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A phenotypic comparison of regional populations of *Hemileuca maia* (Drury, 1773) with designations of new subspecies (Bombycoidea, Saturniidae, Hemileucinae).

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ABSTRACT. Following refinement of the type locality of *Hemileuca maia* to the Long Island Pine Barrens of New York State by the author (Pavulaan, 2020), an evaluation of phenotypic characters of regional populations of *H. maia* is presented. The Long Island population is the nominotypical subspecies. Populations in southeastern coastal New England and offshore islands are presently considered nominotypical *maia*. However, several continental inland populations show evidence of subspecific variation. Four new subspecies are designated. Detailed phenotypic information of other interior regions is lacking.

Additional key words: Pitch Pine Barrens, Scrub Oak Plains, isolate, *Menyanthes trifoliata*.

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INTRODUCTION

The Buckmoths of North America are a bewildering blend of intergrading phenotypes that have been the subject of numerous studies (Ferguson, 1971; Tuskeset al., 1996; Rubinoff et al., 2017; Dupuis et al., 2018). Results of these studies are inconclusive over where to draw taxonomic limits. Michener (1952) proposed a subdivision of genus *Hemileuca* into four subgenera: *Hemileuca* (Walker, 1855), *Pseudohazis* (Grote & Robinson, 1866), *Euleucophaeus* (Packard, 1872) and *Argyrauges* (Grote, 1882). Nestled within subgenus *Hemileuca* is the *Hemileuca maia* complex, presently considered to be a closely-related group of species and unnamed populations of species *H. maia*. This group is characterized by variation in ground color (gray to black), bold median bands (white to yellow), and scale translucence. Described members include: *H. maia* (Drury, 1773), *H. grotei* (Grote & Robinson, 1868), *H. nevadensis* (Stretch, 1872), *H. juno* (Packard, 1872), *H. diana* (Packard, 1874), *H. lucina* (Henry Edwards, 1887), *H. artemis* (Packard, 1893), *H. peigleri* (Lemaire, 1981), and *H. slosseri* (Peigler & Stone, 1989). The present paper focuses on subspecific divisions within the species *H. maia*.

Most members of the *H. maia* complex feed on various species of *Quercus* sp. (Oaks), but several peripheral populations in the northern states specialize on non-*Quercus* hosts. Eggs are laid in lines encircling thin branches of the host or alternate substrates. Eggs then overwinter. Larvae emerge in spring and feed gregariously on the primary host until the last two instars, when they disperse seeking alternate, unrelated hosts to complete development. Pupation occurs in soil, leaf litter, or gravel

throughout the summer. Eclosion generally occurs immediately after the first frost in late September in northern latitudes, then progressively later with the advance of fall in the southern states. Emergence as late as December in Louisiana and February in Florida is not unusual. Some pupae do not eclose during the first year, delaying eclosion for two, three or more years. Delayed eclosion is likely a response to unpredictable weather trends (e.g. rainfall amount) and other environmental conditions.

Tuskes *et al.* (1996) comprehensively reviewed adaptations to local environments within the *H. maia* complex. These authors described varying degrees of ecologic and genetic differentiation. They pointed out "some populations within the *maia* complex defy neat categorization into species and subspecies". Rubinoff *et al.* (2017) suggested "most of the populations in the *H. maia* complex have been viewed as isolated relics surviving on the remaining "islands" of what were formerly more widespread suitable habitat" which now tend to be localized and fragmented. They found that isolated populations frequently gave rise to phenotypic variation in adults and larvae with some switching to non-*Quercus* hosts. They concluded these differences were still within conspecific level and there was little to no genetic difference among members of the complex. Branching topology of their genomic trees showed some members of the complex clustered in neat groups. For example, Florida, Louisiana and Bog Buckmoth populations each formed tight groupings in COI trees and concatenated mt-DNA and nuclear DNA maximum likelihood trees. Their elongation factor 1-alpha (EF1a) and carbamoyl phosphate synthetase (cpsi) maximum likelihood trees showed New York samples of the Bog Buckmoth clustering together, separate from the rest of the *H. maia* complex.

