# *Conservation Assessment*
# *for*
# *the mayapple borer moth (Papaipema rutila (Guenee))*


***USDA Forest Service, Eastern Region***

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*This document is undergoing peer review, comments welcome*

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Figure 1. Current Distribution of the Mayapple Borer Moth (*Papaipema rutila*) in Eastern North America.

## EXECUTIVE SUMMARY

The mayapple borer moth (*Papaipema rutila* (Guenee)) is a medium-sized, yellow and brown moth associated with forest, woodland and barrens. It is considered uncommon and local throughout its range, always being found in close association with the larval food plant, mayapple (*Podophyllum peltatum*). This moth produces a single brood per year, with the adults appearing in early fall. The species is never common (except on a local level) and most states contain only 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. During this time, the mayapple borer moth lost a considerable amount of habitat. Given the current degraded status of our oak forest and woodland ecosystems, this species' 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 species 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

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## NOMENCLATURE AND TAXONOMY

The genus *Papaipema* was first designated by Smith in 1889. The mayapple borer (*Papaipema rutila*) was previously described by Guenee in 1852 as "*Gortyna rutila*", from specimens collected in Illinois (FUNET, 2005; Poole, 1989). Gunee's original type specimen was in quite poor condition, leading to much confusion in the identification of specimens based on this name. Several "new" species of *Papaipema* were subsequent described only to be sunk into synonymy by later workers on the group. One such synonym, *Papaipema rutila,* was described by Henry Bird in 1907 and based on adults reared from larvae found boring into the rootstocks of mayapple (*Podophyllum peltatum*) in western Pennsylvania (New Brighton). This description provided a long series of immaculate specimens and foodplant associations to provide more conclusive evidence for future identification. Another synonym is *P. placida,* also described by Bird, in 1921.

## 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, with or without large white spots on the forewings. *P. rutila* is one of the yellowish orange species, being superficially identical to *Papaipema arctivorens* and *P. baptisiae*. This moth typically measures 30-32 mm (1-1.25 inches) in wingspan and is a golden yellow, dusted with orange scales. The wings are marked dorsally with a series of vertical lines and bands, all of which are brown in color. The outer quarter of the forewing is entirely of the dark brown color. There may or may not be approximately three white spots in the central and basal parts of the forewings. In some instances, the yellowish ground color of the forewing is almost entirely replaced by the powdery orange color. The ventral ground color is typically light tan or brown.

### DESCRIPTION OF IMMATURE STAGES

Eggs of *Papaipema rutila* are chalk white and spherical, strongly ribbed, with numerous crossridges under magnification. The eggs are likely placed on dead mayapple stems, root crowns and nearby vegetation. The eggs overwinter in this detritus around the base of the foodplants. The young larvae are greenish white, highly mobile and are "semi-loopers", meaning they are missing the central prolegs and locomote by inching their hind prolegs up to the front prolegs and then moving their front half forward, as with an inchworm.

From the second through final instars, *Papaipema* larvae are of the normal noctuid type, possessing all their prolegs. The larvae of this genus are typically purplish brown with longitudinal white stripes extending from head to tail. These stripes may or may not be interrupted over the thoracic region (area above jointed, true legs). The head is a dull brownish orange color, with a dark brownish black stripe down side side of the face. The larvae reach maturity in five instars, with the larval brood period lasting roughly two months (Bird, 1907).

## LIFE HISTORY

### REPRODUCTION

Like all other Lepidoptera, the mayapple borer moth goes through four distinct developmental stages: egg, larva, pupa and adult. A single brood is produced each year. Eggs hatch in the early spring and larvae feed all spring and summer. The larvae are full grown by late July and then pupation. The pupal stage lasts one to three weeks, depending on weather. The adults appear in early fall (late August through September) and may feed on nectar from flowers and overripe fruit. They mate and females lay eggs over a protracted period of a few weeks to a month.

### ECOLOGY

*Papaipema rutila* is a species of high quality, mesic hardwood forest and oak woodland, often occurring along stream corridors. It is always associated with large populations of mayapple (*Podophyllum peltatum*), the larval food plant. There is one adult brood per season from mid-

August through September. The adult brood period lasts roughly a month, during which they mate and females lay eggs. The adults may feed on nectar, flowing tree sap, rotten fruit and probably other liquids. However, this species is shorter-lived than some other *Papaipema* (e.g. *P. beeriana*) and only live for a few weeks to a month. In the spring (following first green-up of mayapple), the eggs hatch and the active larvae seek out fresh mayapple sprouts, where they immediately begin to bore into the base of the stalk and continue down into the rootstock. The larvae mature by late July and leave the rootstock to pupate in the soil nearby.

