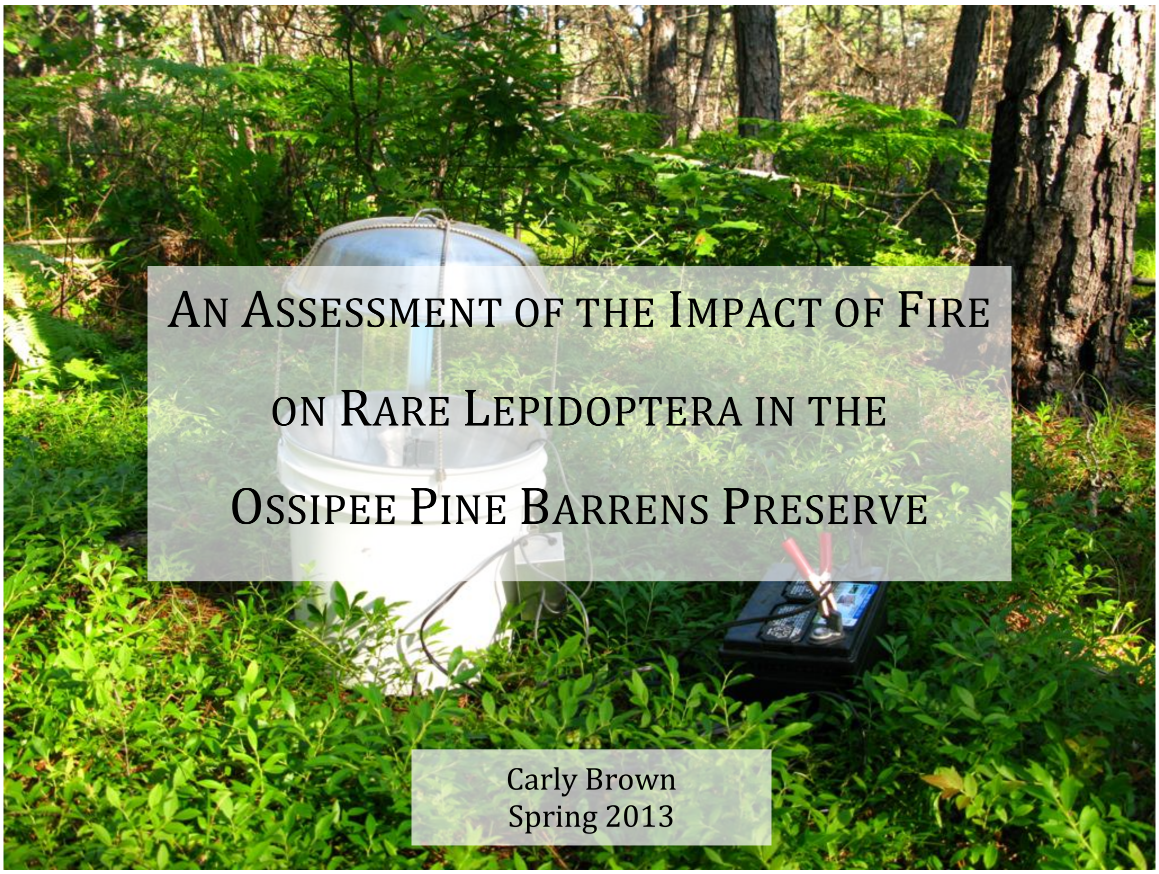

An Assessment of the Impact of Fire on Rare Lepidoptera in the Ossipee Pine Barrens Preserve

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EXECUTIVE SUMMARY

The Ossipee Pine Barrens Preserve, managed by The Nature Conservancy (TNC), was once part of a much larger pine barrens ecosystem. Currently, the pine barrens stretch across the towns of Madison, Freedom, Ossipee, and Tamworth in Carroll County, New Hampshire. The pine barrens ecosystem is an imperiled rare natural community that was historically maintained by fire. Pitch pine, the dominant tree in the pine barrens, is well adapted to a fire regime. Scrub oak and blueberry, the dominant shrub and ground cover, can also flourish post-fire.

The Ossipee Pine Barrens host a suite of rare species, including Lepidoptera, i.e. moths and butterflies. The Nature Conservancy has identified 18 conservation target Lepidoptera that are expected to be present in the Preserve, though some have not been verified on the landscape for several decades. There have been multiple surveys of the Ossipee Pine Barrens moths, the most recent intensive survey having occurred in the summer of 2002. The goal of the 2002 survey was to identify rare and non-rare moths, and to provide management and monitoring recommendations that will most benefit these pine barrens specialists.

Prescribed fire is just one management technique for returning historically fire-adapted ecosystems to a desired condition. The Nature Conservancy first began burning the pine barrens in 2007, and as of the summer of 2011 had burned just under 400 acres. TNC also mows and harvests parts of the landscape as a way to remove unwanted encroaching vegetation. The goals of these management techniques are not only to favor the desired vegetation (pitch pine, blueberry, and scrub oak), but also to provide habitat for the fauna that rely on pine barrens conditions.

The goal of this project was to assess the impact that prescribed fire has had on rare moths, as well as to provide additional records of moth presence. We collected moths using black light bucket traps, black light sheet traps, and sugar baiting. I chose four land management units to sample intensively: two that have been managed by fire within the past four to five years, and two that have not burned for several decades. Three sample points were randomly selected in each management unit. I sampled from each of these sample points once a month from May to September in the summer of 2012. I also sampled for moth species presence in several other management units of interest to TNC. Furthermore, TNC sampled spring flying moths in March in five management units, generally using sugar bait.

During the course of the study, I collected 5,846 moths representing 290 species. Between June and September I collected six of the TNC defined conservation target Lepidoptera species in the four intensively sampled management units. I collected three additional species that I included in my analyses since they are described as pine barrens specialists and potentially rare (Wagner et al. 2003, Kart 2003). Using a chi-square analysis, I found that three Lepidoptera species (*Nepytia pellucidaria*,

Zanclognatha martha, and *Euretegrotis attentus*) were significantly higher in abundance in the unburned management units as compared to the burned. Six Lepidoptera showed no significant difference between burned and unburned units. I used a t-test to compare the abundance, richness, Shannon-Weiner Diversity Index, and Simpson Index of all moth species in the burned and unburned units and did not find a significant difference in these factors.

When I included the early spring collections, and those from the less intensively sampled management units, I identified a total of ten target Lepidoptera species: *Lithophane lepida lepida, Lycia rachelae, Nepytia pellucidaria, Sympistis dentata, Xestia elimata, Xylena thoracica, Zale lunifera, Zale obliqua, Zale submediana*, and *Zanclognatha martha*. I collected five additional pine barrens specialist species: *Abagrotis brunneipennis, Eueretagrotis attentus, Sideridis maryx, Xestia youngii*, and *Xylena cineritia* (Wagner et al. 2003, Kart 2003).

Based on the chi-square evaluation of target moth abundance between burned and unburned units, I do not recommend any drastic changes in the current prescribed fire management regime. While there were significant differences in three species, with the numbers being lower in the burned units, the majority of moth species showed no difference in abundance between burned and unburned units. Thus, after just a one-year monitoring effort, it is premature to alter the current prescribed fire practice. I do highly recommend that the conservation target Lepidoptera continue to be monitored. I also highly recommend following conservative guidelines on the length of burn intervals, in order to ensure that the moths have regained healthy populations prior to more burning.

Summary of the management recommendations based on my findings:

- Continue managing for pitch-pine scrub oak habitat, but pay particular attention to moth life histories as outlined in Kart 2003.

- Maintain corridors of unburned vegetation to provide a refuge and source population when burning larger management units.

- Coordinate the current post-burn vegetation surveys carried out by TNC with moth collections, as a way to evaluate the habitat moths are collected from.

- Monitor target moths more frequently using a less intensive sampling design that allows the target moths to be the focus in collections. Instead of collecting all moths in black light bucket traps, black light sheet traps will allow for target moths to be captured and released.

- Continue doing intensive monitoring every ten years or so, and include microlepidoptera in the collection data.

- Explore the possibility of monitoring other well-known taxa in addition to the moths to track multiple responses to prescribed fire.

INTRODUCTION

THE OSSIPEE PINE BARRENS

The Ossipee Pine Barrens Preserve, managed by The Nature Conservancy (TNC), currently spreads across the towns of Madison, Freedom, Ossipee, and Tamworth. About half of the 3,000 acre preserve is documented by the New Hampshire Natural Heritage Bureau as the largest, and most ecologically viable pitch pine-scrub oak woodland in the state. This ecosystem supports a unique Lepidoptera fauna, including 18 conservation target Lepidoptera species and the newly documented Henry's elfin (*Callophrys henrici*). Lepidoptera are not the only rare taxa in the pine barrens: the Ossipee Pine Barrens themselves are considered a critically imperiled rare natural community by the New Hampshire Natural Heritage Bureau, with a state rarity rank of S1S2 (see Appendix A for a description of rarity codes). The barrens community also includes rare bird species such as whip-poor-wills (*Antrostomus vociferous*), common nighthawk (*Chordeiles minor*), and the Eastern towhee (*Pipilo erythrophthalmus*) (Ossipee 2012)

The structure and species composition of pine barrens throughout the northeast can vary, but all share the following characteristics:

- Shifting assemblages of few plant species (Grand and Mellow 2004)
- Dependence on periodic fire disturbance (Foster et al. 2002; Motzkin et al. 2002b; Parshall & Foster et al. 2002; Grand & Mellow 2004)
- Acidic, nutrient-poor, drought-prone soils, often originating from glacial outwash (Motzkin et al. 1999; Foster et al. 2002; Grand & Mello 2004)

Many pine barrens, including the Ossipee Pine Barrens, also support highly specialized Lepidoptera (Wagner et al. 2003). The Lepidoptera are adapted to the unique soil conditions, temperature regimes, structure, and species composition (Wagner et al. 2003). Wagner et al. found that scrub oak (*Quercus ilicifolia*), which is abundant in the Ossipee Pine Barrens, is the sole larval host for 16 of 56 rare shrubland Lepidoptera species in the northeast. Lowbush blueberry (*Vaccinium* spp.), the dominant ground cover in the Ossipee Pine Barrens, is the sole larval host for 8 of the 56 rare shrubland Lepidoptera species. The rare shrubland species listed by Wagner et al. (2003) include the target species that are a focus of this project.

In addition to the host plants, pine barrens provide unique climatic conditions. The low canopy cover characteristic of pine barrens allows a high amount of solar radiation to reach the ground (Motzkin et al. 2002a). The resulting warmth may allow larval stages to more successfully develop at this northernmost extent of their range. However, the relatively low canopy cover may also result in rapid cooling at night (Motzkin et al. 2002a; Wagner et al. 2003)

Pitch pine (*Pinus rigida*), the dominant tree in the Ossipee Pine Barrens canopy, is well adapted to fire regimes: it maintains dormant buds on the bole of the tree that activate post-fire, and its seeds require bare mineral soil for germination (Brose & Waldrop 2006). Pine barren ecosystems are dependent on fire and other periodic disturbance (Grand & Mellow 2004). Though Native Americans are often cited as major contributors to the historic fire disturbance regime, there is disagreement on how often they purposefully burned landscapes in the northeast and what effect they did have on the fire regime (Russell 1983). Fires allow the shade intolerant pitch pine to persist and prohibit fire intolerant, but generally more shade tolerant, tree and shrub species from encroaching. In the absence of fire, these shade tolerant tree species may slowly close the canopy gaps, altering microclimate, structure, and species composition (Lafon et al. 2007).

Since 2007, TNC has carried out prescribed burns on the preserve in an effort to restore and maintain the pitch pine-scrub oak woodland conditions (see Threats to Lepidoptera). TNC had burned just less than 400 acres by the fall of 2011. Other management units and some of the burned units have been managed by mechanical mowing or tree harvesting (mostly of white pine (*Pinus strobus*)). TNC plans to continue managing the Ossipee Pine Barrens with prescribed fire to maintain this natural community.

