from high quality, fire-maintained barrens in the Central Highlands and central to southern Appalachians. The only places where *Flexamia reflexa* is currently known to occur in relatively large numbers (indicating robust populations) are:

1. High quality barrens on the Hoosier National Forest of southern Indiana,

2. The Kankakee Sands Prairie Restoration in northwest Indiana,
3. barrens and prairie remnants of central and western Kentucky, and
4. the Flint Hills Prairies of Kansas.

STATE AND NATIONAL FOREST DISTRIBUTION

The following state-level distribution information for the reflexed Indiangrass leafhopper is gathered from a number of sources, including Bess (1990- 2004), Blocker and Reed (1976), Cuthrell (2005, pers. comm.), Cwikla and Blocker (1977); DeLong (1948); Fattig (1954), Hamilton (2005, pers. comm.), Hicks (2004), Lawson (1920), Panzer (2005 pers. comm.), Sauer (2005, pers. comm.),Whitcomb and Hicks, (1988) and Young and Bierne (1954). 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 species occurs elsewhere in the state, especially in the Ouachita and Ozark National Forests. Females of either *F. reflexa* or *F. prairiana* were 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 at least 13 known 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. Populations are known from just to the south, over the Ohio River, in Kentucky. *Flexamia reflexa* is currently known from a number of fire-maintained prairie preserves in the state of Illinois, including the Savanna Army Depot (USDoD) on the Mississippi River.

Indiana

Flexamia reflexa is known from at least 15 populations in the state, 11 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, but are on small, highly isolated wet-mesic prairie remnants. Panzer (2005) reports that a fairly large metapopulation occurs in the Kanakakee Sands Restoration managed by The Nature Conservancy. Another large metapopulation occurs within the Hoosier National Forest.

Iowa

Osborn and Ball described this species from specimens collected around Ames, Iowa. No other records are known for the state. No National Forests occur in Iowa.

Kansas
There are four records for *Flexamia reflexa* from Kansas, all in the eastern half of the state. No National Forests occur in eastern Kansas.

Kentucky
Known from several 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
At least seven populations are known from Michigan, on small prairie and fen remnants scattered over the southern half of the Lower Peninsula. Additional potential habitat for this species occurs in the Huron-Manistee National Forest and the Allegan and Barry State Game Areas. Only limited leafhopper sampling has been undertaken in the state, so additional populations are possible. There is extensive potential fen habitat for this species on state and privately owned property in the southern two tiers of counties.

Minnesota
Although Medler (1942) reported *Flexamia reflexa* as common in the state, Whitcomb and Hicks (1988) found all of the Minnesota specimens in collections to represent *Flexamia prairiana*.

Missouri
Whitcomb and Hicks (1988) show a population of *Flexamia reflexa* from the southwestern portion of the state, near or in the Mark Twain National Forest. They also show two additional populations in the central and northern portions of the state. It is quite probable that additional undiscovered populations remain to be found in the state, especially in the numerous prairie ramnants scattered throughout the state and barrens in the Mark Twain NF.

Oklahoma
A single record is known from the northeastern part of the state. There are likely several additional, undiscovered, populations in the Crosstimbers and Osage Hills regions.

Texas
Three populations occur in the state; two in the south-central portion and one in the panhandle region. There is likely suitable habitat for this species in the Davey Crockett National Forest in the "Eastern Pineywoods" section of the state. Only limited leafhopper sampling has been undertaken in Texas, so additional populations of this species are likely.

Wisconsin
Despite extensive leafhopper sampling on the state's prairie remnants, populations of this species are known from only a handful of sites in six counties, scattered across the southern two-thirds of the state. Nearly all are associated with the Great Lakes or Mississippi drainages. There are no known National Forests occurrences, although the Burnett County site is near the St. Croix National Scenic Riverway.

RANGE WIDE STATUS

Flexamia reflexa is considered imperiled by most states in its range (NatureServe, 2005). Even in its supposed stronghold (Illinois, Indiana and Kentucky) there is strong evidence to conclude that the reflexed Indiangrass leafhopper is imperiled. This is especially true with regards to its preferred habitats; high quality wet to mesic prairie, barrens and fens having an abundance of Indiangrass. 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 (NatureServe, 2005). The reflexed Indiangrass leafhopper is considered an imperiled species in Arkansas (S1S2), Indiana (S1S2), Michigan (S1) and Wisconsin (S2). Illinois, Iowa, Missouri and North Dakota have the species either listed as Not Ranked or Unrecorded. The Illinois DNR has this leafhopper listed on their website of Species of Greatest Conservation Concern (ILDNR, 2005). *Flexamia reflexa* is listed as a State Threatened species in Indiana (INDNR, 2005) and State Special Concern in Michigan (MNFI, 2001; D. Cuthrell, 2005 pers. comm.)

POPULATION BIOLOGY AND VIABILITY

Prior to European settlement of the continent, *Flexamia reflexa* and it food plants probably occurred on native grasslands from the Dakota's east to Ohio and south to Texas and Florida. The rapid transformation of the Nation's grasslands from native pasture to intensive row crop agriculture following westward expansion of European colonials in the mid-1800's led to a rapid reduction in habitat acreage for this and other grassland species. Today, this leafhopper exists as a collection of isolated populations varying greatly in size. It is quite possible that some historic populations may no longer be extant. Conversely, the Dakota's, Missouri, Iowa, Kansas and Nebraska all contain fairly extensive amounts of potential habitat for this species but are poorly sampled for leafhoppers.

POTENTIAL THREATS

PRESENT OR THREATENED RISKS TO HABITAT

The reflexed Indiangrass leafhopper's preferred 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 grasslands to row crop agriculture, road construction, hydrologic manipulation and other human activities.

The remaining suitable habitat for *Flexamia reflexa* typically occurs as small (10 acres or less), highly isolated grasslands, separated from one another on the landscape by vast expanses of 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 reflexed Indiangrass 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 are easily eradicated when fire consumes their habitat completely. Real and potential threats to this species and its habitat are outlined below.

Ditching and Drainage of Wetlands

Throughout its range, vast areas of reflexed Indiangrass leafhopper habitat were ditched, tiled, drained and tilled for agricultural production in the late 19th and 20th centuries. Many large peatlands (including prairie fens and pannes) were also drained and then mined for their valuable peat or marl (calcium and magnesium carbonates). Disturbed or degraded sites were often subsequently invaded by non-native plant species, which quickly excluded native ones. Dried peatlands were prone to cataclysmic wildfires, which often burned the peat deposit down to its mineral soil base or created areas of open water (Allan and Anderson. 1955; Bancroft, 1977; Cohen, 1974; Lynch, J. J. 1941; Miller, 1963; Wein and Maclean, 1983). In northwest Indiana, extensive marsh and peat fires covering many square miles burned for days or weeks on end (see Gabbert, 1992, page 15). It is quite probable that these fires eliminated large tracts of habitat for *Flexamia reflexa* and other wet prairie species.

Even in these early years, researchers understood the dangers associated with destroying the nation's wetlands. Hanson (1939) warned that peatlands and other wetlands "should not be burned, drained, or altered in any way that hinders their ability to store water, mitigate floods, and maintain the water level in surrounding lands." However, these warnings went largely unheeded, even after the passing of the Rivers and Harbors Acts of 1890 (superseded) and 1899 (33 U.S.C. 401, et seq.). Section 10 of the Act (33 U.S.C. 403) covered construction, excavation, or deposition of materials in, over, or under such waters, or any work which would affect the course, location, condition, or capacity of those waters. In 1972, amendments to the Federal Water Pollution Control Act added what is now commonly called "Section 404 Authority" (33 U.S.C. 1344) to the program. The act authorizes the Secretary of the Army, acting through the Chief of Engineers, to issue permits (after notice and opportunity for public hearings) for the discharge of dredged or fill material into waters of the United States.

The Federal Water Pollution Control Act was further amended in 1977 and given the common name of "Clean Water Act" and was again amended in 1987 to modify criminal and civil penalty provisions and to add an administrative penalty provision. The Food Security Act of 1985 (P.L. 99-198), enacted on December 23, 1985, was aimed at alleviating the financial pressures on

many debt-stricken farmers. Key components of this Act were the Conservation Reserve Program (CRP), Conservation Compliance, and "Swamp Buster" laws. The Conservation Reserve Program (CRP) was designed to pay farmers to retire land with highly erodible soils from production for at least 10 years and preferrably for the lifetime of the farm. The CRP had a beginning goal of retiring 45 million acres of erodible cropland and was to provide the dual benefits of reduced soil erosion and reduction in Federal Commodity Program payments through limiting the production of surplus crops. The CRP Program was subdivided into several categories, the most important being the Wetland Reserve Program (WRP) and the Grassland Reserve Program (GRP). The "Swamp Buster" law was designed to conserve existing wetlands on farms. Conservation Compliance and Swamp Buster make any producer who cultivates highly erodible land, or converts wetlands to cropland, ineligible for most Federal Farm Administration Program benefits.

Unfortunately, and despite legislatively mandated protections for the Nation's wetlands and grasslands, these habitats continue to be filled, drained and converted to intensive human use. This includes habitat suitable for *Flexamia reflexa* and many other (now) rare species. Recent political maneuverings in the Nation's Legislature have greatly weakened the ability of the Act to protect our wetlands, particularly "isolated wetlands" that are not immediately adjacent to "navigable waterways" (see USEPA, 2005). In efforts to compensate for this lack of oversight, many states have enacted their own wetland protection laws, some of which are more stringent than the previous Federal Codes.