**DISPERSAL/MIGRATION**

Given its specific foodplant requirements, the mayapple borer moth probably does not travel far from colonies of *Podophyllum*. Maximum individual dispersal distances are probably on the order of a few hundred yards and the species is generally regarded as being rare and highly local in occurrence. However, populations are likely capable of dispersing over large areas of contiguous suitable habitat, particularly along stream corridors. *Papaipema rutila* is not known to migrate.

**OBLIGATE ASSOCIATIONS**

The obligate habitat for the mayapple borer moth is a mixture of high quality hardwood forest and mesic woodland containing an abundance of the larval foodplant, *Podophyllum peltatum*. Typically these habitats occur along stream corridors. The moth rarely (if ever) occurs far from stands of mayapple.

## HABITAT

**RANGE-WIDE**

The mayapple borer moth occurs in high quality, forest and woodland. Optimal habitat always contains an abundance of the larval food plant *Podophyllum peltatum*. Throughout much of the moth's range, these habitats are characterized by a closed canopy, dominated by broadleaf hardwoods such as oaks (*Quercus alba* and *Q. rubra*, primarily), hickories (*Carya*), ashes (*Fraxinus*), beech (*Fagus*) and maples (*Acer*). Other characteristic species may include walnut (*Juglans* spp.), hackberries (*Celtis* spp.), ash (*Fraxinus*), sweetgum (*Liquidambar styraciflua*), tuliptree (Liriodendron tulipifera), hop hornbeam (*Ostrya virginiana*), sycamore (*Platanus occidentalis*) and elms (*Ulmus alata* and *U. americana*).

Shrubs may include bluebeech (*Carpinus carolinus*), New Jersey tea (*Ceanothus americanus*), dogwoods (*Cornus drumondii C. florida*), wild plum (*Prunus* spp.), sumacs (*Rhus copallina* and *R. glabra*), soapberry (*Symphoricarpos orbiculatus*), blueberries (*Vaccinium* spp.) and/or prickly ash (*Xanthoxylum*). Vines such as trumpetcreeper (*Campsis radicans*), virgin's bower (*Clematis virginiana*), climbing hempvine (*Mikania scandens*), Virginia creeper (*Parthenocissus quinquifolia*), catbrier (*Smilax glauca, S. rotundifolia*), poison ivy (*Toxicodendron radicans*) and grapes (*Vitis* spp.) may also be frequent, especially in fire suppressed ecosystems.

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

In the Hoosier National Forest (HNF) of Indiana, the known site for *Papaipema rutila* is typical of drier habitat for the species in the central and eastern parts of its range. At the known population in Perry County, the overstory is dominated by oaks (*Quercus alba, Q. phellos, Q. stellata* and *Q. marilandica*) and seveeral other species, including red maple, hickories, ash 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 virginiana*), 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*).

**SITE SPECIFIC**

**Hoosier NF: Cloverlick Barrens Special Area**

The only known occurrence for *Papaipema rutila* 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 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. *Podophyllum* grows locally in large colonies under the closed canopy, especially on open, gentle slopes and along terraces and

hilltops. 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 mayapple borer moth has a patchy and discontinuous range in eastern North America (see Figure 1). The following is taken directly from the NatureServe Website (dated July 31, 2004), "approximately northern New Jersey (at least formerly) across southern Pennsylvania much of Ohio to southern Wisconsin. Southern limits much less clear but widespread in Kentucky. Fairly widespread in the Mid-Atlantic, Appalachian and Midwestern parts of the USA, probably into the northern parts of the Gulf States. Basically ranges where mayapple is or was common." .

### STATE AND NATIONAL FOREST DISTRIBUTION

The following state-level distribution information for the mayapple 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 DE, IL, IN, MD, MI, NJ, OH, PA, VA, WI.

## RANGE WIDE STATUS

Despite having a Global Rank of 4, *Papaipema rutila* is considered uncommon to potentially imperiled in most or all parts of its range (see NatureServe, 2004). 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 throughout much of the eastern part of its range. This is especially true with regards to its preferred habitats (i.e. undisturbed mesic forest and 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: 31Jul2004**
**Global Status Last Changed: 15Aug1999**
**Rounded Global Status: G4 - Apparently Secure**
**National Status: N4**

**Reasons**: The following is taken directly from the NatureServe Website (Dale F. Schweitzer), in December of 2005: "At present there are probably hundreds of occurrences scattered over a wide area. This species is still locally common in some well forested regions and apparently even in areas of forest-residential mix where native forest understory still exists. However threats do exist in many places and will become more widespread. The species may be gone from the northeast edge of its range. Threats from alien plants and deer are likely to get much worse. For now this species is probably secure but its long term outlook is less clear, threats will increase in some areas if not all, and its rank will need to be periodically reconsidered."