Landscape Context

The Ossipee Pine Barrens are bordered to the North by Silver Lake and to the South by Ossipee Lake, but the water wasn't always contained within these two lakes. As the Laurentide glacier retreated more than 10,000 years ago a large lake formed near where the two lakes sit today. As the glacier continued to retreat, meltwater streams flowed out in front of the glacier, bringing gravel and sand sediments with them. These meltwater streams formed outwash deposits, which make up the sandy soil of the pine barrens. The Ossipee Pine Barrens are especially interesting because of what is below the sand and gravel deposits that support the pine barren plant communities. The ancient Ossipee Lake deposited its own fine silts and clays, forming a lens, which bound the sand and gravel deposited by the meltwater. The gravel beds formed a stratified silt aquifer that serves as an important water source for the surrounding towns (Ossipee 2012).

It is thought that Europeans did not settle near the Ossipee Pine Barrens until 1770, though the majority of development has been in recent decades. Recognizing the poor soil conditions from an agricultural and development perspective in the Pine Barrens, they primarily used this ecosystem for timber (Patterson & Finton 1996). Due to human disturbance (see Threats to Lepidoptera) the current extent of the pine barrens falls far short of the historical stretch. The Ossipee Pine Barrens, historically, were much larger, covering around 8,600 acres. Currently the large (greater than 10 acres) patches of pitch pine-scrub oak woodland add up to about 2,500 acres, with an additional 1,500 acres that are degraded with potential of being restored.

THREATS TO LEPIDOPTERA

All species have two similar needs: food and utilities (Bauerfeind et al. 2009). In the case of moths, the food includes both larval host plants and adult food sources (for species in which the adults feed). For many of the rare moths of the Ossipee Pine Barrens, pitch pine, scrub oak or blueberry are essential larval food sources (Kart 2003). In addition to food, moths require natural structures for perching (Wagner et al. 2003; Bauerfeind et al. 2009). Though we often lack knowledge on all of the specifics of what moth species require for survival, we can make general inferences as to what habitat conditions act as constraints to the populations.

It has already been established that pine barrens provide critical habitat for highly specialized and rare Lepidoptera (Wagner et al. 2003). As this habitat is encroached upon by human activities, the moths and other pine barren specialists are left with a smaller area to inhabit, and thus fewer host plants and resources.

Management of the gypsy moth (*Lymantria dispar*) may greatly impact moths in some regions. *Compsilura concinnata*, a parasitoid fly from Europe was released as a biocontrol of *L. dispar* and the brown-tail moth (*Euproctis chrysorrhoea*). Like other well-intended biocontrols, *C. concinnata*, a generalist parasitoid, impacts native moth populations as well as its anticipated targets (Wagner et al. 2003). Though historic moth declines, such as *Nepytia pellucidaria*, coincided with the introduction of *C. concinnata* in the early 1900’s, there is some evidence that many moth species have since bounced back (Schweitzer et al. 2011). Still, there is a current trend of moth decline, which may be, in part, related to the parasitoid. Wagner suggests that while it is very possible, we don’t yet know enough to make this conclusion (Wagner 2012).

Natural fire disturbance was once more common throughout the region due to the dry and flammable vegetation (Wagner et al. 2003). Pitch pine-scrub oak communities are currently threatened by fire suppression and habitat destruction due to development and fragmentation (Grand & Mello 2004). Even if development does not occur within the pine barrens themselves, surrounding development often results in fire suppression in order to protect people and structures from fire damage. This altered natural fire regime has allowed more shade tolerant hardwoods to creep in and shift the historical tree species composition and structure (Motzkin et al. 2002b). Both structural and composition changes will impact the food and perching sites available to the moths specialized to survive in pitch pine-scrub oak ecosystems. Active management is essential to maintaining the natural structure and composition of pine barrens (Motzkin et al. 1999; Wagner et al. 2003)

RARE LEPIDOPTERA OF THE OSSIPEE PINE BARRENS

TNC has determined 18 state listed (by the New Hampshire Natural Heritage Bureau and the New Hampshire Fish & Game Non-game and Endangered Wildlife Program) Lepidoptera as Ossipee Pine Barrens conservation targets. Seventeen of the target Lepidoptera are moths, and one, *Erynnis brizo brizo,* is a butterfly (Table 1). Several additional species have been described by Wagner et al. (Wagner et al. 2003) and Dale Schweitzer (Kart 2003) as shrubland and pine barrens specialists, and may be important indicators of pine barrens ecosystem health.

Table 1. Ossipee Pine Barrens target Lepidoptera as given by TNC, with updated taxonomy and rarity rank as ranked by the New Hampshire Natural Heritage Bureau (Appendix A).

Family	Species	Updated Taxonomy	Rank
Skipper	*Erynnis brizo brizo*		G5T5 S2
Erebidae	*Apantesis carlotta*		G5 SU
Erebidae	*Grammia speciosa*		G5 SU
Geometridae	*Eumacaria latiferrugata*	*Eumacaria madopata*	G4G5 S2S4
Geometridae	*Glena cognataria*		G4G5 S3
Geometridae	*Itame* sp. 1 nr. inextricata	*Speranza exonerata*	G3Q S1S2
Geometridae	*Lycia rachelae*		No rank
Geometridae	*Nepytia pellucidaria*		GU S1
Noctuidae	*Apharetra dentata*	*Sympistis dentata*	G4 S2
Noctuidae	*Lithophane lepida lepida*		G4T3T4 S1S2
Noctuidae	*Lithophane thaxteri*		G4 SU
Noctuidae	*Xestia elimata*		G5 S3S4
Noctuidae	*Xylena thoracica*		G4 S2
Noctuidae	*Xylotype capax*		G4 S2
Noctuidae	*Zale sp. 1 nr. lunifera*	*Zale lunifera*	G3Q S1
Noctuidae	*Zale obliqua*		G5 S2
Noctuidae	*Zale submediana*		G4 S1
Noctuidae	*Zanclognatha martha*		G4 S1

Lepidoptera have been periodically sampled in the Ossipee Pine Barrens preserve: in the 1980's by Dale Schweitzer, in 1995 and 1996 by TNC, in 2002 by Jonathan Kart of the University of Vermont, in 2003 by TNC (to capture conservation target spring flying moths), and a few sites in 2008 by the New Hampshire Fish and Game. Since the 2002 sampling (the most recent extensive sampling), management units have undergone various treatments, the most recent management being four sites that were burned in 2011.

LEPIDOPTERA AS INDICATORS OF ECOSYSTEM HEALTH

There is value in utilizing a few species that depend on a desired ecosystem as indicators to assess the overall health of that ecosystem. Land managers often need to know how management activities impact various populations, but it is impractical to survey all species and all taxa. The population dynamics of an obligate species taxon can cue land managers into how successful the management practices are in reaching the desired ecosystem condition or the status of organisms at the community level

(Summerville et al. 2004).

Among arthropods, Lepidoptera are one of the taxonomic groups useful as indicators of ecosystem health (Summerville et al. 2004; Ferster et al. 2008). Indicator taxa should:

- Be easy to recognize and identify
- Have a taxonomy that is established and well-known
- Be important to the functioning of the ecosystem (e.g. selective herbivores or important prey)
- Be diverse
- Be easily surveyed

(Brown 1991; Scoble 1992; Pearson 1994; Hilty & Merenlander 2000; Ferster et al. 2008)

Lepidoptera, especially organized in a well-designed indicator species list, may satisfy the requirements for successful indicators (Summerville et al. 2004). While butterflies are more commonly recognized among the general public, moths may be important indicators in areas where the butterfly populations are low. Moths may also be more easily sampled (Summerville and Crist 2003). Moths and butterflies together are some of the most well studied terrestrial arthropods. Taxonomy at the species level of macro-Lepidoptera is well established and relatively stable, though there have been recent changes in the classification and names of the target Lepidoptera of this project. There is also a more complete understanding of immature phases of Lepidoptera as compared to other terrestrial arthropods (Wagner et al. 2003).

There are multiple applications for moths as indicators. Different species, or groups of species, can serve as indicators for habitat and community conditions. One study suggests that moths in the family Arctiidae are important indicators of species richness, while those of Notodontidae are important disturbance indicators (Summerville et al. 2004). Some studies suggest that Lepidoptera diversity can predict bird diversity (Blair 1999; Swengel & Swengel 1999), while others warn that moth diversity does not necessarily predict the diversity of other taxa, including birds (Grand et al. 2004).

Within the Ossipee Pine Barrens, moths may be successful indicators of the health of the pine barrens ecosystem, especially following management treatments, e.g. prescribed burning. In the future, a narrowed indicator list of easily identifiable moths could allow for more frequent, less intensive moth sampling that could provide information over multiple years.

Introduction to the Research Question

Though prescribed fire is the recommended management to maintain pine barrens ecosystems in which natural fire disturbance has been suppressed, there is controversy about how fire affects invertebrate populations, including moths. Some research suggests that fire may be damaging to invertebrate populations in the long term (Andrew & Leach 2006; Williams 1997). Other research suggests that rotating prescribed fire on the landscape or implementing the burning during the dormant season of the taxa of concern do not have a detrimental impact on the populations (McCabe 1995, Panzer and Schwartz 2000; Andrew and Leach 2006). In some cases insects return when their host plants regenerate post-burn (Tooker & Hanks 2004). In other studies, though the insect species did return to the burned site, this took up to two years (Panzer 2002). The life history of the species will dictate how susceptible the moths are to fire (Andrew & Leach 2006).

Following a pre-burn study on the moths in the Ossipee Pine Barrens in 2002 (Kart 2003), TNC began to manage some units within the barrens by prescribed fire. The ultimate management goal is to restore and maintain the unique pitch pine-scrub oak woodland natural community and, by doing so, maintain the biodiversity that the pine barrens currently support. Research has shown this to be an effective approach in other regions (Panzer & Schwartz 2000; Summerville et al. 2004), so this monitoring effort is to determine if the management techniques have been effective in supporting the moth fauna of the Ossipee Pine Barrens.

The overall goal of this project is to quantitatively evaluate the impact of prescribed fire on moths in the Ossipee Pine Barrens in order to guide future management. This goal can be broken down into five objectives:

Objective 1: Trap, collect, and identify moths from four different management units within the Ossipee Pine Barrens to compare differences in species composition and abundance between burned and unburned stands.

Objective 2: Carry out additional samplings to gather presence-absence data on priority management units.

Objective 3: Evaluate habitat conditions on the sites where moths were collected to determine differences in stand composition and structure.

Objective 4: When possible, pin at least two specimens representing each collected moth species for the University of New Hampshire and TNC for future reference and study.

Objective 5: Provide management recommendations for the Ossipee Pine Barrens as well as identify areas for further research.

METHODS

SITE DESCRIPTION

All Lepidoptera sampling occurred in the Ossipee Pine Barrens in Carroll County, New

Hampshire. *Pinus rigida* (pitch pine), *Quercus ilicifolia* (scrub oak) and *Vaccinium* spp. (blueberries) are the dominant tree, shrub, and ground cover, respectively, of the Ossipee Pine Barrens. The management units sampled, though essentially contiguous, span across four towns: Madison, Ossipee, Tamworth, and Freedom. Table 2 outlines the location, composition, and management treatment for each sampled unit and Figure 1 clarifies the collection methods at each.

Four management units within the Ossipee Pine Barrens were intensively sampled in order to study the effects of prescribed fire on rare Lepidoptera. Two of the units were burned by prescribed fire 4-5 years ago, while two have not undergone any management treatment (Table 2). Within the two burned units, Thickets 3 and 4 were mowed prior to burning while South Jackman Ridge was not. I selected units that represented different amounts of canopy cover, as canopy cover is assumed to be an important habitat factor for moths.

In addition, four management units – Triangle 3, West Branch 4-2, Goodwin 4, and Tragenza - were less intensively sampled in order to gather desired presence/absence data for The Nature Conservancy (Table 2; Figure 1). TNC also sampled several sites, mostly using sugar baiting in March 2012 (Figure 1).

Figure 1. Outline of the methods and intensity in the 2012 Ossipee Pine Barrens Lepidoptera sampling.