A subsequent analysis by Dupuis *et al.* (2018), to a large degree, corroborated the findings of the Rubinoff *et al.* (2017) study. These authors expressed: "Local adaptation can be a fundamental component of speciation, but its dynamics in relation to gene flow are not necessarily straightforward". The charismatic, day-flying moths of the *Hemileuca maia* species complex "are such taxa, as they are geographically widespread, exhibit considerable ecological and morphological variability and host and habitat specificity, but lack genetic differentiation across their range." They noted that previous studies based on sequences of one mitochondrial and three nuclear genes failed to identify genetic divergence even between taxa treated at species rank within the complex. To assess population structure and genomic relationships of the *H. maia* complex, their study employed genome-wide single nucleotide polymorphisms in a combination of population genomic and phylogenomic approaches. They uncovered fine-scale population divisions among members of the complex. A maximum-likelihood consensus tree and a distance-based phylogenetic network showed distinct clustering of various groups, including some named species within the complex and other groups not currently recognized at any level below species *H. maia*. Of note, their Floridian and Louisiana populations clustered distinctly and separately from other members of the complex. They also found the Bog Buckmoth samples from New York clustered separately from the rest of the complex, primarily due to geographic isolation, and that this "definitely satisfy[ies] the criteria of genetic differentiation." The authors suggested that interpretation of their results would support treating any cluster within the *maia* complex as a distinct species or subspecies.

The status of *proserpina* (Fabricius, 1775) is uncertain. The holotype and co-type in the Hunterian Museum (University of Glasgow) do not reliably fit the nominotypical phenotype or any of the inland phenotypes (Pavulaan, 2020). The original description merely gives "America". It is not possible to reliably determine where the specimens originated (Jeanne Robinson, pers. corr.) or whether they represent any population of *maia* or of a different species. Currently, there are two possible treatments of *proserpina*. One is to treat *proserpina* as a junior synonym of *H. maia maia*, and the other is to treat it as *nomen incognitum* (my preference). Lastly, the one specimen residing in the Macleay Museum (University of Sydney), often thought to be the model for Drury's *maia*, does not match the drawing in the original description (Pavulaan, 2020).

PHENOTYPIC FINDINGS & TAXONOMIC DECISIONS

Recent studies have demonstrated that several ecotypes in the *H. maia* complex display low levels of genetic divergence (Rubinoff *et al.*, 2017; Dupuis *et al.*, 2018), while maintaining their ecological differences in sympatry. My analysis of phenotypic traits of members of the complex reveals a number of stable phenotypes, which I propose to be subspecific. Some of these subspecies may eventually warrant elevation to species. Hopefully this paper will help to further conservation efforts at the federal level.

The Bog Buckbean population of northern New York State, utilizing *Menyanthes trifoliata* as larval host, has unique status and is recognized as endangered in that State. However, it is unnamed and lacks formal description. To complicate matters, a large, complex zone of integration occurs in the Great Lakes region from Ohio to Minnesota that is still unresolved and under study as of this writing. Complicating any resolution are a broad variety of full and intermediate phenotypes encompassing *maia*, *nevadensis*, *lucina*, and the undescribed Bogbean Buckmoths, all of which reside in a complex patchwork of habitats, mainly wetland/bog types. Scholtens & Wagner (1994) studied and compared transitional phenotypes in Michigan to *maia*, *nevadensis* and *lucina* and concluded that the Michigan populations are a single variable species, spanning the entire range of phenotypes, hosts and habitats (mainly wetlands) of the three named species, thus calling to question the taxonomic distinctness of the three *Hemileuca* species. Recorded hosts (both primary and secondary) in the Great Lakes complex include: *Betula nana* (Dwarf Birch), *B. pumila* (Bog Birch), *Dasiphora* (= *Potentilla*) *fruticosa* (Shrubby Cinquifol), *Menyanthes trifoliata* (Buckbean), *Populus deltoides* (Eastern Cottonwood), *P. tremuloides* (Quaking Aspen), *Quercus velutina* (Black Oak), *Salix bebbiana* (Bebbø Willow), *S. candida* (Sageleaf Willow), *S. discolor* (Pussy Willow), *S. exigua* (Narrowleaf Willow), *S. humilis* (Prairie Willow), *S. pedicellaris* (Bog Willow), *S. petiolaris* (Meadow Willow), *S. serissima* (Autumn Willow), *Spiraea alba* (White Meadowsweet) and *Vaccinium macrocarpon* (Cranberry). Metzler & Lucas (1990) successfully reared larvae from northern Ohio on *S. nigra* (Black Willow), but larvae reared on Pin Oak did not complete development and died. Gratton (2006) documents use of *Lythrum salicaria* (Purple Loosestrife) in Wisconsin.