Schweitzer goes on to say that " while the species overall is not imperiled common threats to colonies or metapopulation include habitat loss such as development, alien weeds like garlic mustard, mile a minute, *Rosa multiflora* and alien *Rubus* species displacing native forest understory plants such as the foodplant (may-apple). Out of control deer are probably a much greater threat and these do eat mayapple. Between alien plants and deer many small or isolated populations probably have been or soon will be lost in places like Pennsylvania and New Jersey, and undoubtedly the species has been affected by the massive overgrazing in some National Parks. Deer can easily eat a colony of *Papaipema* in spring without permanently affecting the hostplant. Any dormant season, fall or spring fires will also kill most immatures but this would seem unlikely as a major threat to this species. All of these threats are amplified by habitat fragmentation and populations should generally recover in regions of intact forest."

**Status (S-Rank) in the Following States:**
Delaware (SU), Illinois (SNR), Indiana (S1S3), Maryland (SNR), Michigan (SNR), New Jersey (SNR), Ohio (SNR), Pennsylvania (SNR), Virginia (SNR), Wisconsin (SNR).

## POPULATION BIOLOGY AND VIABILITY

The mayapple borer moth occurs in a series of habitats that were once widespread across the southeast and central United States. It is a species of woods and forests, all characterized (in their primordial state) by a woody canopy dominated by hardwoods, typically white oak (*Quercus alba*), and is usually closed, although it often graded into open woodland in the past. These habitats are always characterized by mature or over-mature canopy trees, with a rich herbaceous layer. Many of were fire-maintained savannas and barrens, with pockets of protected forest and woodland along streams that only occasionally received fire. The larval foodplant, *Podophyllum*, is also widespread across eastern North America.

Prior to the westward expansion of Europeans on the American continent in the 1800's, the mayapple borer moth was probably locally common wherever *Podophyllum* occurred in the region delineated in Figure 1. However, pressures from grazing by domesticated animals and deforestation began to reduce the acreage of pristine forest and woodland. As a result, the remaining suitable habitat for *Papaipema rutila* 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 mayapple borer moth depends. Extensive deforestation and 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 undisturbed, mature forests and woodlands. These grasses frequently invade adjacent natural area remnants, further degrading them and competing with the local flora. This isolation of often small populations can lead to inbreeding and extinction (see Wilson and MacArthur, 1967).

**Grazing**

Browsing by deer is probably a threat to mayapple borer moth rangewide. *Podophyllum peltatum* is eaten by deer (Bess, pers. obs.; NatureServe, 2005) and heavy browsing of the herbaceous layer could have an overall negative impact on this species by reducing availability of larval foodplant or direct killing of young larvae in the spring. Domesticated cattle and horses will also eat *Podophyllum* as forage and may pose a threat to the moth by consuming larval food sources, eggs, larvae and/or pupae. Well-managed, rotational, grazing by cattle 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 mayapple 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

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 rutila* 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 mayapple borer moth is somewhat of concern to moth enthusiasts, although comparatively few people pursue it 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 frequently dig up plants in search of larvae. These are then reared in captivity to obtain perfect specimens. This practice not only removes moths from the population, but also destroys foodplant populations 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 these 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 rutila* 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 mayapple 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 mayapple growing in areas 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 mayapple 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 rutila*. These defoliation events result in the direct mortality of many other insect species that feed on oak, and change 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 tops of food chains (such as insectivores) accumulate 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 mayapple borer moth, the gypsy moth currently occurs throughout the northeastern portion of its range. Oak barrens, woodlands and forests also typically adjoin prairies and related plant communities. Therefore, the potential for co-occurrence is high. Because of this, large scale spraying efforts within the range of *Papaipema rutila* could likely have 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 mayapple 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 rutila* 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, including mayapple, 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 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 resources does not currently afford legal protection to the mayapple 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 forested communities 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, development of new medicines, education, research, observation and enlightenment.