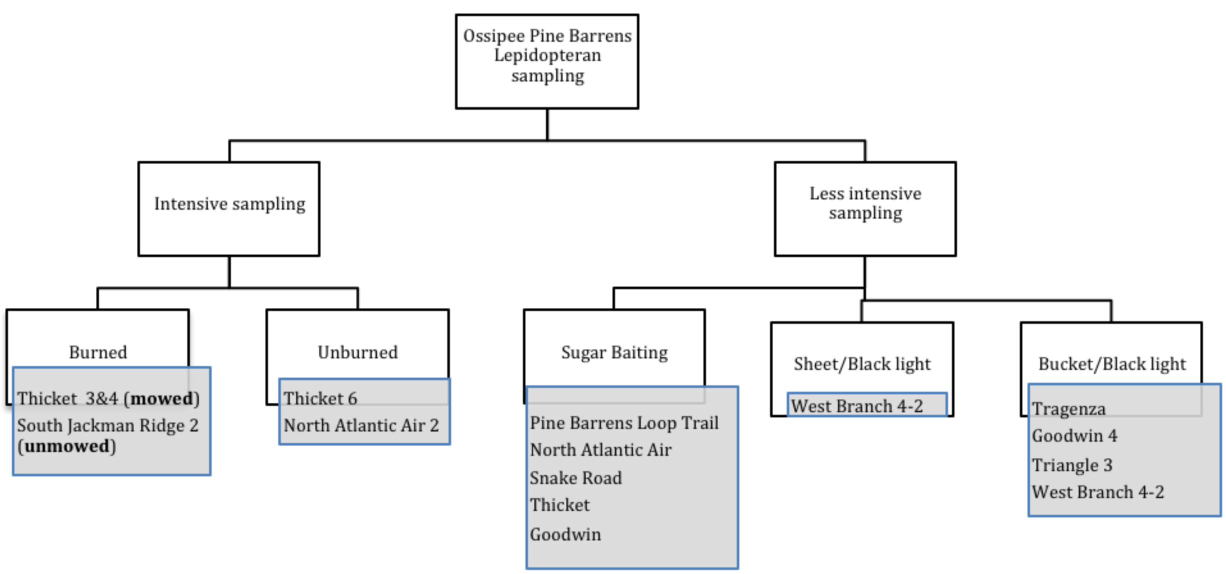


Table 2. Summary of location, composition, treatment regimes, and sample method of the Ossipee Pine Barrens management units sampled for moths. 2012.

Management unit	**Acres**	**Town**	**Sample intensity**	**Composition**	**Pre-treatment description**	**Pre-treatment year**	**Prescribed burn (year)**
Thicket 3	9.9	Freedom	2x per month (included with Thicket 4)	Pitch pine-scrub oak thicket[1]	Scrub oak mowed with a 3' lifter on the mower head to minimize sand and duff mixing in order to reduce lag time needed before burning	2005	2007
Thicket 4	6.7	Freedom	1x per month (included with Thicket 3)	Pitch pine-scrub oak thicket[1]	Scrub oak mowed with a rotary mower leaving much of the *V. angustifolium* and leaf litter intact	2007	2007
Thicket 6	31.0	Freedom	3x per month	Pitch pine-scrub oak thicket[1]	None	None	None
South Jackman Ridge 2	11.0	Freedom	3x per month	Pitch pine-scrub oak woodland[2]	Scrub oak mowed within 20' of the unit perimeter and several ignition lines mowed into unit	2008	2008
North Atlantic Air 2	30.1	Ossipee	3x per month	Pitch pine scrub oak woodland[2]	None	None	None
Triangle 3	8.2	Tamworth	1x per month	Pitch pine-scrub oak woodland[2]	White pine removed	2008	None
West Branch 4-2	23.6	Madison	1x per month; blacklight sheet trap used in May	Pitch pine-scrub oak woodland[2]	Scrub oak mowed within 20' of unit perimeter and one ignition line mowed down the center of the unit	2010	2010
Goodwin 4	27.2	Madison	1x per month	Transitional Pitch pine-scrub oak woodland-forest[3]	None	None	None
Tragenza	26.9	Madison	3x per month	Transitional Pitch pine-scrub oak woodland-forest[3]	None	None	None

[1] Pitch pine-scrub oak thickets are dominated by pitch pine, scrub oak, and early low blueberry, with a canopy cover range of 10-25%; scrub oak height and cover has increased with sunlight.

[2] Pitch pine-scrub oak woodlands are dominated by pitch pine, scrub oak, early low blueberry, and black huckleberry, with a canopy cover range of 25-60%; white pine may also be present in the tree layer, and other shrubs, such a grey birch, may be present in the shrub layer.

[3] Transitional pitch pine-scrub oak woodland-forests may have a similar canopy cover to pitch pine-scrub oak woodlands, or it may exceed 60%. White pine, red maple, and red oak may also be prominent in the canopy. Shrub density and cover is reduced from reduced sunlight.

Sampling and Identification

Moths were collected at night, generally using a standard Universal Collection Bucket, 15watt black light bulb and 12V battery. Ethyl acetate was used as a killing agent in mason jars partway filled with plaster. In some cases a photocell was used to automatically turn the black lights on and off at sunset and sunrise. In all cases the traps were set and the black lights turned on just before dusk. When traps were collected the following morning between 6:00am and 8:00am, the black lights were tested to make sure they had worked throughout the night. Moths were organize by site and date sampled. Though black light bucket traps favor moths with a phototactic response to UV light (Summerville et al. 2004), they are the standard quantitative sampling tool for collecting moths (Southwood 1978).

The Goodwin 4 unit was so productive that in the months of July, August and September a second bucket was swapped into the collection site between 11:15pm and 12:00am to prevent damage to collected specimens. The first bucket was removed from the site and stored until the next morning.

Each collection cycle was organized around the new moon and spanned over, at most, 11 days (Appendix B-3). It is standard to sample moths close in time to the new moon whose darkness allows the black light to be more visible. I sampled within an 11-day period to favor sampling from the same hatch population. In addition to organizing the samplings around the new moon I also, as much as possible, made sure that samplings were timed with target Lepidoptera seasonal flight times (Table 3). The final sampling took place in mid-September, meaning that we may not have adequately sampled for *Xylotype capax*. I did not attempt to sample for the butterfly, *Erynnis brizo brizo*.

Table 3. Ossipee Pine Barrens target Lepidoptera and associated best sample periods

Species	Best sample period
Apantesis carlotta	Unknown
Erynnis brizo brizo	Mid-late May
Eumacaria madopata (brood 1)	Late May to mid-June
Eumacaria madopata (brood 2)	Late July to mid-August
Glena cognataria (brood 1)	Late May to mid-June
Glena cognataria (brood 2)	Late July to mid-August
Grammia speciosa	Unknown
Speranza exonerata	July
Lycia rachelae	Mid-late April
Sympistis dentata	Early July to mid-August
Lithophane lepida lepida	Mid-April
Lithophane thaxteri	Mid-April
Xestia elimata	Mid-July to mid-September
Xestia thoracica	Mid-April
Xylotype capax	Mid-September to October
Zale lunifera	Mid-May to early June
Zale obliqua	July to mid-August
Zale submediana	May to early July
Zanclognatha martha	Early July to mid-August
Nepytia pellucidaria	September

Within each intensively sampled site, moths were collected from three sample points randomly assigned using ArcGIS 10 Random Point Generator (Map 1). Thicket 3 Sample Point 1-3 was moved from its randomly assigned location by TNC staff because the original location was in a white pine plantation that is part of the management unit. As the black light will attract moths from the area surrounding the trap, I minimized sampling from the same source by ensuring that each sample point was at least 50 meters from the next, with the assumption that the trap was sampling from, at most, a 25m radius from the sample point. The sample points were also 50 meters from the management unit boundary to minimize collection from adjacent management units. It is important to note that the true collection distance from the trap is unknown, and will vary from each site with the density of shrub cover and the phase of the moon (Southwood 1978; Scoble 1992; Baker 1995; Ricketts et al. 2001).

Each sample point was sampled once a month within an 11-day sample period. In a few cases the black lights were not functioning when checked in the morning (Appendix B-3). If none, or just a few, moths were collected the traps were set again at the same sample point on a different night. If many moths were collected, the sample point was not re-sampled, though there is no way of knowing when the light stopped functioning. I sampled three nights a month, cycling through the three sample points at each management unit.

The less intensively sampled management units were treated differently in order to capture presence/absence data, though abundance was also recorded. Goodwin 4, Triangle 3, and West Branch 4-2 were sampled once a month, with the exception of May where Goodwin and Triangle were each sampled twice. These units were sampled by TNC request to provide a species list for the newly acquired Goodwin property and to compare to the 2002 survey at a different location on the Triangle property.

It may take several years for moth populations to repopulate a burned area (McCabe 1995; Panzer 2002), so I did not include management units that were burned less than 2 years prior to intensive sampling. However I included one unit burned in 2010 (West Branch 4-2) to corroborate what we expect in recently burned areas. The sample points for these management units were chosen by TNC staff and were maintained throughout the summer. In May, West Branch 4-2 was sampled using a black light sheet trap instead of a black light bucket trap.

Sheet trapping and sugar baiting were used to gather additional presence/absence data for TNC. Sugar baiting, in particular, was used as the primary sampling method in March as the early spring and late fall moths tend to be attracted to sugar baiting, as opposed to black lights (Kart 2003; Schweitzer pers. comm.). Generally, the adult moths of these spring flying species are expected in mid-April, though an unusually warm spring may have allowed for this earlier March sampling. Sugar baiting occurred on the Pine Barrens Loops Trail, Snake Road, North Atlantic Air, Hobbs Road Wildland Urban Interface, and Goodwin. TNC staff used a combination of 1 bottle of beer, 2-3 ripe bananas, cornmeal, sugar, and molasses. The bait was made a day prior to sampling to allow the mixture to ferment. In most cases, the bait was set about an hour before sunset to allow the scent to permeate the area. TNC staff painted between 20 and 40 trees with the mixture per sample site, taking care to bait multiple size classes and on different aspects of pitch or red pine trees. Moths were collected using kill jars with ethyl acetate.

Sheet traps were used in May at West Branch 4-2. A white sheet was set up with a black light to attract the moths. Similar to sugar baiting, the moths were collected in kill jars with ethyl acetate. While sugar baiting and sheet trapping are more labor intensive than bucket traps, they are useful in that the moths are less likely to become damaged during collection. Both techniques may capture moths that are not attracted to, or easily captured in, bucket traps.

Though microlepidoptera are becoming increasingly better studied and understood, they have not been included in the current or past Ossipee Pine Barrens final collections (Schweitzer, pers. comm.). This is consistent with other moth population studies

(Ricketts et al. 2001, Summerville & Crist 2003).

Macrolepidoptera from all sample points were sorted by approximate family and species. They were identified, and their identity confirmed by entomologist Dale Schweitzer through pictures, pinned, spread or stored specimens. Identities were also confirmed using the following sources:

Beadle D. and Leckie S. 2012. Peterson Field Guide to Moths of Northeastern North America. Houghton Mifflin Harcourt.

Covell, C.V. 1984. A Field Guide to the Moths of Eastern North America. Houghton Mifflin Company.

Lafontaine, J.D. 1998. Noctuoidea, Noctuidae (part) in Dominick, R.B., et al. The Moths of America North of Mexico, fasc. 27.3.

Wagner, D.L. 2005. Caterpillars of Eastern North America: a guide to identification and natural history. Princeton University Press.

Wagner, D.L., Ferguson, D.C., McCabe, T.L., and Reardon, R.C. 2001. U.S. Department of Agriculture.

Wagner, D.L., Schweitzer, D.F., Sullivan, J.B., and Reardon, R.C. 2011. Owlet Caterpillars of Eastern North America. Princeton University Press.


Ossipee Pine Barrens
Management Units and Moth Sample Points
N
Goodwin 4
Tragenza
West Branch 4-2
Triangle 3
Thicket 3
Thicket 6
Thicket 4
South Jackman Ridge 2
North Atlantic Air 2
Legend
Moth sample points
Intensive sampling - unburned
Intensive sampling - burned 4-5 years ago
Less intensive sample points
0 0.5 1 2 Kilometers
Date: 4/22/2013

Vegetation Survey

Habitat characteristics of each intensively sampled point, including Tragenza, were collected in a 25-meter radius from the collection point (the assumed reach of the black light). Ground cover, shrub canopy cover, tree canopy cover, and tree basal area were estimated using four 25-meter transects in each cardinal direction. Habitat characteristics were measured along each transect using the following methods:

Ground Cover

Ground cover was estimated using quadrat sampling. Four $0.5m^2$ quadrats were placed directly to the left the 25meter transects at 6, 12, 18, and 24 meters, resulting in 16 quadrats for each sample point. The percent cover and species of all plants less than 50cm high were visually estimated, along with the area occupied by woody debris, live wood (tree stems), mineral soil and leaf litter. Ground cover percentages for each cover type were averaged across all quadrats for each sample point and management unit.