Row Crop Agriculture

The conversion of much of the Great Plains and central Midwest to large scale, row crop agricultural production following World War II coincided with a precipitous loss of wet prairie, fen and sedge meadow 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 bean monocultures. Center-pivot irrigation allowed many formerly unfarmable acres to be tilled, especially in the drier prairies and barrens of the Midwest and Great Plains. Historically, state and federal government incentives were given to farmers to ditch, tile and wetlands to increase agricultural production. Oftentimes, the states themselves would actively participate in the ditching and draining of large wetlands (see Illinois DNR, 2000).

Fire Suppression

The suppression of wildfires 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).

Like the grasslands with which they are often associated, North American peatlands were also fire-regulated in the past (Cohen, 1974; Heinselman, 1981; Kelsall, et al. 1977; Komarek, 1971; Rowe and Scotter, 1973; Slaughter, et al.1971; Vierick, 1973; Vierick and Schandelmeier, 1980; Wein and McClean, 1983; Wells and Boyce, 1953). The large peatlands, smaller bogs and swamps of the northern Lake States, Canada and upper New England also support boreal vegetation but their fire regimes are different from areas with mineral soils (Amon et al., 2002; Heinselman, 1981; Vierick and Schandelmeier, 1980). Acidic, forested peatlands typically lack highly flammable grasses and sedges, instead having a wet, moss-dominated ground layer that will not readily carry spring ground fires (Foster, 1984; Heinselman, 1981).

In contrast, sedge and grass fens on mineral soils, even those with partial tree cover, burn best in spring before succulent vegetation develops (Heinselman, 1981). Thus, most fires in forested peatlands occur in July, August, or September of severe drought years, and most fires in sedge-grass fens occur in April, May, or early June. Heinselman (1981) also found evidence that the presettlement fire regime for large, spruce (*Picea* spp.) and sphagnum moss bogs in Minnesota was a cycle of cataclysmic crown fires roughly every 100-150 years. In contrast, his data suggested that the once vast grass-sedge fens of north-central and northwestern Minnesota burned at more frequent intervals, with periodic surface fires every 5-30 years. Heinselman further went on to state that the removal of fire from these ecosystems would be "among the greatest upsets in the environment that man could impose."

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 wetlands by burning deep into peat deposits and creating depressions, exposed mineral soil or areas of open water (Allan and Anderson. 1955; Bancroft, 1977; Cohen, 1974; Lynch, 1941; Miller, 1963; Wein and Maclean, 1983). Changes to the vegetative structure of wetlands 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.

Fire Management

In the case of *Flexamia reflexa*, 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, *Sorghastrum nutans*, 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, Indiangrass can decrease in abundance, sometimes being replaced by little bluestem (Oregon State, 2005). Therefore, although fire is essential to the long-term survival of *Flexamia reflexa* habitat, some precautions are necessary to ensure that the entire population of leafhoppers (or Indiangrass) 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 and Schwartz, 1998). In the southern part of its range, *Flexamia reflexa* is double brooded and the second generation of adults is typically larger than the earlier one. These adults can move into adjacent, recently burned habitat, allowing them to more rapidly colonize newly managed habitat than more northern populations. The increased production in Indiangrass 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 and Mowing

Domesticated cattle and horses eat Indiangrass, and their foliage is esteemed by a number of other grazing animals (Bess, pers. obs.; Oregon State University, 2005; Damhoureyeh and Hartnett, 2002). In Montana and North Dakota, the dotted Indiangrass (*Sorghastrum nutans*) is considered a decreaser in response to light or moderate grazing pressure (Montana State University, 2002; NDSU, 2005). It is assumed that *Sorghastrum nutans, S. elliottii* and *S. secundum* respond similarly. Although direct mortality would not be of prime concern (given the larvae are root borers), continued grazing would 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 *Sorghastrum* that will re-colonize previously disturbed areas.

Extensive livestock grazing also reduces the cover of native grasses and forbs on which the adult reflexed Indiangrass leafhopper depends for resting places and nectar sources. 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 *Flexamia reflexa*, 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 wet-mesic 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. 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 Indiangrass) from grass pastures. These factors eliminate potential habitat for the reflexed Indiangrass 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 pastures often harbor large populations of pest insect 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 reflexed Indiangrass 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 mesic prairies of the Midwest, non-native pasture species such as reed canarygrass, 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 and occur as weeds across much of North America, often to the exclusion of the native flora. Canada thistle is also a noxious weed in these habitats. 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 leafhoppers integumen and feeds on the internal organs. Typically, the leafhopper dies when the fully developed larva 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 *Flexamia reflexa* 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 *Flexamia reflexa* 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 *Flexamia reflexa* 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).

Gypsy moth outbreaks tend to occur in oak-dominated forests, woodlands and barrens. Throughout the eastern two-thirds of its range, *Flexamia reflexa* occurs in scattered areas of Indiangrass dominated prairie set in a matrix of oak-pine barrens and woodlands. Unfortunately for the reflexed Indiangrass leafhopper, the gypsy moth currently occurs throughout much of its range. Therefore, the potential for co-occurrence is high. Fortunately for the leafhopper, a biocontrol agent, *Bacillus thuringiensis kurstaki* or *Btk*, is currently the preferred control agent for outbreaks of the gypsy moth and in Wisconsin alone, more than 250,000 acres were sprayed in 2004 (see USDA, 2004a). This bacterium does not appear to harm leafhoppers, although it indiscriminately kills all Lepidoptera and members of several other insect orders. The spraying of *Btk* for both gypsy moth and spruce budworm control is known to have long-lasting, deleterious effects on resident populations of non-target Lepidoptera (Boettner et al., 2000; Butler et al., 1995, 1997; Cooper et al., 1990; Hall et al., 1999; Herms et al., 1997; Johnson, et al., 1995; Krieg and Langenbruch, 1981; Miller, 1990; Morris, 1969; Schweitzer, 2000, 2004b; Severns, 2002; Wagner and Miller, 1995; Wagner et al., 1996; Whaley, 1998).

These control efforts not only indiscriminately kill countless insects, but also have long-lasting effects on the habitats that are sprayed. The loss of caterpillars from spraying is known to negatively affect fecundity and body weight in nesting birds, bats and small mammals (Bellocq et al., 1992; Cooper et al., 1990; Holmes, 1998; Sample, 1991; Sample et al., 1993a-b, 1996;

Seidel and Whitmore, 1995; Whitmore et al., 1993a-b; Williams, 2000). This effect is typically carried over through at least a second year, mimicking the reduction in observed Lepidoptera larvae during the season of application.

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 *Flexamia reflexa* 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 *Flexamia reflexa* through increased mortality from parasitism and disease, when applied in adjacent or occupied habitats.

Over-Utilization

The reflexed Indiangrass leafhopper's secretive habits and small size make it 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 *Flexamia reflexa* 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 the Midwest, high-end and exclusive residential developments are often located in remnants of barrens or savannas in rural areas adjacent to large Metropolitan areas like Chicago, Illinois or Louisville, Kentucky. Hundreds of subdivisions were platted and developed in the Lake Chicago basin of Illinois on wet-mesic prairie that contains (or contained) *Flexamia reflexa*. 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. Fire suppression is also a key factor in the development and maintenance of these human-made habitats.

Inadequacy of Existing Regulatory Mechanisms

The lack of any long-standing Federal program to protect, manage and restore the nation's grasslands has led to the degradation or elimination 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 entities such as *Flexamia reflexa*. 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 the Nation's natural resources. Many organisms are endangered simply because their habitats are becoming increasingly fragmented and degraded by unchecked human activity. This is especially true for those requiring prairie fens, wet-mesic prairie or southern barrens. Federally mandated efforts to restore our Nation's wetlands (some of which are already underway), prairies and barrens would not only protect thousands 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 *Flexamia reflexa* 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 (e.g. Department of Defense). 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 AND RECOMMENDATIONS

CURRENT MANAGEMENT ACTIVITIES

Little or no management is currently being directed at *Flexamia reflexa* habitat based solely on the species' presence or absence. However, the leafhopper's preferred habitats happen to include globally imperiled plant communities; prairie fen, wet-mesic silt loam prairie and oak-pine barrens. Therefore, its habitat has received management in some areas, 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 larval food plant and adult nectar sources.

RECOMMENDATIONS

In most areas, grassland restoration and management has depended on prescribed fire as a primary tool. Given that Indiangrass respond favorably to fire, *Flexamia reflexa* 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 must 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 between burns. In a single year, no more than 25 percent of occupied *Flexamia reflexa* habitat should be burned on small sites.

PAST AND CURRENT CONSERVATION ACTIVITIES

The reflexed Indiangrass leafhopper has always been reported as rare and local (see Whitcomb and Hicks, 1988), 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 grasslands. Only recently have researchers begun to suggest that *Flexamia reflexa* is 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, this species is considered Threatened in Indiana (INDNR 2005). In Illinois, it is proposed as a "Species of Greatest Conservation Concern" (ILDNR, 2005). Both Kentucky and Michigan need to re-assess their respective insect faunas and begin to update the local status of the globally rare species that occur there.

