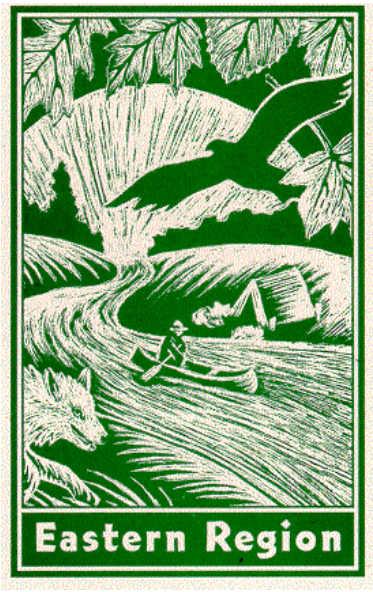
Conservation Assessment for the Brick-Red Borer Moth (Papaipema marginidens (Guenee))



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This document is undergoing peer review, comments welcome

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EXECUTIVE SUMMARY

The brick-red borer moth (*Papaipema marginidens* (Guenee)) is a medium-sized, dark red and purplish brown moth associated with seepage areas in open oak woodland and barrens. It is considered uncommon and local throughout its range. This moth produces a single brood per year, with the adults appearing in the fall. The species is never common (except on a local level) and most states where it is known contain only one or a few populations. During the westward expansion of Europeans following the American Revolution, vast acreage of oak woodland and forest was felled for timber, home sites and agricultural production. Barrens and woodlands were heavily grazed by cattle, horses, sheep and swine. During this time, the brick-red borer moth likely lost a considerable amount of habitat. Given the current degraded status of the oak barrens and woodland ecosystems, this moth's remaining habitat is patchy and occurrences are often widely separated. Ongoing efforts to protect and restore remnants of these ecosystems will hopefully provide additional habitat for this species. Whenever feasible, ongoing and new projects should track the effects of their restoration efforts on potentially sensitive organisms such as the mayapple borer moth. This would provide land managers with useful information for measuring the effectiveness of various restoration techniques in enhancing and maintaining habitat.

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 Cloverlick Barrens Special Area, where I eventually discovered what appears to be a healthy population of *Papaipema marginidens*.

NOMENCLATURE AND TAXONOMY

The genus *Papaipema* was first designated by Smith in 1889. The brick-red borer (*Papaipema marginidens*) was described by Guenee in 1852 as *"Gortyna marginidens"*, from specimens of unknown origin, possibly Georgia. Dyar subsequently named *Gortyna* (=*Papaipema*) *nephrasyntheta* in 1908 from a specimen collected at Plummers Island, Maryland on September 27, 1904 by E. A. Schwarz (see Bird, 1917). These two taxa are now considered synonyms by the current authority on the group, Eric Quinter (formerly with the Museum of Natural History in New York). However, the name *Papaipema marginidens* has been widely misapplied to specimens of any reddish *Papaipema* having a prominent, white reniform spot on the forewing. Forbes' 1954 description of *Papaipema marginidens* (presumably repeating that of Guenee) more closely fits the taxa know known as *Papaipema birdi* (Dyar) (a northern, orange, red and yellow wetland species), while the short description of *Papaipema nephrasyntheta* Dyar is closer to what we now call *Papaipema marginidens* Guenee. This confusion needs to be rectified.

DESCRIPTION OF SPECIES

DESCRIPTION OF ADULT STAGE

The borer moths of the genus *Papaipema* are quite variable in appearance; some being entirely dark brown, while others are golden yellow or red, all with or without large white spots (claviform and orbicular near base of wing and reniform spot near the center) on the forewings. *P. marginidens* is one of the red species, being superficially similar to *Papaipema birdi* and several other species (see Figure 2). This moth typically measures 40-45 mm (1-1.25 inches) in wingspan and is a dull brick red with no apparent yellow scaling in the forewing. The wings are marked dorsally with a series of vertical lines and bands, all of which are dark brown or purplish brown in color. The outer quarter of the forewing is entirely of the dark purplish brown color. There are three white spots in the central and basal parts of the forewings, the outer one being largest and made up of several, tightly clustered, smaller spots. The ventral ground color is typically light tan or brown.