Shrub Canopy Cover

Shrub cover - woody plants taller than 50cm and with a diameter at breast height (dbh) of less than 5cm - was estimated using the line intercept method (Canfield 1941). Along each 25m transect, I noted the starting and stopping locations for all shrub species. The result was a total distance of each transect covered by a given species. Percent cover of each species was calculated by dividing the total cover of that species by the total distance of transects per sample point. Because of overlaps of multiple species along transects, the total percent cover by species may be higher than the total percent cover. Scrub oak was always considered a shrub unless a seedling was less than 50cm tall.

Tree Canopy Cover

Tree canopy cover was also estimated using the line intercept method. Following the same methods as for shrub canopy cover, starting and stopping points for each tree species were recorded. This included all woody plants greater than 5cm dbh.

Basal Area

Basal area was estimated using a strip sampling method. The dbh for any woody stem greater than 5cm dbh was measured if the center of the tree trunk fell within 1 meter of the 25meter transect. Trees that fell into multiple transects (e.g. they were close to the sample point, so were recorded in two adjacent transect lines) were included in the tallies for both transects. The basal area for each tree was calculated using Basal area =

$\pi(d/2)^2$. The tree basal areas were then summed for all four transects and the total multiplied by 50 to estimate the basal area of the sample point in m^2/ha. I then averaged the basal area from each sample point to estimate the management unit average basal area.

WEATHER

The weather conditions for each sample night were determined using the NOAA Daily Climate Report (http://www.nws.noaa.gov/climate/index.php?wfo=gyx) from the station in Grey, Maine (Appendix B-4). Monthly summaries of temperature, precipitation and average wind were also collected.

DATA ANALYSIS

In order to compare differences in species composition and abundance between burned and unburned stands, I used a chi-square goodness of fit test with a significance level of $p<0.05$. Species counts were recorded as the total number of moths collected across all six sampling locations and all collection dates in both the burned and unburned units. The species used for the analysis include the target Lepidoptera as indicated by TNC and pine-barrens specialist indicated in other studies (Wagner et al. 2003, Kart 2003).

In order to determine if the composition of moths has changed over time, I compared presence/absence data for each species between the original 2002 survey and the 2012 survey. I did not compare the two surveys statistically, because there were differences in the sampling intensity and technique.

Using a t-test (JMP 9.0), I compared total moth abundance, richness, and two measures of diversity (Shannon-Wiener Diversity Index and Simpson Index) to identify significant ($p<0.05$) differences between all moth species in the burned and unburned sites. I did not include unidentified moths or moths identified only to genus (unless they were the only representative of that genus) in these calculations.

STUDY LIMITATIONS

Though the protocol of this study is consistent with those widely accepted for moth population sampling, there are still some limitations, most of which have been previously mentioned. Not all moth species will respond in the same way to black lights and black light bucket traps; some moths tend to be more attracted to the light than others, thus will be favored in the sampling (Summerville et al. 2004). Weather conditions will play a large role in the activity of moths, with warm moist air being the optimal condition for most. Though general weather conditions will be similar across sites, it will impact the number of moths collected each night (Yela & Holyoak 1997; Hirao et al. 2008). During this study there were several nights of cold weather, as well as two nights of short but heavy rain.

Given that the moths are being attracted to the trap by a black light, any shifts in the quality of the black light can affect collections. Microsite differences, such as the amount of cover over the trap, will affect the reach of the black light (Ricketts et al. 2001). A light with a wider reach will have a larger sample area than that of a light with a more narrow reach. It was not within the scope of this study to account for the differences in the reach of the light. Similarly, the black light bulbs will exhibit different intensities depending on the condition of the bulb: as the bulbs get older they are not as bright (Ricketts et al. 2001). I accounted for this by preemptively changing in new bulbs towards the end of their life. Though this was mostly settled towards the end of the study, some lights did go out in the night. I was unable to record the time that the lights went out, and even so, would be unable to account for how the collection was impacted. In some cases, I collected from the same sample point on a different night within the cycle. In others where the number of moths collected was consistent with the norm for that site, I did not resample.

Though Lepidoptera are effective indicators of ecosystem health, it is common to sample them over many seasons before making general conclusions about the ecosystem (Summerville et al. 2003; Grand & Mello 2004). As mentioned above, moths are greatly affected by small changes in the weather. It is possible, for example, that the overall dry conditions experienced in 2012 had an effect on some, if not all, populations. Sampling over multiple years will also reduce the chance of sampling outside of some of the moth flight times, especially among the target Lepidoptera.

RESULTS

The vegetation components for burned and unburned plots were, for the most part, similar, although there were some differences in the measured percent ground, shrub, and tree cover and basal area (Table 4, Figure 2, Appendix B-2). A summary of the vegetation in each of the management units that were intensively sampled, including Tragenza, shows that *Vaccinium* spp., scrub oak, and pitch pine were the dominant ground cover, shrub, and tree, respectively, at all sample points (Table 4).

Table 4. Summary of dominant vegetation and cover in each intensively sampled management unit in the Ossipee Pine Barrens. The three species listed for each category are the dominant three species. Note that total cover may be different from the total of cover by all species due to cover overlap.

Management Unit	Ground Cover	Shrub Cover	Tree Cover	Basal Area (m/ha)
Thicket 3&4		Total Cover: 77%	Total cover: 25%	2.33
(Burned)	*Vaccinium* spp. (48.71%)	*Quercus ilicifolia* (71.83%)	*Pinus rigida* (22.33%)	
	Graminoids (7.79%)	*Pteridium aquilinium* (14.62%)	*Pinus strobus* (3.33%)	
	Gaultheria procumbens (5.94%)	*Comptonia peregrina* (0.90%)		
Thicket 6		Total cover: 75%	Total cover: 49%	19.96
	Vaccinium spp. (35.67%)	*Quercus ilicifolia* (61.33%)	*Pinus rigida* (46.13%)	
	Gaultheria procumbens (7.44%)	*Pteridium aquilinium* (23.38%)	*Pinus strobus* (5.20%)	
	Graminoids (4.44%)	*Comptonia peregrina* (0.47%)	*Betula populifolia* (1.10%)	
South Jackman Ridge 2		Total cover: 72%	Total cover: 42%	19.63
(Burned)	*Vaccinium* spp. (39.13%)	*Quercus ilicifolia* (62.77%)	*Pinus rigida* (40.78%)	
	Graminoids (5.00%)	*Pteridium aquilinium* (7.38%)	*Populus tremuloides* (1.00%)	
	Gaultheria procumbens (4.27%)	*Comptonia peregrina* (1.42%)		
North Atlantic Air 2		Total cover: 85%	Total cover: 63%	20.92
	Vaccinium spp. (21.33%)	*Quercus ilicifolia* (73.93%)	*Pinus rigida* (40.10%)	
	Gaultheria procumbens (11.40%)	*Pteridium aquilinium* (24.98%)	*Pinus strobus* (32.87%)	
	Kalmia polifolia (9.83%)	*Pinus strobus* (1.77%)	*Acer rubrum* (0.63%)	
Tragenza		Total cover: 71%	Total cover: 78%	40.78
	Vaccinium spp. (19.02%)	*Quercus ilicifolia* (63.83%)	*Pinus rigida* (58.03%)	
	Gaultheria procumbens (7.73%)	*Pteridium aquilinium* (12.43%)	*Pinus strobus* (25.77%)	
	Quercus ilicifolia seedling (6.52%)	*Pinus strobus* (2.03%)	*Acer rubrum* (12.27%)	

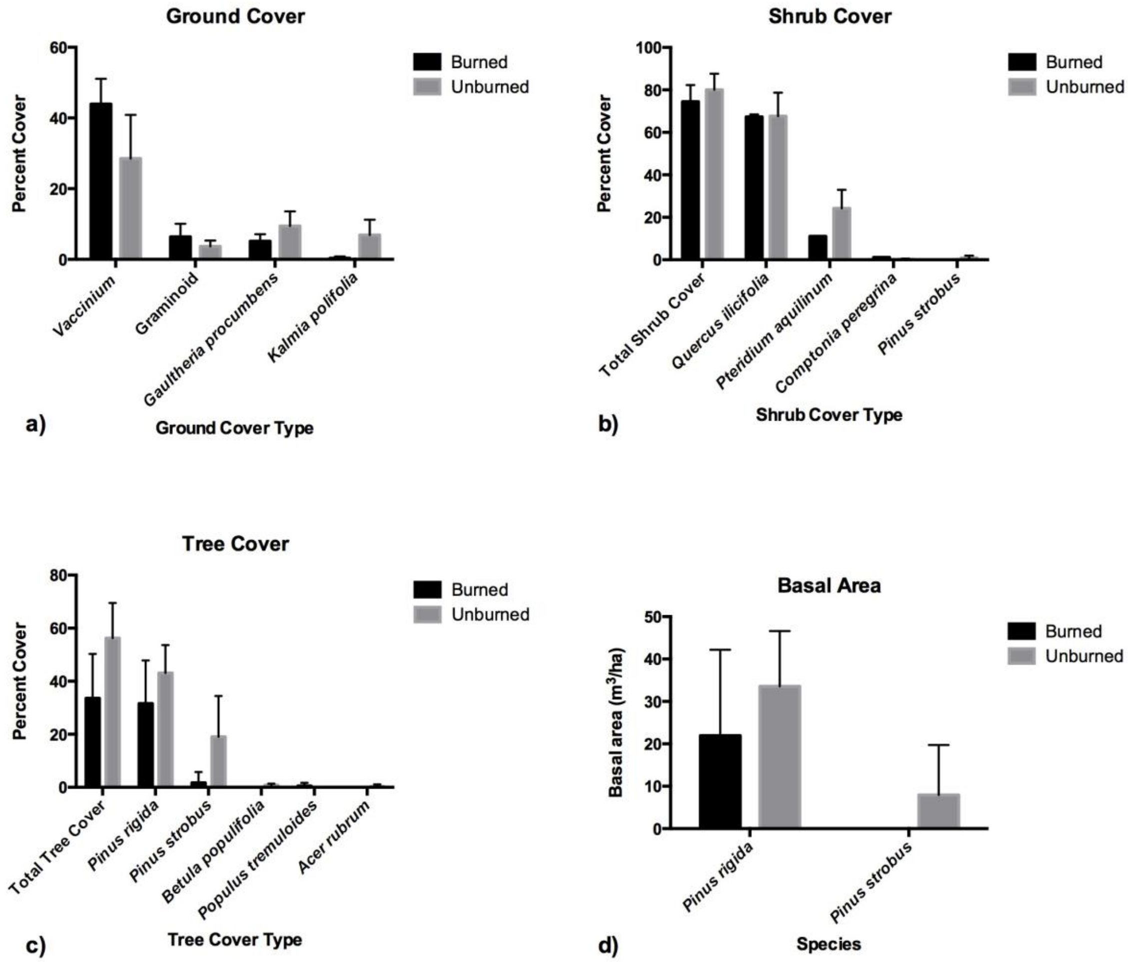


Figure 2. Comparison of dominant vegetation characteristics in burned and unburned units with standard error bars displaying: a) ground cover percentage by species, b) total percent shrub cover and percent shrub cover by species, c) total percent tree cover and percent tree cover by species, as well as d) total basal area.

Target Lepidoptera were found at both the burned and unburned sites, in addition to those sites that were less intensively sampled (Figure 3; Table 6; Table 7). There was an especially high abundance of *Nepytia pellucidaria* and *Zanclognatha martha*. The collected target Lepidoptera are often specialists on certain larval host plants (Table 5).

Figure 3. Abundance of rare moth species collected in burned and unburned sites in the Ossipee Pine Barrens. 2012.