On an individual level, Dr. Ronald Panzer (Northeastern Illinois University) has gone to great lengths to educate local and regional land managers about the juducious use of fire in restoring and maintaining native grasslands. Dr. Panzer and his associates have conducted thousands of hours of research on the prairies of the Chicago region, assessing the effects of fire on the resident insect populations. His conclusion is that fire is an essential part of managing native grasslands and that, when used wisely, does not negatively affect fire sensitive insect species (i.e. those that overwinter aboveground). This is the current author's determination as well. As a rule of thumb, if no more than twenty-five percent of a fire sensitive insect's habitat is burned in any one season, then that species should have no trouble re-colonizing the newly managed habitat. For sites with *Flexamia reflexa* and having abundant and evenly distributed Indiangrass, managers could even burn as much as fifty percent of the occupied habitat in a given year. However, on small sites (1 acre or less), the more conservative numer (25) is recommended.

RESEARCH AND MONITORING

Currently, little research is being conducted regarding the reflexed Indiangrass leafhopper 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 *Flexamia reflexa*) 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 larval food plant of this leafhopper is an attractive species and highly valuable for grazing forage. Indiangrass also produces seeds that are food for a variety of songbirds, small mammals and insects. It provides nesting and resting habitat for numerous birds and small mammals. The preferred habitats of the reflexed Indiangrass leafhopper are also visually attractive, features which make them excellent candidates for raising public awareness of (and funding for) grassland protection, restoration and creation. Indiangrass is a preferred element in grassland seed mixes and most "prairie restorations" contain an abundance of this grass. However, the leafhopper rarely occurs in these re-created habitats unless an occupied remnant of native grassland occurs directly adjacent to the restoration. Therefore, in many cases, active re-introduction of the species (along with the rest of the prairie leafdhopper fauna) may be necessary.

EXISTING SURVEYS, MONITORING, AND RESEARCH

Many of the historic sites for this species have not been visited in over 50 years. Verification of all 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 *Flexamia reflexa*, despite its rarity. However, recent surveys for rare insects on the Hoosier National Forest uncovered new populations (Bess, 2004). Additional surveys have been conducted for this and other rare grassland insect species throughout the Midwest (Bess, 1990-2005). Dr. Ronald Panzer (Northeastern Illinois University) has also been monitoring this species at known sites in Illinois. Dr. Panzer has conducted numerous fire effects studies on the leafhoppers, 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 Indiangrass leafhopper. As a rule of thumb, surveys should concentrate on prairie and barrens remnants with large populations of Indiangrass, particularly *Sorghastrum nutans, S. elliottii,* and *S. secundum*. 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, but are cryptically colored, fairly sedentary and sometimes difficult to locate. Vegetation in this species' habitat is typically tall and dense, making sweeping difficult. 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.

Specimens of suspected adults must be kept with precise information regarding location, date and time of collection. Given the similarity of this to more common species, a specimen from any new locality must be collected as a voucher. These should be placed dry into a vial and frozen. They can be stored frozen or dried and attached with a small drop of glue to a small paper point through which an insect pin is drawn. Locality and collecting information must be affixed to the pin immediately. Adults can also be kept in the original container and kept frozen or dried. If drying, remove lid to avoid mold growth. In the case of entire sweep samples, the leafhoppers must be removed from the detritus and placed into a vial following the procedures outlined above. At the very least, collected adults must be kept 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.

Any collected specimens should be forwarded to an expert on the group for verification (see list at end of this Conservation Assessment).

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 *Flexamia reflexa* 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 Indiangrass. 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 *Flexamia reflexa* specimens should then be segregated and counted.

Information on the habitat characteristics should also be recorded, such as frequency and cover of Indiangrass, 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.

RESEARCH PRIORITIES

To date, no research has been conducted regarding the impacts of potential dispersal barriers such as cultivated fields, roads, thick brush, forest tracts, highways or waterways on this species. My personal experience shows that this leafhopper is fairly sedentary and adults are slow to move into areas of recently managed habitat, when compared to other species with which they co-occur. However, they are probably capable of moving at least a couple hundred yards in the course of their adult lives, especially in tracts of contiguous habitat. 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 insect 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 Indiangrass 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 for rare leafhoppers,
8. Effects of invasive plants (and efforts to control them) on Indiangrass, 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 *Flexamia reflexa* 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 *Flexamia reflexa* in the central and southeastern 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 *Flexamia reflexa*

Historically, this 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 *Flexamia reflexa* (Bess, 2004; Blocker and Reed, 1976; Panzer et al., 1998). These include the albarufan dagger moth (*Acronycta albarufa*: G3), Bell's roadside skipper (*Amblyscirtes belli*: G3), swamp metalmark butterfly (*Calephelis mutica*: G3), great plains mole cricket (*Gryllotalpa major*: G2), Dakota skipper (*Hesperia dakotae*: G2 and candidate for listing as a Federally Endangered Species), American burying beetle (*Nicrophorus americanus*: G1G2 and federally endangered), Powesheik skipper (*Oarisma powesheik*: G2), Beer's blazingstar borer moth (*Papaipema beeriana*; G2G3); rattlesnake master borer moth (*Papaipema eryngii*: G1 and candidate for listing as a Federally Endangered Species), byssus skipper (Problema byssus; G2G3), jaguar flower moth (*Schinia jaguarina*; G4) and regal fritillary (*Speyeria idalia*: G2 and candidate for listing as a Federally Endangered Species).

REFERENCES

Allan, P. and W. Anderson. 1955. More wildlife from our marshes and wetlands. Pages 589-596 in Water: The Yearbook of Agriculture 1955. USDA., Washington, DC.

Anderson, D. 1996. The vegetation of Ohio: Two centuries of change. Draft. Ohio Biological Survey.

Anderson, K., E. Smith, and C. Owensby. 1970. Burning bluestem range. *Journal of Range Management* 23:81-92.

Anderson, R., T. Fralish and J. Baskin. 1999. Savannas, Barrens and Rock Outcrop Plant Communities of North America. Cambridge University Press, London, UK. 470 pages.

Anderson, R. and S. Brown. 1986. Stability and instability in plant communities following fire. *American Journal of Botany* 73:364-368.

Arend, J. S. and H. F. Scholz. 1969. Oak forests of the Lake States and their management. *USDA Forest Service, North Central Forest Experiment Station Research Paper NC-31. 36pp.*

Auclair, A., A. Bouchard, and J. Pajaczkowski. 1973. Plant composition and species relationships on the Huntingdon Marsh, Quebec. *Canadian Journal of Botany 51:1231-1247.*

Bancroft, S. 1977. Natural fire in the Everglades. Pages 47-60 in Fire Management, Southern Region, Forest Service, and Cooperative Fire Protection, Southeastern Area, State and Private Forestry, Forest Service, sponsors. *Fire by prescription symposium proceedings. 13-15 October 1976. Atlanta, GA.*

BASF Corp. 2005. Four Threats to U. S. Forests and Grasslands. Timberlines Website http://www.vmanswers.com/magazines.aspx.

Bayley and Odum, 1976. Simulation of Interrelations of the Everglades' Marsh, Peat, Fire, Water and Phosphorus. *Ecological Modeling 2: 169-188*

Bellocq, M.I., J.F. Bendell, and B.S. Cadogan. 1992. Effects of Bacillus thuringiensis on Sorex cinereus (masked shrew) populations, diet, and prey selection in a jack pine plantation in northern Ontario. *Canadian Journal of Zoology 70:505-510.*

Bess, J. 2005. A report on the remnant-dependent insects of coastal zone natural area remnants in northwest Indiana. Unpublished Report to the INDNR: Division of Nature Preserves.

Bess, J. 2004. A final report on insect surveys at three barrens special areas. Unpublished Report to the Hoosier National Forest, US Forest Service, USDA. 40 pages, 3 maps, 3 tables(117 pp.).

Bess, J. 2002. A Report on the Remnant-Dependent Insects of Blacksoil Prairie and Sand Savanna Remnants in Northwest Indiana. Unpublished Report to the INDNR: Division of Nature Preserves.

Bess, J. 2001a. A Report on Insect Surveys at Eastview Barrens Nature Preserve. Unpublished Report to the Kentucky Division of Nature Preserves.

Bess, J. 2001b. A Report on Insect Surveys at the Blue Licks and Crooked Creek Nature Preserves. Unpublished Report to the Kentucky Division of Nature Preserves.

Bess, J. 1999. A Report on Insect Surveys at Three Arkansas Natural Area Complexes. Unpublished Report to the Arkansas Field Office of The Nature Conservancy.

Bess, J. 1998a. The insect fauna of Mantle Rock Nature Preserve. Unpublished Report to the Kentucky Chapter of The Nature Conservancy.

Bess, J. 1998b. The Insect Fauna of the Kankakee Sands and Grand Prairie Regions of Indiana. Unpublished report to the Indiana Department of Natural Resources-Division of Nature Preserves.

Bess, J. 1998c. A report on the insect fauna of the Pine Bluff Arsenal with special reference to proposed construction activities. Unpublished report to the U. S. Department of Defense and The Nature Conservancy.

Bess, J. 1998d. A Report on Insect Surveys at the Cressmoor Blacksoil Prairie and Coulter Sand Prairie Nature Preserves: with Management Recommendations Concerning the Remnant-Dependent and Fire-Sensitive Species. Unpublished report to the Indiana Department of Natural Resources-Division of Nature Preserves.

Bess, J. 1994. A report on status surveys for Papaipema eryngii and Acronycta albarufa conducted at Eastview Barrens Nature Preserve.