DESCRIPTION OF IMMATURE STAGES

unknown.

LIFE HISTORY

REPRODUCTION

unknown

ECOLOGY

Papaipema marginidens occurs in high quality, woodland and barrens remnants, usually along stream corridors. There is one adult brood per season, typically from mid-September through October. The adult brood period lasts roughly a month, during which they mate and females presumably lay eggs. The adults may feed on nectar, flowing tree sap, rotten fruit and probably other liquids.

DISPERSAL/MIGRATION

Maximum individual dispersal distances for this species are probably on the order of a few hundred yards and *Papaipema marginidens* is generally regarded as being uncommon and highly local in occurrence. However, individuals are probably capable of dispersing over large areas of contiguous suitable habitat, particularly along stream corridors. *Papaipema marginidens* is not known to migrate.

OBLIGATE ASSOCIATIONS

The obligate habitat for the brick-red borer moth is a mixture of high quality barrens and dry-mesic woodland along stream corridors. The moth rarely (if ever) occurs in highly degraded habitats.

HABITAT

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

In the Hoosier National Forest (HNF) of Indiana, the habitat for *Papaipema marginidens* is typical of that for the species throughout much of the central parts of its range. It is also superficially similar to habitat in the southwestern part of the moth's range, with many plant species and genera shared between them. As in the southwestern part of its range, this species is associated with streamside prairies and/or barrens. At the two known populations in Perry County, the overstory is dominated by oaks (*Quercus alba, Q. phellos, Q. stellata* and *Q. marilandica*) and several other species, including red maple (*Acer rubrum*), hickories (*Carya*), ash (*Fraxinus*) and tulip tree (*Liriodendron tulipifera*). Beech (*Fagus grandiflora*), persimmon ( ), black gum (*Nyssa sylvatica*), hop hornbeam, red elm, and other species may be locally important. The shrub layer includes saplings of canopy species, plus paw paw (*Asimina triloba*), redbud (*Cercis canadensis*), flowering dogwood (*Cornus florida*), hazelnut (*Corylus americana*), huckleberry (*Gaylusaccia baccata*), witch hazel (*Hamamelis virginiana*), spicebush (*Lindera benzoin*), Carolina buckthorn (*Rhamnus caroliniana*), raspberries (*Rubus alleghaniensis, R. occidentalis*), coralberry, sassafras (*Sassafras albidum*) and blueberries (*Vaccinium* spp.).

Characteristic herbaceous species include Virginia snakeroot (*Aristolochia serpentaria*), indian plantain (*Cacalia atriplicifolia*), bellflower (*Campanula americana*), poison hemlock (*Cicuta maculata*), Carolina thistle (*Cirsium carolinianum*), tall tickseed (*Coreopsis tripteris*), wild oregano (*Cunila origanoides*), numerous sticktights (*Desmodium canescens, D. glutinosum, D. nudiflorum, D. paniculatum, D. rotundifolium*), coneflowers, bonesets (*Eupatorium* spp.), woodland sunflowers (*Helianthus divaricatus* and *H. hirsutus*), dwarf crested iris (*Iris cristata*), wild bergamot (*Monarda fistulosa*), scurfy pea (*Psoralea psoralioides*), Jacob's ladder (*Polemonium reptans*), cup plant (*Polymnia uvedalia*), mountain mint (*Pycnanthemum tenuifolium*), rattlesnake master, black-eyed Susan, wild petunia (*Ruellia humilis*), skullcaps (*Scutellaria elliptica, S. leonardii*), goldenrods (*Solidago glauca, S. caesia, S. ulmifolia*), American columbo (*Swertia caroliniensis*), Virginia spiderwort (*Tradescantia viriginiana*), ironweed (*Vernonia altissima*) and wingstem (*Verbesina* spp.).