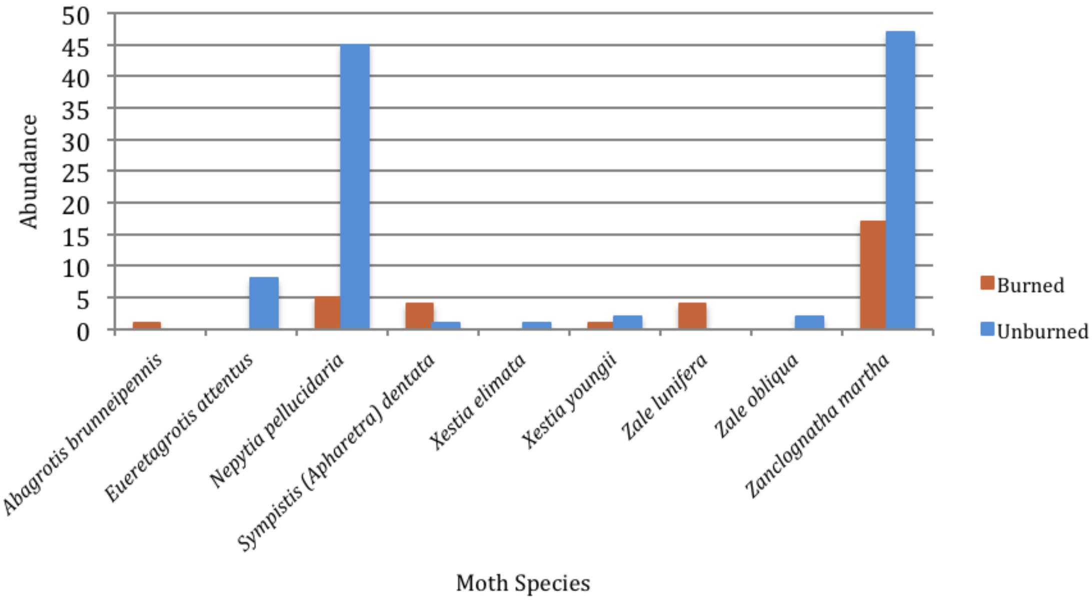


Table 5. Collected target Lepidoptera species and associated larval host plants (Kart 2003).

Species	Larval host plant
Abagrotis brunneipennis	Blueberry
Eueretagrotis attentus	Blueberry
Nepytia pellucidaria	Pine needles
Sympistis (Apharetra) dentata	Blueberry and other Ericaceae
Xestia elimata	Pitch pine. May be facultative on white pine and/or blueberry
Xestia youngii	Heaths
Zale lunifera	Scrub oak leaves and possibly oak catkins
Zale obliqua	Pitch pine
Zanclognatha martha	Leaf litter, possibly old pine needles

A Chi-square analysis of rare moth abundance in burned and unburned management units indicated a significant difference in three moth species: *Nepytia pellucidaria, Zanclognatha martha, and Eueretagrotis attentus* (Table 6). In all three cases of significance, the burned management units had fewer moths than would be expected if unburned and burned sites were equally suitable habitat.

Table 6. Chi-square analysis of rare moth abundance in burned and unburned management units in the Ossipee Pine Barrens. If there is no difference between units, the observed frequency of rare moths will be equal between the burned and unburned units. Note the three moth species with a significant chi-square test value.

	Observed observations		Expected observations		$\chi 2$[1]
Species	Burned	Unburned	Burned	Unburned	
Nepytia pellucidaria	5	45	25	25	**16.00**[2]
Sympistis (Apharetra) dentata	4	1	2.5	2.5	0.90
Xestia elimata	0	1	0.5	0.5	0.50
Zale lunifera	4	0	2	2	2.00
Zale obliqua	0	2	1	1	1.00
Zanclognatha martha	17	47	32	32	**7.03**[2]
*Abagrotis brunneipennis**	1	0	0.5	0.5	0.50
*Eueretagrotis attentus**	0	8	4	4	**4.00**[2]
*Xestia youngii**	1	2	1.5	1.5	0.17

[1] Critical $\chi 2$ value = 3.84

[2] Denotes significant $\chi 2$ test values

* Denotes moth species that are not included in the target Lepidoptera list of TNC, but are suggested by Wagner et al. and Dale Schweitzer as pine barrens specialists (Kart 2003, Wagner et al. 2003)

The results from a comparison of all moth species between burned and unburned sites suggested no significant differences between the total abundance, richness, evenness, or diversity of moths in these four management units (Table 7).

In addition to the rare moths collected in June through September in the four intensively sampled management units, rare moths were collected in March and May as well as from the other sampled sites (Table 8, Figure 4). I collected ten conservation target Lepidoptera throughout the entire study and five additional species of conservation concern. Seven specimens of *Lithophane lepida* were collected in March. All specimens were considered *Lithophane lepida lepida*, though at least one may have been subspecies *adipel*. March, July and August collections were the months of the highest rare species richness (Figure 4).

Table 7. Summary of total number of moths, species richness, Shannon-wiener Diversity Index, and Simpson Index for all three sample points in each burned and unburned management unit in the Ossipee Pine Barrens, including the t-test results.

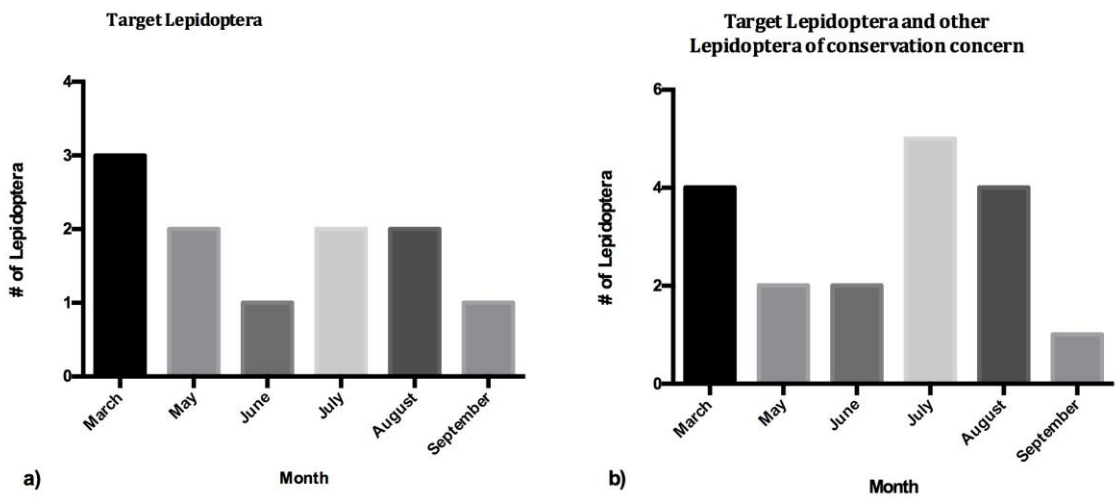
	Thicket 3&4 (burned)			**South Jackman Ridge 2 (burned)**			**North Atlantic Air 2 (unburned)**			**Thicket 6 (unburned)**			**p-value**
Species	**1-2**	**1-1**	**1-3**	**2-1**	**2-2**	**2-3**	**6-1**	**6-3**	**6-4**	**7-1**	**7-2**	**7-3**	
Total individuals	136	126	73	209	238	281	375	344	286	69	160	282	0.2205
Species richness	39	36	24	61	68	89	87	71	61	15	31	61	0.9205
Shannon-Wiener Index	2.81	2.60	2.18	3.12	3.55	3.87	3.44	3.08	3.12	1.91	2.82	3.33	0.8455
Simpson Index	0.88	0.85	0.79	0.88	0.95	0.97	0.91	0.88	0.90	0.79	0.92	0.94	0.9270

Table 8. Summary of rare and pine barrens specialist moths collected at all sites from March through September by species.

Species	Hobbs Road WUI	Pine Barrens Loop Trail	Snake Road	Thicket	North Atlantic Air	Triangles	West Branch 4-2	Goodwin	Tragenza	Thicket 3&4	South Jackman Ridge 2	North Atlantic Air 2	Thicket 6
*Abagrotis brunneipennis**							2		1	1			
*Eueretagrotis attentus**						1	3	4	7			4	4
Lithophane lepida lepida	5				1			1					
Lycia rachelae				1									
Nepytia pellucidaria						1			167	1	4	15	30
*Sideridis maryx**						1							
Sympistis dentata						4	9			2	2	1	
Xestia elimata													1
*Xestia youngii**											1	2	
*Xylena cineritia**				1									
Xylena thoracica		5	2	6	5								
Zale lunifera							1		4	2	2		
Zale obliqua													2
Zale submediana								1					
Zanclognatha martha						1	3	3	25	1	16	19	28
Total	**5**	**5**	**2**	**8**	**5**	**8**	**18**	**8**	**204**	**7**	**25**	**41**	**65**

* Denotes moth species that are not included in the target Lepidoptera list of TNC, but are suggested by Wagner et al. and Dale Schweitzer as pine barrens specialists (Wagner et al. 2003, Kart 2003)

Figure 4. Summary of the number of a) target Lepidoptera species and b) target Lepidoptera species and other Lepidoptera of conservation concern found throughout the sampling months in 2012.

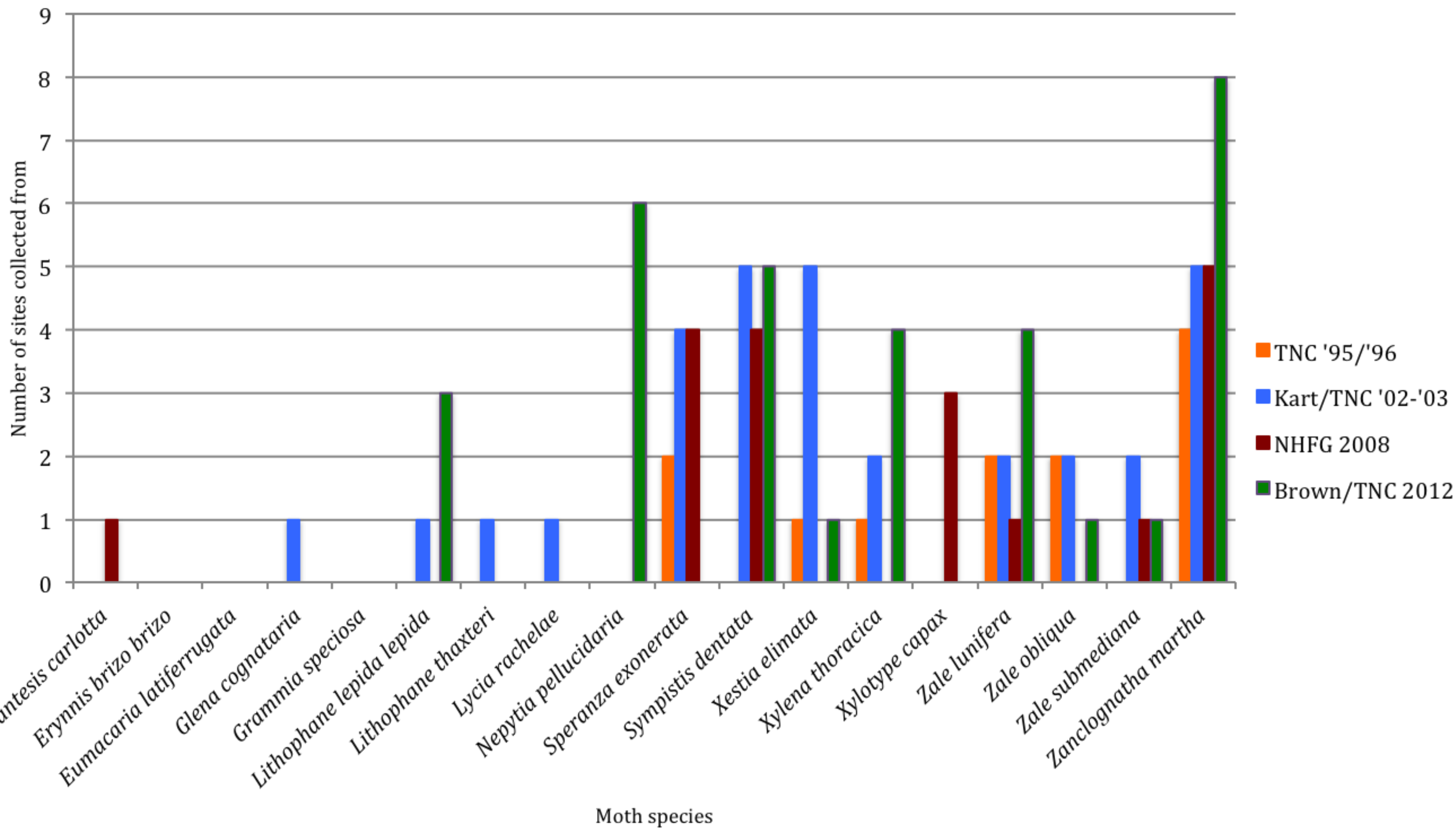


Historical Comparison

Collection methods and intensity differed between the 2002 collection (Kart 2003) and this 2012 collection. While I cannot compare the abundance of moth species between the two collections, I have compared the presence of species in each of the two studies (Appendix C) It is important to note that absence in the collection is not equal to absence at the study site. 126 species were collected in both the 2002 and 2012 studies, 120 species were only collected in the 2002 study, and 152 only in 2012. The 2002 collections were focused in the summer, thus many of the early and spring flying moths were not represented. A follow up collection occurred in 2003 to capture the presence of spring flying moths. Most interesting to note is the high abundance of *Nepytia pellucidaria, Zale lunifera, Lycia rachelae*, as well as some representatives of the Saturniidae, which though expected, were not present in the 2002 collections (Kart 2003).