Bess, J. 1992. A report on the insects associated with Kentucky remnant grasslands. 36pp. + 8 Maps, 3 Tables. Unpublished Report to The Nature Conservancy.

Bess, J. 1990. A Report on the Insect Fauna of Kentucky Remnant Grasslands. *Unpublished Report to the Kentucky Chapter of The Nature Conservancy.*

Bess, J., K. O'Neill and W. Kemp. 2004. An ecological study of the leafhopper fauna of southwestern Montana. *American Midland Naturalist.*

Bess, J.A. and Hamilton, K.G.A. 1999a. A new Flexamia (Homoptera: Cicadellidae: Deltocephalinae) from Southern Michigan. *The Great Lakes Entomologist 32(1&2): 9-14.*

Bethke, J, Blua, M and R. Redak. 2001. Effect of selected insecticides on Homalodisca coagulata (Homoptera: Cicadellidae) and transmission of oleander leaf scorch in a greenhouse study. *Journal of Economic Entomology 94: 1031-1036.*

Blatchley, W. 1920. The Orthoptera of northeastern North America. The Nature Publishing Company. 784 pp.

Blocker, H. and R. Reed. 1976. Leafhopper populations of a tallgrass prairie (Homoptera: Cicadellidae): Collecting procedures and population estimates. *Journal of the Kansas Entomological Society 49: 145-154.*

Boettner, G., J. Elkington, and C. Boettner. 2000. Effects of a biological control introduction on three nontarget native species of saturniid leafhoppers. *Conservation Biology 14(6):1798-1806.*

Bradt, P. and J. Williams. 1990. Response of Hydropsychidae (Insecta: Trichoptera) larvae to diflubenzuron. *Journal Pennsylvania Academy Science 64:19-22.*

Britton, N. and A. Brown. 1913. An Illustrated Flora of the Northern United States, Canada and the British Possessions. Charles Scribner's Sons. New York.

Britton, C., J. Cornely, and F. Sneva. 1980. Burning, haying, grazing, and non-use of flood meadow vegetation. Oregon Agricultural Experiment Station. Special Report no. 586:7-9.

Brown, J., K. Smith and J. Kapler, eds. 2000. Wildland Fire in Ecosystems: Effects of Fire on Flora. General Technical Report RMRS-GTR-42-vol. 2 Ogden, Utah. USDA Forest Service, Rocky Mountain Research Station. 257 pages.

Butler, S., C. Zivkovich, and B. Sample. 1995. Richness and abundance of arthropods in the oak canopy of West Virginia's Eastern Ridge and Valley Section during a study of impact of Bacillus thuringiensis with emphasis on macrolepidoptera larvae. *West Virginia University Experiment Station Bulletin 711. 19pp.*

Butler, S., G. Chrislip, V. Kondo, and E. Townsend. 1997. Impact of diflubenzuron on nontarget canopy arthropods in closed deciduous watersheds in a central Appalachian forest. *Journal Economic Entomology 90.*

Campbell, J. 2001. Native vegetation types of Appalachian Kentucky. Unpublished report to The Nature Conservancy, Lexington, KY. 210 pp.

Clark, D. 2004. Dallas Butterflies Website: http://www.dallasbutterflies.com/Butterflies/html/belli.htmS.

Cohen, A. 1974. Petrography and paleoecology of Holocene peats from the Okefenokee swamp-marsh complex of Georgia. *Journal of Sedimentary Petrography 44:716-726.*

Cohen, A., D. Casagrande, M. Andrejko, and G. Best. 1984. The Okefenokee Swamp: its natural history, geology, and geochemistry. Wetland Surveys, Los Alamos, NM. 709 pp. + map.

Comer, P., D. Faber-Langendoen, R. Evans, S. Gawler, C. Josse, G. Kittel, S. Menard, M. Pyne, M. Reid, K. Schulz, K. Snow, and J. Teague. 2003. Ecological systems of the United States: A working classification of U.S. terrestrial systems. NatureServe, Arlington, VA.

Cooper, R., K. Dodge, D. Thurber, R. Whitmore, and H. Smith. 1993. Response of ground-level wildlife food plants to canopy defoliation by the gypsy moth. *Proceedings Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 1993:268-275.*

Cooper, R., K. Dodge, P. Martinat, S. Donahoe, and R. Whitmore. 1990. Effect of diflubenzuron application on eastern deciduous forest birds. *Journal of Wildlife Management 54:486-493.*

Covell, C. 1999. An Annotated Checklist of the Butterflies and Leafhoppers (Lepidoptera) of Kentucky. *Kentucky State Nature Preserves Commission Scientific and Technical series no. 6.*

Cowen, R. 1991. The sacred turnip. *Science News. 139(20): 316-317.*

Cwikla, P. and H. Blocker. 1981. An annotated list of the leafhoppers (Homoptera: Cicadellidae) from tallgrass prairie of Kansas and Oklahoma. *Transactions of the Kansas Academy of Science 84: 89-97.*

Cypert, E. 1961. The effects of fires in the Okefenokee Swamp in 1954 and 1955. *American Midland Naturalist 66:485-503.*

Damhoureyeh, S. and D. Hartnett. 2002. Variation in grazing tolerance among three tallgrass prairie plant species. *American Journal of Botany 89:1634-1643*

Daubenmire, T. 1968. Ecology of fire in grasslands. *Advances in Ecological Research* 5:209-266.

Deam, C. 1940. Flora of Indiana. Blackburn Press. Caldwell, New Jersey.

Delcourt, H., and P. Delcourt. 1997. Pre-Columbian Native American use of fire on southern Appalachian landscapes. Conservation Biology 11(4):1010-1014.

DeLong, D. 1926. A monographic study of the North American species of the genus Deltocephalus. *Ohio State University Studies 2(13): i-x, 1-129.*

DeLong, D. 1937. Some new Deltocephaloid leafhoppers (Homoptera, Cicadellidae) from Illinois. *Pan-Pacific Entomologist 13(1-2): 32-34.* [*F. prairiana*, n.sp.]

Delong, D. 1948. The leafhoppers, or Cicadellidae, of Illinois. *Illinois Natural History Survey Bulletin 24(2):97-376.*

DeLong, D. and R. Hershberger. 1948 [dated 1947]. The genus Flexamia (Homoptera, Cicadellidae) in Mexico. *Bulletin of the Brooklyn Entomological Society 42: 136-139.*

DeLong and Knull. 1945. Checklist of the Cicadellidae (Homoptera) of America north of Mexico. *Ohio State University Graduate School Studies, Biological Science Series I. 102 pages.*

DeLong, D.M. and Sleesman, J.P. 1929. New genera and subgenera from the genus Deltocephalus. *Annals of the Entomological Society of America 22: 81-114.*

DeSelm, H., and N. Murdock. 1993. Grass-dominated communities. Pages 87-141 in: W. H. Martin, S. G. Boyce, and A. C. Echternacht, editors. Biodiversity of the southeastern United States: Upland terrestrial communities. John Wiley and Sons, New York.

Dietrich C., Whitcomb R., Black W. 1997. Phylogeny of the grassland leafhopper genus Flexamia (Homoptera: Cicadellidae) based on mitochondrial DNA sequences. *Molecular Phylogenetic Evolution 8(2): 139-149.*

Dorney, C. and J. Dorney. 1989. An unusual oak savanna in northeastern Wisconsin: The effect of Indian-caused fire. *American Midland Naturalist* 122:103-113.

Dubey, T., 1995. Aquatic fungi. In R.C. Reardon (coordinator). Effects of Diflubenzuron on non-target organisms in broadleaf forested watersheds in the Northeast. USDA Forest Service.FHM-NC-05-95, 174 pp.

Dubey, T.; Stephenson, S. S.; Edwards, P. J. 1995. Dimilin effects on leaf-decomposing aquatic fungi on the Fernow Experimental Forest, West Virginia. In: Gottschalk, Kurt W.; Fosbroke, Sandra S.C., eds. 1995.Proceedings, 10th central hardwood forest conference 1995, March 5-8 Morgantown, WV. *General Technical Report NE-197. Radnor, PA: U.S. Department of Agriculture, ForestService, Northeastern Forest Experiment Station: 421-429.*

Duever, M., J. Carlson, J. Meeder, S. Duever, S. Gunderson, S. Riopelle, T. Alexander, R. Myers, and D. Spangler. 1986. The Big Cypress National Preserve, 2nd printing. Nat. Audubon Soc. Res. Rep. 8. 455 PP.

Eyre, F., editor. 1980. Forest cover types of the United States and Canada. Society of American Foresters, Washington, DC. 148 pp.

Fairbrothers, D. and J. Gray. 1972. *Microstegium vimineum* (Trin.) A. Camus (Gramineae) in the United States. *Bulletin of the Torrey Botanical Club 99:97-100.*

Faulkner, S., and A. de la Cruz. 1982. Nutrient mobilization following winter fires in an irregularly flooded marsh. *Journal of Environmental Quality 11:129-133.*

Forbes, W. 1954. The Lepidoptera of New York and Neighboring States: Part III Noctuidae.

Forman, R., editor 1979. Pine Barrens: ecosystem and landscape. Academic Press, New York. 601 pp.