As elsewhere in the moth's range, grasses, sedges and rushes are important components of the herbaceous layer in areas of occupied habitat. These include wood reed (*Cinna arundinacea*), bottlebrush grass (*Elymus hystrix*), Virginia wild rye (*Elymus virginicus*), panic grasses (*Panicum anceps, P. boscii, P. dichotomum, P. laxiflorum, P. virgatum*), sedges (*Carex albicans, C. cephalophora, C. complanata, C. glaucodea, C. rosea*), rushes (*Juncus* spp.), nodding bulrush (*Scirpus pendulus*) and nut rush (*Scleria oligantha*).

The only known occurrence for *Papaipema marginidens* within the HNF is the Cloverlick Barrens Special Area, a ca. 1,300 acre complex of open and closed canopy oak and oak-pine barrens. This site contains several hundred acres of potential habitat for the moth, with a diverse flora as listed above. Much of the occupied Bell's moth habitat at Cloverlick Barrens was formerly open oak barrens, with old, widely-spaced white, black, blackjack and post oaks occupying the canopy layer. Currently, young (15-25 yr old) oak, ash, tulip tree and red maple saplings dominate much of the former barrens, forming a closed-canopy forest.

In the central portion of the Cloverlick barrens complex, open grassland dominated by little bluestem and Indian grass intermingles with the wooded barrens. Recent fire management and mechanical brush removal has opened much of the fire suppressed barrens and encouraged a diverse array of wildflowers and grasses. This is especially true along the ecotone between these two community types, with a corresponding richness in butterflies and moths. Several hundred to a few thousand acres of superficially similar habitat occurs on adjacent Forest Service and private lands.

DISTRIBUTION AND ABUNDANCE

RANGE-WIDE DISTRIBUTION

The brick-red borer moth has a patchy and discontinuous range in northeastern North America (see Figure 1). Most known populations occur in a band along the Appalachians, with outlying populations in southern Indiana and Kentucky. Throughout its range, this moth is considered uncommon to rare and always local in occurrence. Several state records for this species consist of one or only a few populations.

STATE AND NATIONAL FOREST DISTRIBUTION

The following state-level distribution information for the brick-red borer moth is gathered from the NatureServe Website and additional sources (Bess, 2004). Known populations are plotted in Figure 1. This species is currently known from IN, KY, MD, MS, NC, NJ, NY, OH, PA, SC, VA.

RANGE WIDE STATUS

Papaipema marginidens is considered uncommon to potentially imperiled in most or all parts of its range (Schweitzer, 2002). While it does not appear to be in immediate danger of extirpation, there seems to be insufficient information to conclude that it is demonstrably secure. This is especially true with regards to its preferred habitats (i.e. fire maintained oak barrens and dry-mesic oak woodland), which are globally imperiled. The following information was taken directly from the NatureServe.org Website in 2005 (see NatureServe, 2005).

Global Status: G4
Global Status Last Reviewed: 15Aug1999
Global Status Last Changed: 15Aug1999
Rounded Global Status: G4
National Status: N4

Reasons:
The NatureServe Website Provides no additional supporting information for this species other than to state that it is secure in Kentucky and Maryland. Most states have the species unranked. It is listed as being of historic occurrence in NY (Long Island?) and PA (New Brighton).

Status (S-Rank) in the Following States:
Indiana (S1S3), Kentucky (S4), Maryland (S4), Mississippi (SNR), New Jersey (SNR), New York (SH), North Carolina (SNR), Ohio (SNR), Pennsylvania (SU), South Carolina (SNR), Virginia (SNR).

POPULATION BIOLOGY AND VIABILITY

The brick-red borer moth occurs in a series of plant communities that were once widespread across the southeast and central United States. In general, it is a species of rocky, wooded habitats characterized (in their primordial state) by having an open canopy dominated by oak, typically white oak (*Quercus alba*) or post oak (*Quercus stellata*). These habitats are always characterized by mature or over-mature canopy trees, with a rich herbaceous layer. Many of the more heavily wooded habitats in which this species occurs were once fire-maintained savannas and barrens, with pockets of protected forest and woodland along streams that only occasionally received fire. Prior to the westward expansion of Europeans on the American continent in the 1800's, the brick-red borer moth was probably locally common throughout the region delineated in Figure 1.