## SUMMARY OF LAND OWNERSHIP & EXISTING HABITAT PROTECTION

The U. S. Forest Service owns occupied mayapple borer moth habitat in Indiana, Kentucky and probably elsewhere. Additional Federal lands may also harbor populations of this species. State and Private Nature Preserves hold additional potential or occupied habitat in a number of states.

## SUMMARY OF EXISTING MANAGEMENT ACTIVITIES

Little or no management is currently being directed at mayapple 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 rutila* 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. *Papaipema rutila* overwinters as ova attached to the base of *Podophyllum* stems or nearby detritus. Larvae hibernating in this dried vegetation would surely be consumed in a fire. Therefore, this species is fire-sensitive, although it is possible that at least some *Podophyllum* may escape fire in a given burn. 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 mayapple borer moth has been reported as either locally common or uncommon, 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 these populations. Unfortunately, this species is listed as globally secure by the NatureServe Group (G4). The mayapple borer moth is considered potentially imperiled only (S1S3) in Indiana. All other states have this moth listed as secure or unranked. However, it is likely imperiled in several eastern states where it is known. This is further supported by statements made in the NatureServe narrative for this species.

## RESEARCH AND MONITORING

Currently, little or no research is being conducted regarding the mayapple borer moth. The larval food plant, *Podophyllum*, is palatable to deer, and effects of deer browsing need to be assessed. *Podophyllum* has attractive foliage, flowers and fruit and is known for its curative qualities. The habitats occupied by this moth and its foodplant are also aesthetically pleasing to the human eye. These attributes could make restoration of occupied and potential mayapple borer moth 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 localized habitat requirements and potential threats facing it and its habitat. However, recent surveys for rare insects on the Hoosier National Forest uncovered one of the two known Indiana populations of *Papaipema rutila* (Bess, 2004).

## SURVEY PROTOCOL

Surveys for the mayapple borer moth should initially be focused on known populations of *Podophyllum*. Timing of surveys should occur when the larvae are present, as these are the

easiest to locate and identify. Best timing for surveys is mid-July. Look for boring signs in the root crown (i.e. piles of whitish "frass" or caterpillar feces). Other, more common, *Papaipema* also will bore into mayapple, particularly the ubiquitous *P. cataphracta*. However, this species is a stem borer only and will not enter the root of *Podophyllum*. Care must be taken to ensure that no bored stems are counted as *Papaipema rutila* occurrences when conducting surveys. Given the extreme difficulty in identifying this species, a specimen from any new locality should be collected as a voucher. Larvae will have to be reared to maturity, although preserved larvae, with foodplant information, can be identified to species. To preserve them, larvae must be placed in boiling water for two minutes and then placed in 90 percent Ethanol in a vial for preservation. A label with location, foodplant and date of collection must also be placed inside the vial. Pencil or India ink works best. 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**

To conduct long-term monitoring programs, a long-term monitoring transect will need to be developed (see Pollard, 1977). Monitoring programs will naturally vary from site to site and depend greatly on the amount of resources available to conduct such programs. At a minimum, a long-term monitoring program for *Papaipema rutila* should involve the designation of at least one permanent, monitoring transect. Monitoring transects should be placed in patches of *Podophyllum* and occur when larvae are roughly half-grown (mid-July).

The monitoring transect should be of a length that can be covered by one or two observers in one to two hours, while walking at a moderate pace. All *Podophyllum* observed within 30 feet of the transect line should be counted and their condition noted (e.g. uninfected or infected with *P. rutila* larvae). Standardized survey forms can easily be developed for such surveys. At a minimum; transect name, location, date and time should be noted on each survey form. If more than one transect is being used, each should be identified individually. Information on plant phenology, species blooming, canopy cover, invasive species, predation, etc. is also useful. Surveys should be conducted when larvae are at their peak of growth (August). These surveys can provide a wealth of data for use in tracking long-term population shifts in size, phenology, distribution and resource utilization.

## RESEARCH PRIORITIES

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

1. Optimal canopy cover,
2. Minimum woodland patch size requirements,
3. Optimal density and distribution of *Podophyllum*,
4. Fire effects and optimal fire regime,
5. Effects of invasive plants (and efforts to control them) on mayapple, nectar sources and the moth,
6. Effects of silvicultural activities such as pine plantations, pesticide application, harvesting, etc.

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 species.

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## APPENDIX

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**REVIEW REQUESTS**

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# FIGURES

**Figure 1. Distribution of *Papaipema rutila* (★) and Large Beech-Birch-Maple Forest Remnants in the Eastern United States (1992).**