Foster, D. 1984. The dynamics of sphagnum in forest and peatland communities in southeastern Labrador, Canada. *Arctic 37:133-140.*

Foster, D., and P. Glaser. 1986. The raised bogs of southeastern Labrador, Canada: classification, distribution, vegetation and recent dynamics. *Journal of Ecology 74:47-71.*

Garren, K. 1943. Effects of fire on vegetation of the southeastern United States. *Bot. Rev. 9:617-654.*

Garrett, H., W.J. Rietveld, and R.F. Fisher, eds. 2000. North American Agroforestry: An Integrated Science and Practice. American Society of Agronomy, Madison, Wisconsin.

Glasser, J. 1985. Successional trends on tree islands in the Okefenokee Swamp as determined by interspecific association analysis. Am. Midl. Nat. 113:287-293.

Gleason, H. and A. Cronquist, 1991. Manual of the vascular plants of the northeastern United states and Canada, 2nd Ed. New York Botanical Garden, New York.

Gordon, A. and S.M. Newman, eds. 1997. Temperate Agroforestry Systems. CAB International, Oxon, UK

Gresham, C. 1985. Clearcutting not enough for early establishment of desirable species in Santee River swamp. Southern Journal of Applied Forestry 9:52-54.

Grimm, E. 1984. Fire and factors controlling the Big Woods vegetation of Minnesota in the mid-nineteenth century. *Ecological Monographs* 54:291-311.

Guglielmino, A. & Olmi, M. 1997. A Host-Parasite Catalog of World Dryinidae (Hymenoptera: Chrysidoidea). *Contributions in Entomology International 2 (2): 165-298.*

Hajek, A., S. Butler, J. Liebherr, and M. Wheeler. 2000. Risk of infection by the fungal pathogen Entomophaga maimaiga among Lepidoptera on the forest floor. *Environmental Entomology 29(3):645-650.*

Hajek, A., S. Butler, S. Walsh, J. Perry, J. Silver, F. Hain, T. O'Dell, and D. Smitley. 1996. Host range of the gypsy moth (Lepidoptera: Lymantriidae) pathogen Entomophaga maimaiga(Zygometes: Entomophthorales) in the field versus laboratory. *Environmental Entomology 25:709-721.*

Hajek, A., S. Butler, and M. Wheeler. 1995. Laboratory bioassays testing the host range of the gypsy moth fungal pathogen Entomophaga maimaiga. *Biological Control 5:530-544.*

Hall, S. P. 1999. Inventory of lepidoptera of the Albemarle-Pamlico peninsular region of North Carolina, including Pettigrew, Goose Creek, and Jockey's Ridge State Parks and Nag's Head Woods Ecological Preserve. North Carolina Department of Environment and Natural Resources, Natural Heritage Program, Raleigh, NC.

Hall, S, J. Sullivan, and D. Schweitzer, 1999. Assessment of risk to non-target macroleafhoppers after Btk application to Asian gypsy moth in the Cape Fear region of North Carolina. USDA Forest Service, Morgantown West Virginia, FHTET-98-16, 95pp.

Hansen, S. and R. Garton. 1982. The effects of diflubenzuron on a complex laboratory stream community. *Archives of Environmental Contamination and Toxicology 11:1-10*.

Hanson, H. 1939. Fire in land use and management. *American Midland Naturalist 21:415-434.*

Heinselman, M. 1981. Fire intensity and frequency as factors in the distribution and structure of northern ecosystems. Pages 7-57 in H. A. Mooney, T. M. Bonnicksen, N. S. Christensen, J. E. Lotan, and W. A. Reiners, tech. coords. Proceedings of the conference: fire regimes and ecosystem properties. 11-15 December. 1978, Honolulu, HI. *U. S. Forest Service General Technical Report WO-26.*

Heitzman, J. and J. Heitzman. 1987. Butterflies and Leafhoppers of Missouri. Missouri Department of Conservation Publication. 385 pages.

Henderson, N. R. and J. N. Long. 1984. A comparison of stand structure and fire history in two black oak woodlands in northwest Indiana. *Botanical Gazette* 145:22-228.

Herms, C.P., D.G. McCullough, S.S. Bauer, R.A. Haack, D.S. Miller, and N.R. Dubois. 1997. Susceptibility of the endangered Karner blue butterfly (Lepidoptera: Lycaenidae) to Bacillus thuringiensisvar. kurstaki used for gypsy moth suppression in Michigan. *Great Lakes Entomologist 30:125-141*.

Hessel, S.A. 1954. A guide to collecting the plant-boring larvae of the genus Papaipema (Noctuidae). Lepidoptera News 8:57-63.

Hicks, A. 2004. Leafhopper Distribution Maps (Flexamia). http://ucsu.colorado.edu/~hicks/.

Higgins, K F. 1986. Interpretation and compendium of historical fire accounts in the Northern Great Plains. *U.S. Fish Wildlife Service, Resource Publication 161. 39 pp.*

Hofstetter, R. H. 1974. The effect of fire on the pineland and sawgrass communities of southern Florida. Pages 201-212 in P. J. Gleason, ed. Environments of south Florida: present and past. *Miami Geological Society Memoirs 2.*

Holmes, S.B. 1998. Reproduction and nest behaviour of Tennessee warblers Vermivora peregrina in forests treated with Lepidoptera-specific insecticides. *Journal of Applied Ecology 35:185-194.*

Hough, R. 1907. Handbook of the Trees of the Northern States and Canada. The MacMillan Company, New York.

Hulbert, S. 1969. Fire and litter effects in undisturbed bluestem prairie in Kansas. *Ecology 50: 874-877.*

Hulbert, S. 1981. Causes of fire effects in tall grass prairie. *Ecology 69:46-58.*

Hunt, D. M. and Robert E. Zaremba. 1992. The northeastward spread of Microstegium vimineum (Poaceae) into New York and adjacent states. *Rhodora 94:167- 170.*

Hutchinson. 1996. Monitoring Changes in Landscapes from Satellite Imagery. Eros Data Center, U. S. Geologic Survey, Sioux Falls, SD. http:/biology.usgs.gov/s+t/noframe/m3229.htm

Illinois DNR. 2000. Critical Trends Assessment Program: Kankakee River Area Assessment, Volume 5: Early Accounts of the Ecology of the Kankakee River Area (John White, editor). 444 pages. See: http://dnr.state.il.us/ctap/ctaphome.htm.

Illinois Plant Information Network. 2004. Gallery of Illinois Plants. Illinois Natuural History Survey, Champaign-Urbana, IL. http://www.inhs.uiuc.edu/cwe/illinois_plants/PlantsofIllinois.html

IMLS. 2005. National Institute of Museum and Library Services: 2005 Grant Recipients. http://www.imls.gov/results.asp?keyword=&inst=&city=&state=0&year=9&program=1001&description=on&sort=year

Johnson, K.S., J.M. Scriber, J.K. Nitao, and D.R. Smitley. 1995. Toxicity of Bacillus thuringiensis var. kustaki to three nontarget Lepidoptera in field studies. *Environmental Entomology 24:288-297.*

Kelsall, J. P., E. S. Telfer, and T. D. Wright. 1977. The effects of fire on the ecology of the boreal forest, with particular reference to the Canadian North: a review and selected bibliography. *Canadian Wildlife Service Occasional Papers no. 32. 58 pp.*

Kirby, Ronald E., Stephen J. Lewis, and Terry N. Sexson. 1988. Fire in North American wetland ecosystems and fire-wildlife relations: An annotated bibliography. U.S. Fish and Wildlife Services, Biological Report 88(1):1-146. Jamestown, ND: Northern Prairie Wildlife Research Center Online. http://www.npwrc.usgs.gov/resource/literatr/firewild/firewild.htm (Version 30SEP2002).

Kline, V. 1984. Wisconsin oak forests from an ecological and historical perspective, pp. 3-7. In: J. E. Johnson (ed.), Proc. Challenges in oak management and utilization. *Cooperative Extension Services, University of Wisconsin, Madison.*

Knapp, A. K. and T. R. Seastedt. 1986. Detritus accumulation limits productivity of tall grass prairie. *Bioscience 36:662-668.*

Komarek, E. 1985. Wildlife and fire research: past, present, and future. Pages 1-7 in J. E. Lotan and J. K Brown, compilers. Fire's effects on wildlife habitat--symposium proceedings. Missoula, Montana, 21 March 1984. *U.S. Forest Service General Technical Report INT-186.*

Komarek, E. V. 1971. Effects of fire on wildlife and range habitats. Pages 46-52 in U.S. Forest Service Prescribed burning symposium proceedings. Southeastern Forest Experiment Station, Asheville, N.C.

Kozlowski, T. T., and C. E. Ahlgren, editors. 1974. Fire and ecosystems. Academic Press, New York. 542 pp.

Krieg, A. and G.A. Langenbruch. 1981. Susceptibility of arthropod species to Bacillus thuringiensis. pp. 837-896 In H.D. Burges (ed.), Microbial control of pests and plant diseases. Academic Press, New York.

Kuchler, A. 1964. Potential Natural Vegetation of the Counterminous United States: a Map and Manual. American Geographical Society Special Publication 36. Princeton Polychrome Press, Princeton, NJ. 116 pages.

LaFleur, A. 1996. Invasive plant information sheet: Japanese stilt grass. The Nature Conservancy, Connecticut Chapter Connecticut, Hartford, CT.