However, pressures from grazing by domesticated animals and deforestation began to reduce acreage of suitable habitat for the brick-red borer moth and many other species of flora and fauna. The suppression of wildfires has probably been among the more profound changes to the North American environment in the past 1,000 years. Many open, woodland and barrens communities quickly succeeded to closed canopy forests of young softwoods and hardwoods. Others were invaded by non-native plant species that quickly excluded native ones from the flora. As a result, habitat suitable for *Papaipema marginidens* has become fragmented, often with large expanses of plowed fields, roads, cities and other barriers to dispersal, separating the remnants and isolating populations of the moth.

POTENTIAL THREATS

PRESENT OR THREATENED RISKS TO HABITAT

Human activity over the past 200 years has resulted in a shift in the distribution of the plant communities on which the brick-red borer moth depends. Suppression of wildfires has resulted in the rapid succession of these barrens and savannas to closed canopy forest. Extensive livestock grazing has reduced the cover of native forbs that this moth depends on and repeated, heavy grazing greatly degrades native plant communities. The thin soils underlying this vegetation are easily disturbed and overgrazing often leads to the widespread erosion of topsoil. Many overgrazed pastures have been subsequently replanted with Eurasian, cool-season grasses, further limiting and fragmenting the amount of available habitat for insects dependent on native grasses and grasslands. This isolation of often small populations can lead to inbreeding and extinction (see Wilson and MacArthur, 1967).

Grazing

Browsing by deer is possibly a threat to brick-red borer moth rangewide, although the foodplant at this time is unknown. Whatever this moth's foodplant turns out to be, it is probably eaten by deer. It is also likely that this species is a stem borer, putting larvae at a greater risk of accidental herbivory and predation over the entire larval period. Heavy browsing of the herbaceous layer could have an overall negative impact on this species by reducing availability of larval foodplant or direct mortality of young larvae in the spring through herbivory or trampling. Domesticated cattle and horses would also pose a threat to the moth by consuming larval food sources, eggs, larvae and/or pupae, should the foodplant prove to be palatable. However, it is assumed that well-managed, rotational grazing would probably have only limited negative effects on this species. However, excessive stocking rates (which is often the norm) leads to the compaction and erosion of soils, destruction of foodplant and altering of plant community structure. Swine, goats and sheep eat nearly all green matter and often severely compact and erode soils in areas where they are stocked. These factors have 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. 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. European immigrants used fire to clear brush and enhance the growth of grasses and other plants that provided forage for their domesticated, European livestock. Unfortunately, excessive numbers of animals were often placed on grasslands with marginal amounts of available forage, leading to the destruction of the 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 involved the seeding of cool-season, non-native grasses. Preferred species in upland pastures include smooth brome (*Bromus inermis*), fescue (*Festuca arundinacea* and *F. elatior*), orchardgrass (*Dactylis glomerata*) and the bluegrasses (*Poa compressa* and *P. pratensis*). These methods became indoctrinated into our system of land reclamation and these grasses persist to this day as recommended cover species. Clovers (*Medicago, Melilotus* and *Trifolium* spp.) are often placed in the grass mix to provide nitrogen fixation in the soil and fodder for livestock.

By producing large amounts of seed that germinate under cool temperatures, these 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. Only in

recent times (past 20 years) have native species been marketed as alternatives for use in erosion control, bank stabilization and pasture/range enhancement.

Competition from Introduced Species

In addition to the pasture species mentioned above, a number of other introduced plants threaten the quality and survival of brick-red borer moth habitat (see McKnight, 1993). These include garlic mustard (*Alliaria petiolata*), Japanese honeysuckle (*Lonicera japonica*), bush honeysuckles (*Lonicera mackii* and *L. tartarica*), Japanese stilt grass (*Microstegium vimineum*) and glossy buckthorn (*Rhamnus cathartica*). Each of these will be dealt with separately in the following sections.