To focus on changes in the presence of conservation target Lepidoptera over time, I compared the presence of these target species in sampled sites from the 1995/1996, 2003, 2008, and 2012 monitoring efforts (Figure 5). Though *Eumacaria latiferrugata* (*E. madopata*) has not been collected in the four monitoring efforts presented in Figure 5, it was collected in the 1985-1986 study by Dale Schweitzer. The 1985-1986 data are not included in the summary of monitoring efforts as the number of sites in which the moths were present was not recorded. The following target Lepidoptera species were collected in 1985-1986: *Erynnis brizo brizo, Sympistis dentata, Eumacaria latiferrugata, Glena cognataria, Speranza exonerata, Lithophane lepida lepida, Lithophane thaxteri,* *Xylena thoracica, Xylotype capax, Zale oblique, Zale lunifera, Zale submediana*, and *Zanclognatha martha*. *Erynnis brizo brizo* was not collected for in the 2012 collections, but there is a confirmed record of one present through photographs during the summer.

Figure 5. Summary of the number of sites conservation target Lepidoptera were collected from in the Ossipee Pine Barrens in 1995-1996, 2003-2003, 2008, and 2012.



DISCUSSION

Though two of the units were managed by fire, many of the habitat characteristics appear to be similar between the burned and unburned units. The vegetation survey did not capture the vertical density of the vegetation, especially scrub oak. Visually, the burned units appeared to have vertically denser scrub oak patches. However vertical density varied, and the unburned Thicket 6 unit was also quite dense in many patches. Figure 2 shows the vegetation characteristics in the burned and unburned units that were determined in the vegetation survey. The target moths rely on *Vaccinium* spp. and other heath plants, pitch pine (and maybe white pine), and scrub oak as larval host plants. Thus differences in the vegetation composition may impact larval density and survival. There appears to be a greater percentage of *Vaccinium* spp. ground cover in the burned units, and a greater amount of pitch pine, both in percent cover and basal area, in unburned units. The presence of white pine in the unburned units, but not the burned units, may also be important, though it isn't known to necessarily be an important larval food source for the target Lepidoptera.

During the experimental collection months of June through September and in the intensively sampled management units, six conservation target Lepidoptera were collected: *Nepytia pellucidaria, Sympistis dentata, Xestia elimata, Zale lunifera, Zale oblique*, and *Zanclognatha martha*. Three additional species of conservation concern were also found: *Abagrotis brunneipennis, Eueretegrotis attentus,* and *Xestia youngii*. For three of the above species (*Nepytia pellucidaria, Zanclognatha martha*, and *Eueretegrotis brunneipennis*) there was a significant difference between the burned and unburned units, with a greater number of moths in the unburned units. Figure 3 shows that the numbers of *Nepytia pellucidara* and *Zanclognatha martha* captured towers far above the general trend of target Lepidoptera abundance. Without a greater understanding of the needs of these moths, it is difficult to determine what about the unburned units is particularly beneficial for these moth species.

Moth abundance can be influenced by many variables: e.g. presence and density of larval and adult food plants, canopy cover, edge effects, larval survival, parasitoids, predators, and dispersal distance. The potential variables are too large to pin down the exact cause of the significant difference. Though the dispersal distances of the target moths are largely unknown, it was confirmed with Dale Schweitzer that five years is likely sufficient for the moths to re-inhabit the burned areas from surrounding unburned areas. This presumption is supported by the lack of significance between the burned and unburned units for most target Lepidoptera species. *Nepytia pellucidaria* and *Zanclognatha martha* both rely on pitch pine needles as larval hosts. Though pitch pines are found in both burned and unburned units, the tree cover and basal area are lower in the burned units, so it is possible that this difference in larval food is impacting these two species. Furthermore, fire has likely removed an already established pine needle litter component that these species may rely on for larval food. *Eueretagrotis* *attentus* feeds mainly on *Vaccinium* spp., which was higher in percent cover in the burned units, leading me to believe that abundance of larval host plants was not a significant factor in my findings for this species.

It is also important to note the impact that a small sample size, both spatially and temporally, may have had on the results. In the future, it will be important to monitor these target moths on multiple burned and unburned sites as well as over successive years.

The total number of all moth species in burned units appeared to be higher than those in the unburned units, though a t-test showed there was no significant difference between the total number of moths, species richness, Shannon-Wiener Diversity Index, or the Simpson Index (Table 7). While these indices are commonly used for describing changes in ecosystems, they do not accurately reflect changes in the actual species, just the number species. It is possible that there is a shift in the type of species that has not been captured.

Throughout the course of the study (including all sample dates and all sample sites), ten conservation target Lepidoptera species were collected (Table 8). Five additional species of conservation concern were collected as well. *Nepytia pellucidaria* was a particularly exciting capture, especially in such high numbers. Though *N. pellucidaria* was collected in small numbers in the 1998 collections, there was no previous record of its collection before the 1930's. Since *N. pellucidaria* is a late fall flying moth, it is possible that its absence has simply been due to the timing of past collection efforts.

Conservation target Lepidoptera that were not collected include *Apantesis carlotta, Eumacaria madopata, Glena cognataria, Grammia speciosa, Speranza exonerata, Lithophane thaxteri,* and *Xylotype capax*, as well as the butterfly, *Erynnis brizo brizo*. Though it wasn't collected, *Erynnis brizo brizo* was documented in the Ossipee Pine Barrens by a photographer and confirmed by Jeff Lougee during the summer of 2012. Based on the expected flight times, the collections did occur at appropriate times for the collection of these six moth species, except for possibly *Lithophane thaxteri*, which may have been missed since early spring sampling only occurred in March. Additionally, *Xylotype capax* may have been more abundant after the final collections in mid-September. Finally, *Eumacaria madopata* (previously *E. latiferrugata*) was named in the Kart 2003 report as a species that was expected in the collection, but was not found. Unfortunately, the same is true for this study as well. *E. madopata* flies from May to August, so the samplings occurred at appropriate times to capture this species. In the future, it may be beneficial to especially monitor *Prunus* sp., the larval host plant, to determine if there is a lack of larval food.

In addition to investigating the impacts of management and comparing historical data, I also collected moths in areas that have not been sampled previously. Goodwin and Tragenza are both newer properties to TNC, and thus had not been sampled for moths.

Moths were especially abundant in. Goodwin had so many moths that, as mentioned previously, the black light buckets were changed out in the middle of the night to prevent damage to the collected moths.

MANAGEMENT RECOMMENDATIONS

Target Lepidoptera and other Lepidoptera species of conservation concern were found in both burned and unburned units. Three species were significantly different between unburned and burned sample sites. We can't say for sure why there were more moths of these three species in the unburned management units as compared to the recently burned units, because of a myriad of poorly understood potential variables. There are, however, several opportunities for simpler Lepidoptera monitoring efforts and a collaboration of vegetation surveys.

- Continue managing for pitch pine-scrub oak habitat, keeping moth life histories in mind as outlined in Kart 2003.

- When managing larger units with prescribed fire, maintain corridors of unburned vegetation to provide a refuge as well as a source population post-burning. Recognizing the use of corridors for Lepidoptera appears to be quite recent, and while I was unable to find general recommendations for the size of such corridors there are specific recommendations for the Karner blue butterfly (*Lycaeides melissa samuelis*). Conservation efforts for this butterfly have recommended multiple patches of 25 meters in diameter that are less than 300 meters from a neighboring patch (though it is important to note that this is referring to open patches in a closed woodland) (Karner 2003).

- Include moth-important vegetation characteristics in post-burn vegetation surveys that are already in place. This should include canopy cover, percent cover of *Vaccinium* and scrub oak, and basal area of tree species, especially pitch pine. As some of these variables are already included in the current post-burn vegetation survey, they can simply be applied to discoveries in future moth monitoring efforts.

- Especially with the significant difference seen in the three species of conservation concern, it is important to ensure that the moths are able to regain their population before burning again. Further monitoring efforts will also track changes in the presence of these species. In order to determine the appropriate burn cycle that allows moth populations to regain healthy populations before burning again, it is important to determine the length of time it takes for moth population recover. This can be achieved using a design that is less intensive than the 2012 study. This less intensive monitoring design may also be adapted and useful for continuous monitoring, even if establishing an appropriate burn cycle is not the focus:

- Designate one to several recently burned and unburned management units for sampling.

- Sample using black light sheet traps (or sugar bait in the early spring), which allows for moths to be captured, identified, and released (the preferred method if moths are to be sampled yearly) or captured and killed to confirm identification or to documentation.

- Focus only on the target Lepidoptera species. Depending on the time of the year, there are often only 2 or 3 target moths that are flying. This allows for easier recognition of important moth species, rather than using extensive time and resources to identify all moth species. This simplifying would also allow a non-moth expert (seasonal field staff members and/or dedicated community volunteers) to be trained to sample and identify the target Lepidoptera.

- Though there are certainly downfalls to citizen science projects, especially in regards to accuracy, they allow for more frequent sampling. If the species that are being monitored are narrowed down, it is possible that dedicated trained community members could accurately identify target Lepidoptera. There is a very successful example of a similar, though much larger, citizen science moth monitoring effort in the United Kingdom. See www.mothscount.org for more information.

- Sample the burned and unburned units on the same night, on several targeted nights throughout the spring to fall.

- Record and compare the abundance and richness of target Lepidoptera between the burned and unburned units.

- Completing this survey yearly will help determine the time it takes for target Lepidoptera to repopulate a burned area, thus influencing the prescribed burn interval.

- It will be beneficial to carry out intensive monitoring efforts, like the 2012 study, to capture a potentially more accurate measure of diversity and abundance, as well as to capture any important species or changes not already identified in the conservation target Lepidoptera. In addition, if the sheet trap monitoring shows drastic changes in target Lepidoptera, a more intensive collection effort should help to paint a more accurate picture of changes in moth populations.

- If target Lepidoptera abundance continues to decrease in previously burned units, a larger discussion of different management techniques (e.g. harvesting or mowing) and whether habitat type or the animals within it are the priority conservation objective will be necessary.

- Include microlepidoptera in future intensive collections. They have been excluded in the past because they were not well known, but this is changing and there is increasingly more information on the life history and taxonomy of these species.

- As suggested in Kart 2003, it may be useful to include other well known taxa in monitoring efforts, such as ground beetles (Coleoptera) to provide a more accurate picture of how management impacts invertebrate pine barrens species.

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APPENDIX

Appendix A. Description of State and Global Rank Codes.

Ranks describe rarity both throughout a species' range (globally, or "G" rank) and within New Hampshire (statewide, or "S" rank). The rarity of sub-species and varieties is indicated with a taxon ("T") rank. For example, a G5T1 rank shows that the species is globally secure (G5) but the sub-species is critically imperiled (T1).