Larsen, K and M. Whalon. 1987. Crepuscular movement of Paraphlepsius irroratus (Say) (Homoptera; Cicadellidae) between the groundcover and cherry Trees. *Environmental Entomology 16(5): 1103-1106.*

Lathrop, F. 1917. A preliminary list of Cicadellidae (Homoptera) of South Carolina, with descriptions of new species. *The Ohio Journal of Science XVII(4): 119-131.*

Lawson, P. 1920. The Cicadellidae of Kansas. *Kansas University Science Bulletin. 12: 5-306; pls. II-XVII.*

Lessio, F. and A. Alma. 2004. Seasonal and daily movement of Scaphoideus titanus Ball (Homoptera: Cicadellidae). *Environmental Entomology 33(6): 1689-1694.*

Lih, M. P., F. M. Stephen, K. G. Smith, S. R. Nagy, G. W. Wallis, and S. C. Thompson. 1995. Effects of a gypsy moth eradication program on nontarget forest canopy insects and their bird predators. *Proceedings Annual Gypsy moth Review. Portland, OR. Oct. 30-Nov. 2, 1994.*

Linde, A. F. 1969. Techniques for wetland management. *Wis. Dep. Nat. Resour. Res. Rep. 45. 156 pp.*

Linduska, J. 1960. Fire for bigger game crops. *Sports Afield 143(1): 30-31, 88-90.*

Lorimer, C. 1977. The presettlement forest and natural disturbance cycle of northeastern Maine. *Ecology* 58:*139-148.*

Lotan, J. E., M. E. Alexander, S. F. Arno, R.E. French, O. G. Langdon, R. M. Loomis, R. A. Norum, R. C. Rothermel, W. C. Schmidt, and J. Van Wagtendonk. 1981. Effects of fire on flora: a state-of-knowledge review. *U.S. Forest Service General Technical Report WO-16. 71 pp.*

Loveless, C. M. 1959. A study of the vegetation in the Florida Everglades. *Ecology 40:1-9.*

Luken, J.O., S.M. Kuddes, and T.C. Tholemeier. 1997. Response of understory species to gap formation and soil disturbance in Lonicera maackii thickets. *Restoration Ecology 5:229-235.*

Luken, J.O., and M. Shea. 2000. Repeated Prescribed Burning at Dinsmore Woods State Nature Preserve (Kentucky, USA): Responses of the Understory Community. *Natural Areas Journal. 20(2): 150-158*

Lynch, J. J. 1941. The place of burning in management of the Gulf coast wildlife refuges. *Journal of Wildlife Management 5:451-457.*

Martinat, P. J., V. Christman, R. J. Cooper, K. M. Dodge, R. C. Whitmore, G. Booth, and G. Seidel. 1987. Environmental fate of Dimilin 25-W in a central Appalachian forest. *Bulletin of Environmental Contaminants and Toxicology 39:142-149.*

Martinat, P.J., C.C. Coffman, K.M. Dodge, R.J. Cooper, and R.C. Whitmore. 1988. Effect of Dimilin 25-W on the canopy arthropod community in a central Appalachian forest. *Journal of Economic Entomology 81:261-267.*

Martinat, P. J., C. C. Coffman, K. M. Dodge, R. J. Cooper, and R. C. Whitmore. 1988. Effect of Diflubenzuron on the canopy arthropod community in a central Appalachian forest. *Journal Economic Entomology 81:261-267.*

Martinat, P.J., D.T. Jennings, and R.C. Whitmore. 1993. Effects of diflubenzuron on the litter spider and orthopteroid community in a central Appalachian forest infested with gypsy moth (Lepidoptera: Lymantriidae). *Environmental Entomology 22:1003-1008.*

McCasland, C. S., R. J. Cooper, and D. A. Barnum. 1998. Implications for the use of Diflubenzuron to reduce arthropod populations inhabiting evaporation ponds of the San Joaquin Valley, California. *Bulletin of Environmental Contamination and Toxicology 60:702-708.*

McNight, B. N. (ed.). 1993. Biological Pollution: The Control and Impact of Invasive Exotic Species. Indiana Academy of Science, Indianapolis.

Medina, A. (1990). Possible effects of residential development on streamflow, riparian communities, and fisheries on small mountain streams in central Arizona. *Forest Ecology and Management 33/34: 351-361.*

Medler, J.T. 1943a [dated 1942]. The Leafhoppers of Minnesota. Homoptera: Cicadellidae University of Minnesota Agricultural Experiment Station, Technical Bulletin 155. 196 pp.

Midwestern Ecology Working Group of NatureServe. No date. International Ecological Classification Standard: International Vegetation Classification. Terrestrial Vegetation. NatureServe, Minneapolis, MN.

Miller, H. 1963. Use of fire in wildlife management. *Proceedings Annual Tall Timbers Fire Ecology Conference 2:19-30.*

Miller, J. 2003. Nonnative invasive plants of southern forests: a field guide for identification and control. USDA Forest Service, Southern Research Station. General Technical Report SRS-62. Asheville, NC. 93 pages.

Miller, J. 1990. Field assessment of the effects of a microbial pest control agent on non-target Lepidoptera. *American Entomologist 36:135-139.*

Miller, J. 1990. Effects of a microbial insecticide, Bacillus thuringiensis kurstaki, on nontarget Lepidoptera in a spruce budworm-infested forest. *Journal of Research on the Lepidoptera 29(4):267-276.*

MNNHP [Minnesota Natural Heritage Program]. 1993. Minnesota's native vegetation: A key to natural communities. Version 1.5. Minnesota Department of Natural Resources, Natural Heritage Program, St. Paul, MN. 110 pp.

Montana State University, 2002. MSU Extension Services: 250 Plants for Range Contests in Montana. http://www.montana.edu/wwwpb/pubs/mt8402ag.html.

Morris, O. 1969. Susceptibility of several forest insects of British Columbia to commercially produced Bacillus thuringiensis. II. Laboratory and field pathogenicity tests. *Journal of Invertebrate Pathology 13:285-295.*

Mutanen, R., H. Siltanen, V. Kuukka, E. Annila, and M. Varama. 1988. Residues of diflubenzuron and two of its metabolites in a forest ecosystem after control of the pine looper leafhopper Bupalus pinarius L. *Pesticide Science 23(2):131-140.*

NatureServe Explorer: An online encyclopedia of life (web application). 2005. Search Results for Flexamia reflexa (dated May 01, 2005). Version 1.6. Arlington, Virginia. http://www.natureserve.org/explorer.

Nelson, P. 1985. The terrestrial natural communities of Missouri. Missouri Natural Areas Committee, Jefferson City. 197 pp. Revised edition, 1987.

NDSU, 2005. North Dakota State University Central Grasslands Research Extension Center. http://www.ag.ndsu.nodak.edu/streeter/2001report/Grazing_intensity_Plant%20Comm.htm#Table9

Nuzzo, V. 1986. Extent and status of Midwestern oak savanna: presettlement and 1985. *Natural Areas Journal 6:6-36.*

Oman, P. 1949.

Oregon State University. 2005. Tallgrass Project Website: Indiangrass (Sorghastrum nutans). http://oregonstate.edu/dept/range/projects/plantsdb/tallgrass/tallgrass.htm#sonu

Osborn, H. and Ball, E.D. 1897. Contributions to the Hemipterous fauna of Iowa. *Iowa Academy of Sciences Proceedings 4: 172-234.*

Packard, S. 1988. Chronicals of restoration: restoration and rediscovery of the tall grass savanna. *Restoration and Management Notes* 6:13-20.

Panzer, R., G. Derkovitz and R. Gnaedinger. 1995.

Panzer, R. and M. Schwartz. 1998. Effects of management burning on prairie insect species richness within a system of small highly fragmented reserves. *Biological Conservation (2000): 363-369.*

Peacock, J., D. Schweitzer, J. Carter, and N. Dubois. 1998. Laboratory assessment of the effects of Bacillus thuringiensis on native Lepidoptera. *Environmental Entomology 27(2):450-457.*

Peet, M., T. Anderson, and M. Adams. 1975. Effects of fire on big bluestem production. *American Midland Naturalist 94:15-26.*

Penfound, W. 1952. Southern swamps and marshes. *Botanical Review 18:413-446.*

Perkins, R. 1905. Leafhoppers and their Natural Enemies (Pt. 1 Drinidae). *Report of the Work of the Experiment Station of the Hawaiian Sugar Planters Association 1(1).*

Reardon, R., 1995 (coordinator). Effects of Diflubenzuron on non-target organisms in broadleaf forested watersheds in the Northeast. *USDA Forest Service.FHM-NC-05-95, 174 pp.*

Riemenschneider, V., T. Cordell and B. Allison, 1995. Impact of white-tailed deer on plant cover and biomass in Potato Creek State Park, St. Joseph County, Indiana. Unpublished report.

Ross, H.H. and Cooley, T.A. 1969. A new Nearctic leafhopper of the genus Flexamia (Hemiptera: Cicadellidae). *Entomological News 80(9): 246-248.*

Rowe, J. , and G. Scotter. 1973. Fire in the boreal forest. *Quaternary Research (NY) 3:441 164.*

Sample, B. 1991. Effects of Dimilin on food of the endangered Virginia big-eared bat. Ph.D. Dissertation, West Virginia University, Morgantown, W.Va. 201pp.