Garlic Mustard

Non-native garlic mustard is a severe threat to the long-term survival of many wooded plant communities. This plant is highly adaptable and survives under a broad range of moisture, light and soil conditions (Anderson and Kelley, 1995; Anderson et al., 1996; Brunelle, 1996; Byers and Quinn, 1998; Cruden et al., 1996; Dhillion and Anderson, 1999; Nuzzo, 1993; Roberts and Bodrell, 1983). Garlic mustard overgrows native herbaceous plants, often excluding them from the flora (see Brothers and Springarn, 1992; Luken and Shea, 2000; Luken et al., 1997; McCarthy, 1997; Nuzzo, 1999). Although it is fond of disturbed situations, garlic mustard can invade relatively pristine plant communities, especially along paths, roadsides and utility rights-of-way (Brothers and Springarn, 1992; Brunell, 1996; Luken et al., 1997; Luken and Shea, 2000; Nuzzo, 1999).

Japanese and Bush Honeysuckles

These non-native honeysuckles have long been used for landscape and wildlife plantings. They produce large numbers of berries, which are readily eaten by birds and redistributed across our woodlands. They are now a common (often dominant) component of the understory in our woodlands and forests. Both *Lonicera japonica* and *L. mackii* can become so abundant as to exclude nearly all other flora from the ground and shrub layers. They are especially abundant in woodlands that have experienced a history of grazing that reduced the native vegetative cover. All can be controlled with manual cutting and herbicide application, although re-infestations are often inevitable (Luken et al., 1997).

Japanese Stilt Grass

Like garlic mustard, Japanese stilt grass poses a serious threat to habitat for *Papaipema marginidens* throughout much of the moth's range (Barden, 1987, 1991; Fairbrothers and Gray, 1972; Hunt and Zaremba, 1992; LaFleur, 1996). This fairly recent introduction moves into natural areas quickly along roadsides, paths and waterways. In the south, where many small streamlets dry up or cease flowing during the summer months, this grass can establish itself quickly on newly exposed soil in the streambed. The species forms numerous clones over the growing season, each of which flowers in late summer. Once established, this grass typically forms a solid monoculture along roadsides and pathways. Rain events wash plants and seed down roadways and paths into drains and streams, quickly distributing fresh propagules over a large area. Japanese stilt grass is best controlled with a combination of mowing prior to seed set, with follow up mowing and herbicide application as needed.

Glossy Buckthorn

The threat, mode of dispersal and methods of control for this species are the same as the honeysuckles mentioned previously.

Over utilization

The brick-red borer moth is of concern to moth enthusiasts, with several well-known collectors pursuing members of this genus for the purpose of collecting specimens. Its habitat selection and secretive habits make it relatively difficult to collect on a large scale, although it can be locally common, especially in the western part of its range. Collectors of *Papaipema* frequently dig up plants in search of larvae. These are then reared in captivity to obtain perfect adult specimens. This practice not only removes moths from the population, but also destroys foodplant colonies in the process.

Disease or Predation

A number of insectivorous animals feed on *Papaipema* larvae and pupae, particularly mice, voles, squirrels and skunks. The effect of their depredations can devastate small, isolated populations of these moths. Birds such as woodpeckers also bore into plant stems to extract larvae and pupae and the adults are susceptible to a number of other insectivorous songbirds, small raptors and bats.

Microbial pathogens also affect *Papaipema marginidens* and related species, one of which is the soil born bacteria, *Bacillus thuringiensis kurstaki* (B_{tk}). For the past 30 years, this bacterium has been developed on a massive scale to control a number of agricultural insect pests. The use of B_{tk} for control of the introduced gypsy moth (*Lymantria dispar*) has potential for negatively affecting populations of the brick-red borer. The larvae are present throughout the growing season increasing their susceptibility to the pathogen in the local environment (resulting from both the initial spray efforts and decomposing gypsy moth larval cadavers). This could lead to an increase in mortality in the *Papaipema* larvae. They would also be susceptible to drift of B_{tk} onto occupied habitat adjacent to where gypsy moths are present. Potential effects from the gypsy moth and its control efforts are dealt with in the following section.