Code	*Examples*	*Description*
1	G1 S1	Critically imperiled because extreme rarity (generally one to five occurrences) or some factor of its biology makes it particularly vulnerable to extinction.
2	G2 S2	Imperiled because rarity (generally six to 20 occurrences) or other factors demonstrably make it very vulnerable to extinction.
3	G3 S3	Either very rare and local throughout its range (generally 21 to 100 occurrences), or found locally (even abundantly at some of its locations) in a restricted range, or vulnerable to extinction because of other factors.
4	G4 S4	Widespread and apparently secure, although the species may be quite rare in parts of its range, particularly the periphery
5	G5 S5	Demonstrably widespread and secure, although the species may be quite rare in parts of its range, particularly at the periphery
U	GU SU	Status uncertain, but possibly in peril. More information needed.
H	GH…SH	Known only from historical records, but may be rediscovered. A G5 SH species is widespread throughout its range (G5), but considered historical in New Hampshire (SH).
X	GX SX	Believed to be extinct. May be rediscovered, but evidence indicates that this is less likely than for historical species. A G5 SX species is widespread throughout its range (G5), but extirpated from New Hampshire (SX)
Q	G5Q GHQ	Questions or problems may exist within the species' or sub-species' taxonomy, so more information is needed.
?	G3? S3?	The rank is uncertain due to insufficient information at the state or global level, so more inventories are needed. When no rank has been proposed the may be "G5T?" or "S?".

When ranks are somewhat uncertain or the species status appears to fall between two ranks, the ranks may be combined. For example:

G4G5	The species may be globally secure (G5), but appears to be at some risk (G4).
G5T2T3	The species is globally secure (G5), but the sub-species is somewhat imperiled (T2T3)
G4?Q	The species appears to be relatively secure (G4), but more information is needed to confirm this (?). Further, there are questions or problems with the species' taxonomy (Q).
G3G4Q S1S2	The species is globally uncommon (G3G4), and there are questions about its taxonomy (Q). In New Hampshire, the species is very imperiled (S1S2)

From New Hampshire Natural Heritage Bureau. Rare Animal List for New Hampshire, Including species listed as threatened or endangered under the NH Endangered Species Conservation Act of 1979. January 2012.

Appendix B-1. GPS coordinates of Lepidoptera collection points.

Management Unit	Sample Point	Latitude	Longitude
Thicket 3	1-1	43.834684	-71.128480
Thicket 4	1-2	43.832853	-71.180316
Thicket 3	1-3	43.834763	-71.179977
South Jackman Ridge 2	2-1	43.827860	-71.164953
South Jackman Ridge 2	2-2	43.827481	-71.164298
South Jackman Ridge 2	2-3	43.827746	-71.165804
Tragenza	5-1	43.850612	-71.183257
Tragenza	5-2	43.850947	-71.184580
Tragenza	5-3	43.852571	-71.183877
North Atlantic Air 2	6-1	43.826286	-71.178220
North Atlantic Air 2	6-3	43.825863	-71.178233
North Atlantic Air 2	6-4	43.826219	-71.177571
Thicket 6	7-1	43.832524	-71.178245
Thicket 6	7-2	43.831795	-71.176434
Thicket 6	7-3	43.831935	-71.177567
Triangles		43.840374	-71.198675
Goodwin		43.862995	-71.158831
West Branch		Not available	Not available

Appendix B-2. Summary of vegetation analysis for intensively sampled sites.

Thicket 3 & 4

Ground Cover	
Ground cover type	**Average %**
Vaccinium spp.	48.71
Litter	31.23
Graminoid	7.79
Gaultheria procumbens	5.94
Unidentified woody plant	1.98
Woody debris	1.29
Quercus ilicifolia	1.00
Kalmia polifolia	0.63
Live wood (*Quercus ilicifolia*)	0.35
Uvularia sessilifolia	0.31
Comptonia peregrina	0.31
Pinus rigida seedling	0.10
Lysimachia punctata	0.08
Melampyrum lineare	0.06
Acer rubrum seedling	0.06
Unidentified herbaceous plant	0.04
Moss	0.02
Monotropa uniflora	0.02
Live wood	0.02
Trientalis borealis	0.02
TOTAL	**100.0**

Average total percent shrub cover 77.32%

Average percent shrub cover by species

Quercus ilicifolia	71.83%
Pteridium aquilinum	14.62%
Comptonia peregrina	0.90%
Pinus rigida	0.37%
Prunus sp.	0.37%
Unidentified shrub	0.10%
Rubus sp.	0.13%

Average total percent tree cover 25.33%

Average percent tree cover by species

Pinus rigida	22.33%
Pinus strobus	3.33%

		Total B.A. (/ha)
Average basal area	*Pinus rigida*	2.33

South Jackman Ridge 2

Ground Cover	
Ground cover type	**Average %**
Vaccinium spp.	39.13
Litter	30.13
Woody debris	10.98
Graminoid	5.00
Gaultheria procumbens	4.27
Comptonia peregrina	2.08
Mineral soil	1.44
Live wood (*Quercus ilicifolia*)	1.10
Rubus sp.	1.00
Quercus ilicifolia	0.83
Betula populifolia seedling	0.73
Unidentified herbaceous plant	0.63
Moss	0.52
Spiraea spp.	0.48
Lysimachia quadrifolia	0.42
Pinus rigida	0.33
Trientalis borealis	0.27
Live wood	0.23
Uvularia sessilifolia	0.10
Solidago sp.	0.10
Pyrola rotundifolia	0.10
Pteridium aquilinum	0.10
Live wood (*Betula populifolia*)	0.02
TOTAL	**100.0**

Average total percent shrub cover		71.55%	
Average percent shrub cover by species			
	Quercus ilicifolia		62.77%
	Pteridium aquilinum		7.38%
	Comptonia peregrina		1.42%
	Betula populifolia		0.95%
	Spiraea sp.		0.32%
	Unidentified shrub		0.08%
	Apocynum androsaemifolium		0.10%
	Rubus sp.		0.07%
	Prunus sp.		0.40%
Average total percent tree cover		41.75%	
Average percent tree cover by species			
	Pinus rigida		40.78%
	Populus tremuloides		1.00%

		Total B.A. (/ha)
Average basal area	*Pinus rigida*	19.63

Tragenza

Ground Cover	
Ground cover type	**Average %**
Litter	53.44
Vaccinium spp.	19.02
Gaultheria procumbens	7.73
Quercus ilicifolia	6.52
Moss	5.25
Woody debris	5.21
Graminoid	2.00
Live wood (*Pinus rigida*)	0.31
Live wood (*Quercus ilicifolia*)	0.21
Acer rubrum seedling	0.15
Kalmia polifolia	0.10
Pinus strobus seedling	0.02
Fagus grandifolia seedling	0.02
Live wood	0.02
Total	**100.0**

Average total percent shrub cover 70.60%

Average percent shrub cover by species

Quercus ilicifolia	63.83%
Pteridium aquilinum	12.43%
Pinus strobus	2.03%
Vaccinium spp.	0.17%
Betula populifolia	0.13%

Average total percent tree cover 78.00%

Average percent tree cover by species

Pinus rigida	58.03%
Pinus strobus	25.77%
Acer rubrum	12.27%
Betula populifolia	0.63%
Fagus grandifolia	2.17%
Pinus resinosa	2.57%

Average basal area

	Total B.A. (/ha)
Pinus rigida	39.65
Pinus strobus	0.89
Fagus grandifolia	0.13
Betula populifolia	0.11
Total	40.78

North Atlantic Air 2

Ground Cover	
Ground cover type	**Average %**
Litter	45.69
Vaccinium spp.	21.33
Gaultheria procumbens	11.40
Kalmia polifolia	9.83
Woody debris	3.52
Graminoid	2.88
Live wood (*Pinus rigida*)	1.25
Pteridium aquilinum	0.94
Quercus ilicifolia	0.92
Unidentified woody plant	0.91
Pinus strobus seedling	0.60
Acer rubrum	0.29
Live wood (*Quercus ilicifolia*)	0.23
Trientalis borealis	0.10
Moss	0.10
TOTAL	**100.0**

Average total percent shrub cover 84.57%

Average percent shrub cover by species

Quercus ilicifolia	73.93%
Pteridium aquilinum	24.98%
Pinus strobus	1.77%
Vaccinium spp.	1.43%
Kalmia polifolia	1.37%
Acer rubrum	1.10%
Unidentified shrub	0.07%

Average total percent tree cover 63.27%

Average percent tree cover by species

Pinus rigida	40.10%
Pinus strobus	32.87%
Acer rubrum	0.63%
Betula populifolia	0.47%

		Total B.A. (/ha)
Average basal area	*Pinus rigida*	14.19
	Pinus strobus	6.73

Total 20.92

Thicket 6

Ground Cover	
Ground cover type	**Average %**
Litter	38.52
Vaccinium spp.	35.67
Gaultheria procumbens	7.44
Woody debris	4.46
Graminoid	4.44
Kalmia polifolia	3.96
Quercus ilicifolia	1.56
Comptonia peregrina	1.04
Live wood (*Quercus ilicifolia*)	0.94
Unidentified	0.81
Moss	0.60
Live wood (*Pinus rigida*)	0.42
Live wood	0.15
Total	**100.0**

Average total percent shrub cover	75.43%	
Average percent shrub cover by species		
	Quercus ilicifolia	61.33%
	Pteridium aquilinum	23.38%
	Comptonia peregrina	0.47%
	Kalmia polifolia	0.17%

Average total percent tree cover	49.17%	
Average percent tree cover by species		
	Pinus rigida	46.13%
	Pinus strobus	5.20%
	Betula populifolia	1.10%

		Total B.A. (/ha)
Average basal area	*Pinus rigida*	19.36
	Pinus strobus	0.60
	Total	19.96

Appendix B-3. Dates and methods of all collections. Moths were collected using a black light/bucket unless otherwise indicated

Management Unit	Point	April	May	June	July	August	September
Thicket 4	1-2		5/21/12	6/14/12	7/18/12	8/12/12	9/22/12
Thicket 3	1-1		5/24/12	6/18/12	7/20/12	8/14/12	9/25/12
	1-3		5/31/12	6/20/12	7/25/12	8/19/12	9/20/12
South Jackman Ridge 2	2-1		5/24/12	6/18/12	7/20/2012[e] (redo), 7/25/12[e](redo), 7/27/12	8/14/12	9/20/12
	2-2		5/21/12	6/14/12	7/18/12	8/12/12	9/22/12
	2-3		5/31/2012[d]	6/20/12	7/25/12	8/19/12	9/25/12
Tragenza	5-1		5/24/2012[e]	6/18/12	7/20/12	8/19/12	9/22/12
	5-2		5/21/12	6/14/12	7/18/12	8/12/12	9/20/12
	5-3		5/31/2012[e]	6/20/12	7/25/12	8/19/12	9/25/12
North Atlantic Air 2	6-1		5/24/12	6/18/12	7/20/12	8/14/12	9/25/12
	6-3		5/21/12	6/14/2012[e]	7/18/12	8/12/12	9/20/12
	6-4		5/31/12	6/20/12	7/25/12	8/19/2012[e]	9/22/12
Thicket 6	7-1			6/14/2012[f], 6/18/12	7/18/12	8/12/12	Dates not accurately reported
	7-2			6/18/12	7/20/12	8/14/12	Dates not accurately reported
	7-3			6/20/12	7/25/12	8/19/12	Dates not accurately reported
Goodwin 4 Unit		3/22/12[b]	5/21/12	6/14/2012[e]	7/18/12	8/12/12	9/20/12
			5/24/2012[c]				
Triangles 3 unit			5/21/2012[d]	6/14/2012[d]	7/18/2012[d]	8/12/2012[d]	9/20/12
			5/24/12[e]				
			5/31/2012[e]				
West Branch 4-2			5/24/12[a]	6/14/12	7/18/12	8/12/12	9/20/12
Thicket		3/22/12[a,b]					
Pine Barrens Loop Trail		3/21/12[b]					
Snake Road		3/21/12[b]					
North Atlantic Air		3/22/12[b]					
Hobbs Road WUI		3/22/12[b]					

[a] Sheet/black light trap
[b] Sugar bait
[c] Large black light/bucket used; lights out upon collection
[d] Large black light/bucket
[e] Lights out upon collection
[f] Lights out upon collection; ethyl acetate jars unopened

Appendix B-4. Summary of weather conditions for each sample night from May through September, as reported from a NOAA station in Grey, Maine.