Sample, B., R. Cooper, and R. Whitmore. 1993a. Dietary shifts among songbirds from a diflubenzuron-treated forest. *Condor 95:616-624.*

Sample, B., S. Butler, and R. Whitmore. 1993b. Effects of an operational application of Dimilin on nontarget insects. *The Canadian Entomologist 125:173-179.*

Sample, B., S. Butler, C. Zivkovich, R. Whitmore, and R. Reardon. 1996. Effects of Bacillus thuringiensis and defoliation by the gypsy moth on native arthropods in West Virginia. *Canadian Entomologist 128:573-592.*

Sanders, J. and D. DeLong, 1917. The Cicadellidae (Jassoidea-Fam. Homoptera) of Wisconsin, with descriptions of new species. *Annals Entomological Society of America X: 79-97.*

Schwaegman, J. and T. Anderson. 1984. Effects of eleven years of fire exclusion on the vegetation of a southern Illinois barren remnant, pp. 146-148. In: *Proceedings of the Ninth North American Prairie Conference.*

Schwartz, M. and J. Heim. 1996. Effects of a prescribed fire on degraded forest vegetation. *Natural Areas Journal. 16:184-191.*

Schweitzer, D. 2004b. Gypsy moth (Lymantria dispar): Impacts and Options for Biodiversity-Oriented Land Managers. 59 pp. Nature Serve Explorer. Arlington, Virginia. http://www.natureserve.org/explorer.

Schweitzer, D. 2000. Impacts of the 1999 Gypsy moth Eradication Project at Highlands, North Carolina: Characterization of the leafhopper fauna in the project area, and a preliminary assessment of the impacts from the 1999 treatments. Unpublished consultant's report sent to Jeff Witcosky, USDA Forest Service, Asheville, NC, 22 pp.

Seidel, G. and R. Whitmore. 1995. Effects of Dimilin application on white-footed mouse populations in a central Appalachian Forest. *Environmental Toxicology and Chemistry 14:793-795.*

Severns, P. 2002. Evidence for the negative effects of BT (Bacillus thuringiensis var. kurstaki) on a non-target butterfly community in western Oregon, USA. *Journal of the Lepidopterists' Society 56(3): 166-170.*

Sipple, W. 1978. A review of the biology, ecology, and management of Scirpus olneyi. Volume I: an annotated bibliography of selected references. *Maryland Department of Natural Resources Wetland Publication 2. 96 + [6] pp.*

Sipple, W. 1979. A review of the biology, ecology, and management of Scirpus olneyi. Volume II: a synthesis of selected references. *Maryland Department of Natural Resources Wetland Publication 4. 85 pp.*

Smith, J. 1889. Revision of the genus Hydroecia Trans. American Entomological Society 26: 1-48, 2pls

Slaughter, C., R. Barney, and G. Hansen, editors 1971. Fire in the northern environment-a symposium. *U. S. Forest Service, Pacific Northwest Forest Range Experiment Station, Portland, OR. 275 pp.*

Smith, S., and J. Kadlec. 1985. The effect of disturbance on marsh seed banks. *Canadian Journal of Botany 63:2133-2137.*

Stamps, W. and M. Linit. 1997. Plant diversity and arthropod communities: Implications for temperate agroforestry. *Agroforestry Systems. 39(1): 73-89(17).*

Swearingen, J. 2004. WeedUS: Database of Invasive Plants of Natural Areas in the U.S. Plant Conservation Alliance. http://www.nps.gov/plants/alien

Swift, M.C., R.A. Smucker, and K.W. Cummins. 1988. Effects of Dimilin on freshwater litter decomposition. *Environmental Toxicology and Chemistry 7:161-166.*

Tester, J. 1989. Effects of fire frequency on oak savanna in east-central Minnesota. *Bulletin of the Torrey Botanical Club 116:134-144.*

Tester, J., and W. Marshall. 1962. Minnesota prairie management techniques and their wildlife implications. *North American Wildlife Natural Resources Conference 27:267-287.*

Thomas, M. and D. Schumann. 1993. Income Opportunities in Special Forest Products: Self-Help Suggestions for Rural Entrepreneurs (Agriculture Information Bulletin AIB-666). USDA Forest Service, Washington, DC. http://www.fpl.fs.fed.us/documnts/usda/agib666/agib666.htm

Thompson, D. 1959. Biological investigation of the Upper Fox River. *Wisconsin Conservation Department Special Wildlife Report 2. 41 pp.*

Thor, E. and G. Nichols. 1973. Some effects of fires on litter, soil, and hardwood regeneration. In: Proceedings in the Tall Timbers Fire Ecology Conference. 13:317-329.

Tilman, D. 1987. Secondary succession and the pattern of plant dominance along an experimental nitrogen gradient. *Ecological Monographs* 57:198-214.

Triapitsyn S. and P. Phillips. 2000. First record of Gonatocerus triguttatus (Hymenoptera: Mymaridae) from eggs of Homalodisca coagulata (Homoptera: Cicadellidae) with notes on the distribution of the host. *Florida Entomologist 83: 200-203.*

Uhler, F. 1944. Control of undesirable plants in waterfowl habitats. *Transactions of the North American Wildlife Conference 9:295-303.*

Uniroyal Corporation. 1983. Product profile for experimental use of Dimilin 25 W., 6 pp. plus inserted Material Safety Data Sheet. Distributed by Uniroyal.

USDA, NRCS. 2004. The PLANTS Database, Version 3.5. National Plant Data Center, Baton Rouge, LA. http://plants.usda.gov

USDA Forest Service. 2005. Fire Effects Information System [Online]. www.fs.fed.us/database/feis/plants/forb/psohyp/all.html.

USDA Forest Service. 2004a. Biological evaluation for the gypsy moth "slow the spread" project 2004 on the Washburn, Great Divide and Medford/Park Falls Ranger Districts, Chequamegon-Nicolet National Forest, Wisconsin. www.fs.fed.us/r9/cnnf/natres/eis/04_gypsy_leafhopper/04gm_BE.pdf

USDA Forest Service. 2004b. Forest Stewardship Program Website. Washington, D.C. http://www.fs.fed.us/spf/coop/programs/loa/fsp.shtml

USDA Forest Service. 2004. Chatahootchee-Oconee National Forest, Land and Resource Management Plan, Appendix E: General Recommendations for Rare Communities, Management Prescription 9F. http://www.fs.fed.us/conf/200401-plan/5-PA_E.pdf

USDA Forest Service. 1937. Range plant handbook. Washington, DC. 532 p.

USDA Soil Conservation Service. 1969. Soil Survey, Perry County, Indiana. 70 pages, 70 maps, 1 folding chart.

USEPA, 2005. The U. S. Environmental Protection Agency: Wetlands Website. http://www.epa.gov/owow/wetlands/vital/protection.html.

US Fish and Wildlife Service. 1964. S. Hoffman, compiler. Project MAR. The conservation and management of temperate marshes, bogs and other wetlands. Vol. 1. *Proceedings MAR Conference organized by IUCN, ICBP, and IWRB at Les Saintes-Maries-de-la-Mer, 12-16 November 1962. IUCN Publication (New Series) 3.*

USGS, 2005a. US Geologic Survey: Northern Prairie Wildlife Research Center Website. Effects of Fire in the Northern Great Plains: General Observations of Fire Effects on Certain Plant Species. http://www.npwrc.usgs.gov/resource/habitat/fire/genobser.htm.

USGS, 2005a. US Geologic Survey: Northern Prairie Wildlife Research Center: Leafhoppers of North America Website.

Van Lear, D. and V. Johnson. 1983. Effects of prescribed burning in the southern Appalachian and upper Piedmont forests: a review. Clemson University, Clemson, SC. *College of Forestry and Recreation Resources, Department of Forestry, Forest Bulletin 36. 8 pp.*

Vierick, S. 1973. Wildfire in the taiga of Alaska. *Quaternary Research 3: 465-495.*

Vierick, S., and S. Schandelmeier. 1980. Effects of fire in Alaska and adjacent Canada-a literature review. *U. S. Bureau of Land Management Technical Report no. 6 (BLM/AK/TR-80/06). 124 pp.*

Wade, D., J. Ewel, and R. Hofstetter. 1980. Fire in south Florida ecosystems. *U. S. Forest Service General Technical Report SE-17. 125 pp.*

Wagner, D.S., J.W. Peacock, J.S. Carter, and S.E. Talley. 1996. Field assessment of Bacillus thuringiensis on nontarget Lepidoptera. *Environmental Entomology 25(6):1444-1454.*

Wagner, D. and J. Miller. 1995. Must butterflies die for gypsy moths' sins? *American Butterflies 3(3):19-23.*

Waloff, N. 1980. Studies on grassland leafhoppers and their natural enemies. *Advances in Ecological Research 11: 81-215.*

Weaver, J. 1965. The Natural Vegetation of Nebraska. Johnson Publishing Company, Lincoln, Nebraska.

Weaver, J. and F. Albertson. 1956. The Grasslands of the Great Plains: Their Nature and Use. Johnsen Publishing Company. Lincoln, Nebraska. 395 pages.

Weaver, J. 1954. North American Prairie. Johnsen Publishing Company, Lincoln, Nebraska.

Weaver, J. and T. Fitzpatrick. 1934. The Prairie. *Ecological Monographs 4: 109-295.*

Webb, D., H. DeSelm, and W. Dennis. 1997. Studies of prairie barrens of northwestern Alabama. *Castanea 62:173-184.*

Wein, R., and D. MacLean. 1983. The role of fire in northern circumpolar ecosystems. Scientific Committee on Problems of the Environment (SCOPE 18). John Wiley & Sons Ltd., Chichester, England. 322 pp.