Gypsy Moth Outbreaks and Control Efforts

Since its introduction into New England in the early 1800's, the Eurasian gypsy moth (*Lymantria dispar*) has posed a direct and indirect threat to native Lepidoptera, including the brick-red borer moth. For many years, the gypsy moth had few predators or parasites here, and its populations soared to outbreak proportions throughout the Northeast (see Schweitzer 2004 for a review). The larvae feed primarily on oaks (*Quercus* spp.) and defoliated countless acres of oak and mixed hardwood forest, including habitat for *Papaipema marginidens*. These defoliation events result in the direct mortality of many other insect species that feed on oak and other trees, and canchange the character of the forest, allowing light to reach the ground flora for a prolonged period of time in early summer. On sites where trees are already stressed by edaphic conditions, repeated defoliation can lead to tree mortality. The leaves that remain or re-sprout have characteristic differing from those on trees that did not experience defoliation (Feeny, 1970; Schultz and Baldwin, 1982; Schweitzer, 1979). The effects of canopy defoliation on the herbaceous flora are discussed by Cooper et al. (1993).

Attempts to eradicate the gypsy moth in the mid 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, 2004). 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) 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 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, 1995). Like the earlier pesticides, Dimilin kills insects (and most other Arthropods) indiscriminately across all orders (see Uniroyal, 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; 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, 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).

Bacillus thuringiensis (*Btk*) is a relatively new threat to the butterfly, introduced in the fight to control Gypsy moth outbreaks in the early 1970's. *Btk* is a naturally occurring soil pathogen that is stated to affect only Lepidoptera larvae, causing high rates of mortality in exposed individuals across many families (Peacock et al., 1998). The bacterium attacks the lining of the gut wall, interrupting the uptake of nutrients by the affected caterpillar, causing starvation and death. *Btk* spraying 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., 1990; Herms et al., 1997; Johnson, et al., 1995; Krieg and Langenbruch, 1981; Miller, 1990; Morris, 1969; Schweitzer, 2000, 2004a-b; Severns, 2002; Wagner, 1995; Wagner et al., 1996; Whaley, 1998).

Gypsy moth outbreaks tend to occur in oak-dominated forests, woodlands and barrens. The larvae of this moth also feed readily on a number of other species occurring in forests of which oaks are a component. Unfortunately for the brick-red borer moth, the gypsy moth currently occurs throughout much of its range. Oak barrens and woodlands are preferred habitats for both moths. Therefore, the potential for co-occurrence is high. Because of this, large scale spraying efforts within the range of *Papaipema marginidens* has likely had deleterious effects on its long-term survival. 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). However, there is no evidence to suggest that B_{tk} (in any way) has limited the spread of the gypsy moth.

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. Given that gypsy moth larvae develop at the same time of year as the brick-red borer moth, spraying of *Btk* or other pesticides in occupied habitat could certainly have a negative effect on the resident butterfly population.

Residential Development

Residential Development can negatively affect habitat for *Papaipema marginidens* 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 nearby natural areas, enter streams and rivers and can degrade local and regional water quality (Medina, 1990). In the Northeast and Upper Midwest, high-end and exclusive residential developments are often located in remnants of mature hardwood forests, woodlands and barrens.

Inadequacy of Existing Regulatory Mechanisms

The current, species-based approach to federal laws regarding the protection of imperiled organisms does not currently afford legal protection to the brick-red borer moth. An ecosystem or plant community based approach would be more adequate for the protection of organisms whose habitats are becoming increasingly fragmented and degraded by human activity. This is especially true for those requiring southern barrens and savannas, where there are no federally protected insect species. Federally mandated efforts to restore our Nation's savannas and barrens would not only protect hundreds of species from impending peril, but provide the human population with expanded opportunities for hunting, fishing, gathering of forest products, education, research, observation and enlightenment.