Date	Min. temperature(F)	Max. temperature (F)	Precip. (inches)
5/21/12	56	59	0.02
5/24/12	54	67	0.03
5/31/12	56	77	0.00
6/14/12	56	74	0.00
6/18/12	50	66	0.00
6/20/12	59	93	0.00
7/18/12	63	85	0.03
7/20/12	55	77	0.00
7/25/12	59	78	0.00
7/27/12	61	78	0.19
8/12/12	66	77	0.54
8/14/12	66	83	0.00
8/19/12	57	76	0.00
9/20/12	41	64	0.00
9/22/12	51	69	0.01
9/25/12	43	69	0.00

Appendix C. Comparison of moths present in the 2002 study by Kart (2003) and this 2012 collection, those present in the 2002 collection only and those present in this 2012 study only.

Species present in 2002 and 2012	Species present in 2002 only	Species present in 2012 only
Abagrotis alternata	*Acronicta americana*	*Acronicta afflicta*
Abagrotis brunneipennis	*Acronicta haesitata*	*Acronicta hasta*
Acronicta distans/impressa group	*Anacamptodes ephyraria*	*Acronicta increta complex*
Acronicta ovata	*Anacamptodes humaria*	*Acronicta longa*
Acronicta tritona	*Anacamptodes vellivolata*	*Acronicta noctivaga*
Agrotis venerabilis	*Anagoga occiduaria*	*Acronicta retardata*
Amphipyra pyramidoides	*Apamea alia*	*Acronicta tristis*
Anavitrinella pampinaria	*Apantesis carlotta*	*Acronicta vulpina*
Apantesis nais	*Autographa ampla*	*Actias luna*
Aplectoides condita	*Caenurgina crassiuscula*	*Aethalura intertexta*
Balsa labecula	*Capis curvata*	*Agrotis ipsilon*
Bellura obliqua	*Catocala connubialis*	*Agrotis volubilis*
Bleptina caradrinalis	*Catocala gracilis*	*Anicla (Euratagrotis) forbesi*
Caenurgina erechtea	*Catocala innubens*	*Anicla illapsa*
Callopistria cordata	*Catocala relicta*	*Anisota virginiensis*
Campaea perlata	*Cepphis armataria*	*Antheraea polyphemus*
Caripeta angustiorata	*Cerastis fishii*	*Anticlea multiferata*
Caripeta piniata	*Cerastis tenebrifera*	*Apantesis new sp. near carlotta*
Catocala antinympha	*Ceratomia amyntor*	*Apoda biguttata*
Catocala ilia	*Chortodes inquinata*	*Automeris io*
Catocala similis	*Ctenucha virginica*	*Besma endropiaria*
Catocala sordida	*Cycnia tenera*	*Besma quercivoraria*
Catocala ultronia	*Dasychira basiflava*	*Biston betularia*
Chrysanympha formosa	*Dasychira cinnamomea*	*Bomolocha baltimoralis*
Chytolita morbidalis	*Diarsia jucunda*	*Cabera erythemaria*
Chytonix palliatricula	*Dolba hyloeus*	*Caripeta divisata*
Clostera albosigma	*Drasteria occulta*	*Catocala andromedae*
Cosmia calami	*Dyspyralis puncticosta*	*Catocala praeclara*
Crambidia pallida	*Eilema bicolor*	*Chlorochlamys chloroleucaria*
Crocigrapha normani	*Elaphria festivoides*	*Cladara limitaria*
Cyclophora pendulinaria	*Epidelta metonalis*	*Clostera strigosa*
Cycnia oregonensis	*Euagrotis forbesi*[1]	*Condica vecors*
Dasychira obliquata	*Euagrotis illapsa*	*Darapsa choerilus*
Dasychira plagiata	*Euchactes egle*	*Dargida diffusa*

Species present in 2002 and 2012	Species present in 2002 only	Species present in 2012 only
Datana drexelii	*Euchlaena effecta*	*Deltote bellicula*
Datana ministra	*Euchlaena muzaria*	*Drepana arcuata*
Drepana bilineata	*Euchlaena pectinaria*	*Dyspyralis nigellus*
Dryocampa rubicunda	*Eucirroedia pampina*	*Ectropis crepuscularia*
Euchlaena irraria	*Eufidonia notataria*	*Elaphria allapallida*
Euchlaena marginaria	*Eurois astricta*	*Ennomos magnaria*
Euclea delphinii	*Eusarca confusaria*	*Ennomos subsignaria*
Eueretagrotis attentus	*Euxoa obeliscoides*	*Euchlaena johnsonaria*
Eulithis explanata	*Faronta diffusa*	*Eufidonia convergaria*
Gluphisia septentrionis	*Feltia herilis*	*Euplexia benesimilis*
Halysidota tessellaris	*Feralia comstocki*	*Eupsilia morrisoni*
Hemipachnobia monochromatea	*Glena cognataria*	*Eupsilia sidus*
Hethemia pistasciaria	*Grammia figurata*	*Eupsilia tristigmata*
Hydriomena sp.	*Grammia speciosa*	*Eupsilia vinulenta*
Hypagyrtis piniata	*Grammia virgo*	*Eutrapela clementaria*
Hypagyrtis unipunctata	*Grammia virguncula*	*Euxoa perpolita*
Hyperaeschra georgica	*Graphiphora auger haruspica*	*Fagitana littera*
Hypoprepia fucosa	*Haploa confusa*	*Feltia herilis*
Hyppa xylinoides	*Herculia olinalis*	*Glena cribrataria*
Idia americalis	*Hesperumia sulphuraria*	*Grammia parthenice*
Idia lubricalis	*Heterocampa umbrata*	*Haploa clymene*
Idia rotundalis	*Holomelina ferruginosa*	*Haploa lecontei*
Lacinipolia renigera	*Holomelina opella*	*Harrisimemna trisignata*
Lambdina athasaria	*Homorthodes furfurata*	*Heterocampa biundata*
Lambdina fiscellaria	*Hydriomena transfigurata*	*Heterocampa guttivitta*
Lapara bombycoides	*Hypenodes fractilinea*	*Homochlodes fritillaria (of Wagner)*
Leucania commoides	*Hypenodes sombrus*	*Horisme intestinata*
Leucania inermis	*Hyperstrotia villificans*	*Hypena eductalis*
Lomographa vestaliata	*Idia aemula*	*Idia denticulalis*
Lycophotia (Heptagrotis) phyllophora	*Idia diminuendis*	*Iridopsis larvaria*
Lymantria dispar	*Idia julia*	*Iridopsis vellivolata*
Macrurocampa marthesia	*Itame anataria*	*Lacanobia grandis*
Malacosoma americanum	*Itame argillacearia*	*Lacinipolia lorea*
Malacosoma disstria	*Itame brunneata*	*Lithacodes fasciola*
Metarranthis amyrisaria	*Itame pustularia*	*Lithophane baileyi*
Metarranthis duaria	*Itame Sp.#1*	*Lithophane grotei*
Nadata gibbosa	*Korscheltellus gracilis*	*Lithophane hemina*
Nematocampa resistaria	*Lacinipolia lustralis*	*Lithophane innominata*
Odontosia elegans	*Lacinopolia lorea*	*Lithophane lepida*

Species present in 2002 and 2012	Species present in 2002 only	Species present in 2012 only
Oligocentria lignicolor	*Ledaea perditalis*	*Lithophane tepida*
Orthodes cynica	*Leucania pseudargyria*	*Lochmaeus manteo*
Orthodes detracta	*Lithacodia albidula*	*Lycia rachelae*
Palthis angulalis	*Lithacodia muscosula*	*Macaria bicolorata*
Pangrapta sp.	*Lomographa glomeraria*	*Macaria bisignata*
Panopoda rufimargo	*Lytrosis unitaria*	*Macaria granitata*
Panthea furcilla	*Macrochilo absorptalis*	*Macaria minorata*
Paonias excaecata	*Macrochilo hypocritalis*	*Macaria pinistrobata*
Peridea angulosa	*Melanolophia signataria*	*Macaria transitaria*
Phlogophora periculosa	*Metarranthis sp.1*	*Marathyssa inficita*
Phragmatobia assimilans	*Metaxaglaea inulta*	*Melanolophia canadaria*
Phyllodesma americana	*Morrisonia evicta*	*Metanema inotomaria*
Plagodis fervidaria	*Nephelodes minians*	*Metarranthis angularia group*
Plagodis serinaria	*Oreta rosea*	*Metarranthis near "browerii"*
Polia purpurissata	*Orthodes crenulata*	*Metarranthis sp. 2*
Probole alienaria	*Orthodes goodelli*	*Morrisonia confusa*
Probole nepiasaria	*Orthosia hibisci*	*Morrisonia latex*
Prochoerodes lineola (transversata)	*Orthosia revicta*	*Mythimna unipuncta*
Protoboarmia porcelaria	*Pangrapta decoralis*	*Nacophora quernarnia*
Protorthodes oviduca	*Paonias astylus*	*Nedra ramosula*
Proxenus miranda	*Peridea ferruginea*	*Nemoria bistriaria*
Raphia frater	*Pero hubneraria*	*Nemoria mimosaria*
Renia factiosalis	*Pero morrisonaria*	*Nepytia canosaria*
Renia flavipunctalis	*Plagodis phlogosaria*	*Nepytia pellucidaria*
Renia sobrialis	*Polia imbrifera*	*Noctua pronuba*
Schizura unicornis	*Polia nimbosa*	*Ochropleura implecta*
Scopula limboundata	*Pseudeva purpurigera*	*Oligia minuscula*
Spargaloma sexpunctata	*Pseudorthodes vecors*	*Orgyia definita*
Sphinx poecila	*Pyreferra hesperidago*	*Orgyia leucostigma*
Spilosoma congrua	*Pyrrharctia isabella*	*Orthonama obstipata*
Spilosoma virginica	*Renia aspergillus*	*Pachysphinx modesta*
Symmerista sp.	*Semiothisa aemulataria*	*Paonias myops*
Sympistis (Apharetra) dentata	*Semiothisa bicolorata*	*Parallelia bistriaris*
Tacparia atropunctata	*Semiothisa bisignata*	*Pasiphila rectangulata*
Tacparia detersata	*Semiothisa granitata*	*Petrophora subaequaria*
Tetracis cachexiata	*Semiothisa minorata*	*Phalaenostola eumelusalis*
Tetracis crocallata	*Semiothisa pinistrobata*	*Phalaenostola larentioides*
Tolype laricis	*Semiothisa transitaria*	*Phalaenostola metonalis*
Tolype velleda	*Semiothisa ulserata*	*Phigalia titea*

Species present in 2002 and 2012	Species present in 2002 only	Species present in 2012 only
Ulolonche modesta	*Smerinthus jamaicensis*	*Phlogophora isis*
Xanthotype sospeta	*Symmerista canicosta*	*Phyllodesma "ferruginea"*
Xestia elimata	*Syngrapha epigaea*	*Plagodis alcoolaria*
Xestia normanianus	*Syngrapha octoscripta*	*Plagodis pulveraria*
Xestia praevia	*Tortricida flexuosa*	*Probole amicaria*
Xestia youngii	*Xanthotype sospeta*	*Protodeltote albidula*
Zale aeruginosa	*Xestia badicollis*	*Protodeltote albidula*
Zale metatoides	*Xestia dolosa*	*Protodeltote muscosula*
Zale minerea	*Xestia smithii*	*Protolampra brunneicollis*
Zale obliqua		*Pseudeustrotia carneola*
Zanclognatha laevigata		*Pseudohermonassa bicarnea*
Zanclognatha martha		*Pyreferra citrombra*
Zanclognatha ochreipennis		*Schizura badia*
Zanclognatha protumnusalis		*Sideridis maryx*
		Spaelotis clandestina
		Speranza argillacearia
		Speranza brunneata
		Speranza pustularia
		Spilosoma dubia
		Spiramater lutra
		Syngrapha rectangula
		Ulolonche culea
		Virbia laeta
		Virbia opella
		Xanthorhoe sp.
		Xylena cineritia
		Xylena curvimacula
		Xylena thoracica
		Zale duplicata
		Zale helata
		Zale intenta
		Zale lunata
		Zale lunifera
		Zale submediana
		Zale unilineata
		Zanclognatha cruralis
		Zanclognatha gypsalis
		Zanclognatha marcidilinea
		Zanclognatha theralis group