Wells, B. 1942. Ecological problems of the southeastern United States coastal plain. *Botanical Review 8:533-561.*

Wells, B. 1931. The vegetation and habitat factors of the coarse sands of the North Carolina coastal plain: an ecological study. *Ecological Monographs 1: 465-520.*

Whaley, W., J. Anhold, B. Schaalje. 1998. Canyon drift and dispersion of Bacillus thuringiensis and its effects on select non-target Lepidopterans in Utah. *Environmental Entomology 27(3): 539-548.*

Whitcomb, R.F. and Hicks, A.L. 1988a. Genus Flexamia: new species, phylogeny, and ecology. Great Basin Naturalist Memoirs No. 12: 224-323. [8 n.sp]

Whitcomb, R.F., Hicks, A.L., Lynn, D.E., Allred, K.A., and Blocker, H.D. 1987. Geographic variation in host relationships of leafhoppers (Homoptera: Cicadellidae) in North American grasslands. Proceedings: 2nd International Workshop on Leafhoppers and Planthoppers of Economic Importance. Wilson, M.R. and L.R. Nault [Eds.] Commonwealth Institute for Entomology, London, pp. 293-325.

Whitcomb, R.F., Kramer, J.P., Coan, M.E., and Hicks, A.L. 1987. Ecology and evolution of leafhopper-grass host relationships in North America grasslands. Current Topics in Vector Research 4: 121-178.

White, A. 1983. The effects of thirteen years of annual burning on a *Quercus ellipsoidalis* community in Minnesota. *Ecology* 64:1081-1085.

White, J., and M. Madany. 1978. Classification of natural communities in Illinois. Pages 311-405 in: Natural Areas Inventory technical report: Volume I, survey methods and results. Illinois Natural Areas Inventory, Urbana, IL.

Whitford, P. and P. Whitford. 1978. Effects of trees on ground cover in old-field succession. *American Midland Naturalist* 99:435-443.

Whitmore, R., R. Cooper, and B. Sample. 1993a. Bird fat reductions in forests treated with Dimilin. *Environmental Toxicology and Chemistry. 12:2059-2064.*

Whitmore, R., B. Sample, and R. Cooper. 1993b. Bird fat levels as a measure of effect in forests treated with diflubenzuron. *Environmental Toxicology and Chemistry 12:2059-2064.*

Williams, A. 2000. The effects of gypsy moth treatment applications of Bacillus thuringiensis on Worm-eating Warblers in Virginia. MS Thesis, University of Georgia, Department of Forest Resources, Athens, GA.

Wilson, E. and R. MacArthur (1967). The Theory of Island Biogeography. Princeton, University Press: Princeton, NJ.

Wimmer, M., R. Smith, D. Wellings, S. Toney, D. Faber, J. Miracle, J. Carnes, and A. Rutherford. 1993. Persistence of diflubenzuron on Appalachian forest leaves after aerial application of Dimilin. *Journal of Agricultural and Food Chemistry 41:2184-2190.*

Wright, H. and A. Bailey. 1982. Fire Ecology. John Wiley and Sons, New York.

Young, D. and B. Bierne. 1957.

APPENDIX

LIST OF CONTACTS

INFORMATION REQUESTS

Kirk Larson, Hoosier National Forest, Bedford, Indiana office. Phone: (812) 277-3596
e-mail: kwlarson@fs.fed.us

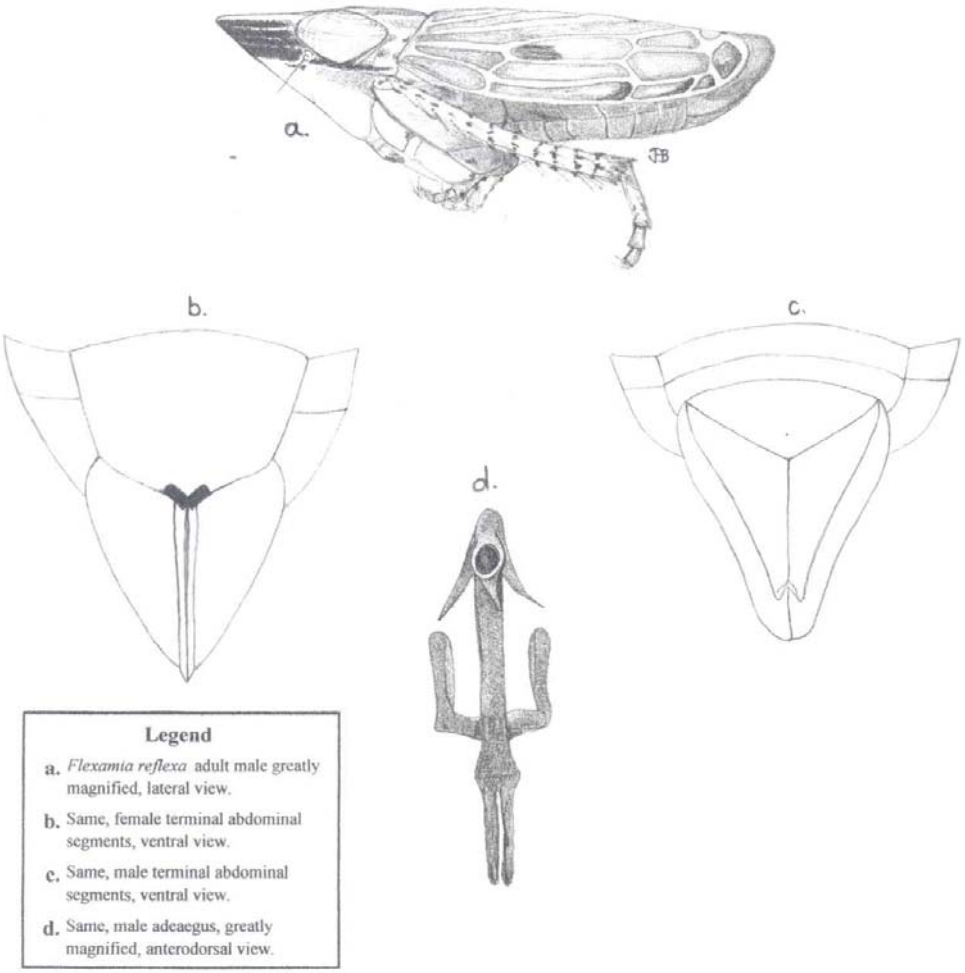
James Bess, OTIS Enterprises, Wanatah, IN 46390. Phone (219) 733-2947. E-mail:
jabess@netnitco.net.

REVIEW REQUESTS

Kirk Larson, Hoosier National Forest, Bedford, Indiana office. Phone: (812) 277-3596
e-mail: kwlarson@fs.fed.us

FIGURES

Figure 1. *Flexamia Reflexa* : Adult and Genitalia



Legend

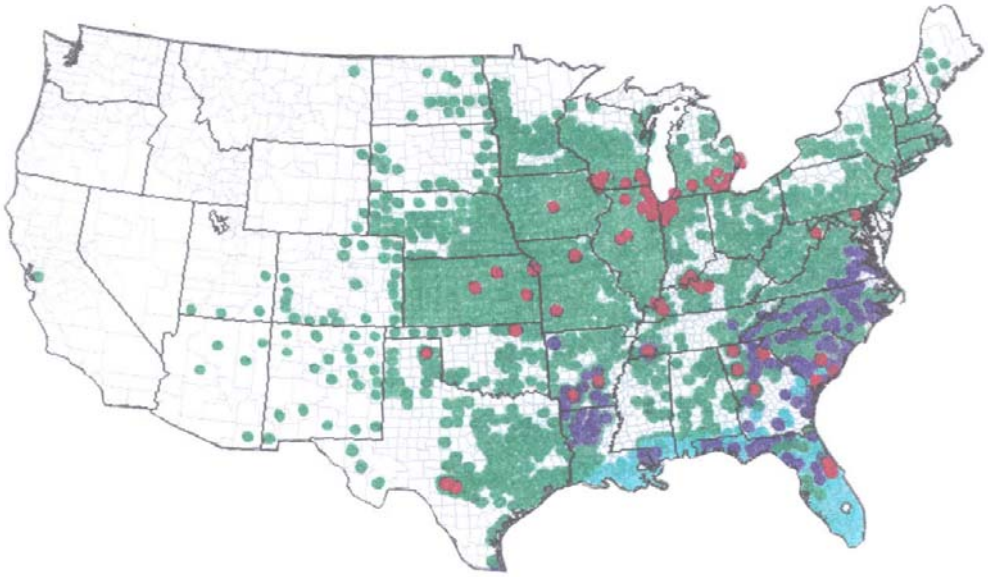
a. *Flexamia reflexa* adult male greatly magnified, lateral view.

b. Same, female terminal abdominal segments, ventral view.

c. Same, male terminal abdominal segments, ventral view.

d. Same, male adeaegus, greatly magnified, anterodorsal view.

Figure 2. Known Distribution of the reflexed Indiangrass leafhopper (*Flexamia reflexa*) and its Foodplants in the Eastern United States.



● = Known Flexamia reflexa Populations
● = Known Sorghastrum elliottii Populations
● = Known Sorghastrum secundum Populations
● = Known Sorghastrum nutans Populations