SUMMARY OF LAND OWNERSHIP & EXISTING HABITAT PROTECTION

The U. S. Forest Service owns occupied brick-red borer moth habitat in Indiana and Kentucky. Three Special Areas (Boone Creek, Cloverlick and Harding Flats) within the Hoosier NF harbor extensive habitat for this and other rare insect species. Specimens have also been collected in the Great Smokey Mountains National Park in North Carolina and Tennessee. Additional Federal lands may also harbor populations of this species throughout its range. State and Private Nature Preserves hold additional potential or occupied habitat in a number of states. The occurrence of populations along stream corridors has also afforded this species some protection correlating with the conservation of wetlands and municipal water supplies.

SUMMARY OF EXISTING MANAGEMENT ACTIVITIES

Little or no management is currently being directed at brick-red borer moth habitat based solely on the species' presence or absence. However, the moth's preferred habitat happens to be the juncture of two highly imperiled plant communities, oak barrens and woodland. Therefore, *Papaipema marginidens* habitat has received management in many areas, given ongoing efforts to protect and restore the Nation's remaining prairies and oak barrens.

In most areas management has taken the form of prescribed fire. The Cloverlick Barrens site has undergone prescribed fire management. The efforts at Cloverlick appear to have created a substantial amount of habitat for this species and it was found scattered throughout the wooded portions of the 1,300 acre site. Like all *Papaipema, P. marginidens* inevitably overwinters as eggs attached to the base of its foodplant's stems or nearby detritus. The eggs, hibernating in dried vegetation, would surely be consumed in a fire. Therefore, this species is considered fire-sensitive, although it is possible that at least some small portion of some populations may escape fire in a given burn. However, efforts need to be taken to leave unburned portions of inhabited sites to allow for re-colonization following prescribed fire management. Efforts to manually remove exotic invasive plants (as mentioned in previous sections) have also benefited this species, by reducing competition with its larval food plant and adult nectar sources. This is especially true with regards to glossy buckthorn and non-native honeysuckles.

PAST AND CURRENT CONSERVATION ACTIVITIES

The brick-red borer moth has always been reported as rare to uncommon and local, though not usually from a conservation standpoint. Only recently have researchers begun to suggest that the species is indeed imperiled and that efforts should be undertaken to identify known and active populations. It is also becoming apparent that we need to assess the health and long-term viability of many (if not all) populations of *Papaipema marginidens*. Currently, the brick-red borer moth is considered potentially imperiled only in Indiana (S1S3) and Virginia (S1S3). All other states have it listed as secure or unranked.

RESEARCH AND MONITORING

Currently, little or no research is being conducted regarding the brick-red borer moth. The larval food plant is unknown and needs to be determined. In addition, the habitats occupied by this moth are very productive from the standpoint of forest goods, timber and medicinal plants. These multiple uses can have conflicting effects on one another, an area of research that has only recently begun to be addressed. *Papaipema marginidens* is a visually attractive species, a factor that could be used in drawing attention to the conservation and restoration of its habitats. Finally, the habitats in which this moth occurs are also aesthetically pleasing to the human eye. These attributes could make protection and restoration of occupied and potential habitat more attractive to land managers and the general public.

EXISTING SURVEYS, MONITORING, AND RESEARCH

At the present time, no monitoring or survey work is being focused on this species, despite its relative rarity. However, recent surveys for rare insects on the Hoosier National Forest

uncovered the only known Indiana population of *Papaipema marginidens* (Bess, 2004). Much additional insect survey work is needed throughout eastern North America, to identify both historic and extant populations of this and many other rare species. In particular, the effects of management practices (such as prescribed fire) need to be addressed with reference to fire-sensitive species such as *Papaipema marginidens*.

SURVEY PROTOCOL

Surveys for the brick-red borer moth should initially be focused on known populations. Timing of surveys should occur when the larvae are present, as these are the easiest to locate and identify. However, with this species, this would be impossible given that the larval foodplant is unknown. Therefore, adult surveys must be carried out in the fall with ultraviolet or mercury vapor lights. Weather at this time is often unpredictable, making surveys frustrating. Given the relative difficulty in identifying this species, a specimen from any new locality must be collected as a voucher. Collected adults can be placed live into a glass or plastic jar and frozen. If a killing jar is at your disposal, this may be used instead. Collected adults should be either kept in a freezer or pinned and affixed with a label bearing the following information:

1. State, County, Town, Range, Section and quarter section (or nearest reference point) of origin;
2. Date of Collection
3. Name of Collector
4. Type of habitat

The specimen can then be forwarded to an expert on the group for verification. A list of potential identification experts for *Papaipema* specimens is given in Appendix A.

MONITORING PROTOCOL

This would be difficult, if not impossible to do at this time. Once a larval hostplant is found, efficient surveys can be conducted to search for larvae.

RESEARCH PRIORITIES

Further research is needed regarding the exact habitat requirements of this species, such as:

1. Identification of the larval foodplant(s)
2. Optimal canopy cover requirements for moth and its foodplant(s),
3. Minimum woodland patch size requirements for moth and foodplant(s),
4. Optimal density and distribution of larval foodplant(s) for long-term survival of moth,
5. Fire effects and optimal fire regime for moth and its foodplant(s),
6. Effects of invasive plants (and efforts to control them) on the moth and its foodplant(s),
7. Effects of silvicultural activities such as pine plantations, pesticide application, harvesting, etc. on survival of moth and its foodplants.

It is also quite probable that there are additional, undetected populations of this species in the central United States. Statewide efforts are needed to survey for this and other rare insect species throughout the eastern United States.

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APPENDIX

LIST OF CONTACTS

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REVIEW REQUESTS

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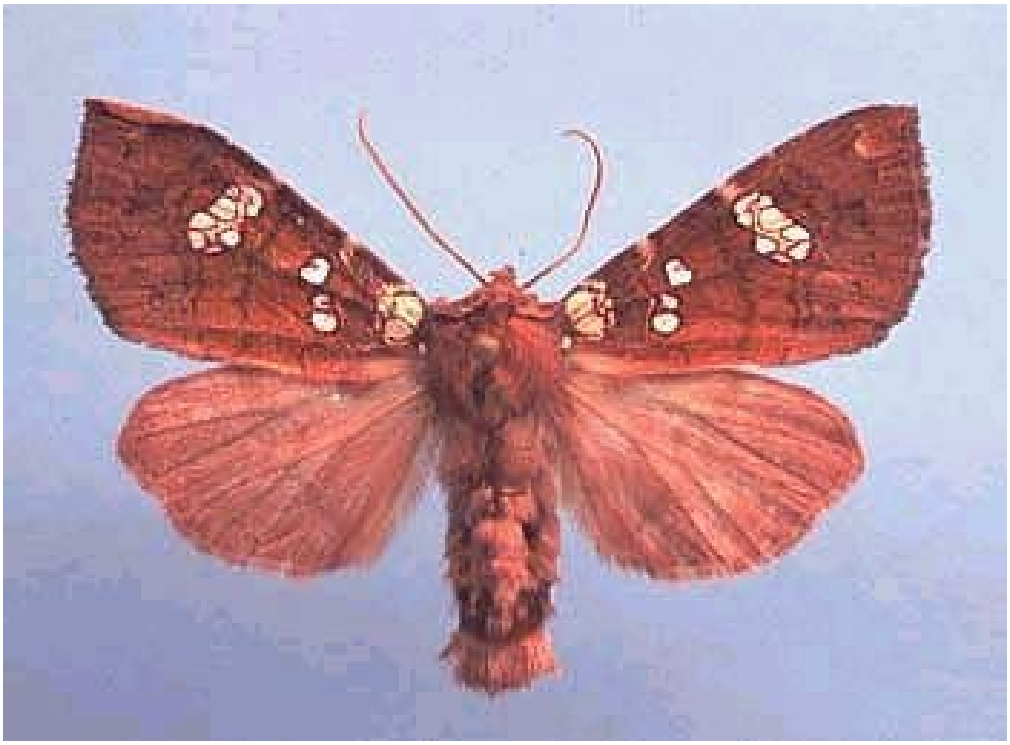
FIGURES

Figure 1. Adult of *Papaipema marginidens* (Guenee).



Photograph by James K. Adams

Figure 2. Current, Known Distribution of the Brick-red borer Moth (*Papaipema marginidens*) in Eastern North America.