Tuskes *et al.* (1996) consider Great Lakes transitional populations reflect incomplete reproductive isolation between *maia* and *nevadensis* with introgression occurring over a broad area. This view suggests *nevadensis* may be better treated as a subspecies of *maia*. It also suggests that the Great Lakes complex may be viewed as three species if only adult morphology is considered: dark southernmost populations (southern Ohio) being *maia*; central and western Great Lakes populations being *nevadensis*; and the northern translucent populations being *lucina*. An outlying wetland-dwelling group of populations in northwestern New Jersey feeds on *B. pumila* (Bog Birch) and *Dasiphora* (= *Potentilla*) *fruticosa* (Shrubby Cinquefoil); this group may represent a *nevadensis* isolate.

Scholtens & Wagner (1997) studied possible north-south clinal variation in a line running through Michigan and Ohio. They concluded the Great Lakes group of populations comprised a single species in which small, washed-out *H. lucina*-like forms occupied wetlands in the upper Michigan peninsula and larger, heavily-marked *maia*-like forms occurred the upland wooded area in southern Ohio. Two intermediate study sites in the lower peninsula of Michigan were attributed to *nevadensis*-like phenotypes. In an earlier significant study, Metzler & Lucas (1990) noted ecological differences between southern and northern Ohio populations of *H. maia*. The northern Ohio population resided in oak barrens and utilized *Salix* sp. (Willow) as larval hosts, while the southern Ohio population inhabited mature oak forests, utilizing on *Quercus* sp. (oaks). They associated the northern Ohio population with the upper Midwest zone of intergradation between *H. maia* and *H. nevadensis*. They suggested the northern and southern Ohio populations may not be conspecific. Given the considerable distance between these populations, one might consider them as separate taxa with the southern ones being more aligned with true *H. maia*.

The present paper focuses on regional phenotypic variation, describing phenotypic characters and providing taxonomic names. I have not relied heavily on life history studies. The hope is this paper will lay the groundwork for continued studies of subspecific taxa and promote conservation efforts such as in the case of Bogbean Buckmoth. Specimens used in this study are mainly in the author's personal collection and in the McGuire Center for Lepidoptera and Biodiversity. Access to specimens in other institutional collections was generally unproductive; specimen numbers were often insufficiently small or too disorganized.

SUBSPECIES

Hemileuca maia maia Drury (1773) Coastal Barrens Buckmoth

The nominotypical taxon (Figs. 1, 2 & 3) was described from New York and determined to most likely originate in the Pitch Pine Barrens region of eastern Long Island. Common name Coastal Barrens Buckmoth (for *Hemileuca maia* ssp. 5) per New York Natural Heritage Program (2020) and NatureServe Explorer (2020) which reflects its limited distribution in coastal Pitch Pine Barrens habitat in southeastern New England and on Long Island, N.Y.

Type locality: Neotype male: Oct. 21, 2017, Long Island Avenue, north of Deer Park train station, Edgewood, Suffolk County, New York, leg. H. Pavulaan (Pavulaan, 2020). Neotype is deposited in the McGuire Center for Lepidoptera & Biodiversity, Gainesville, FL. [5 additional male and 5 female specimens (Westhampton, Suffolk Co., N. Y.) analyzed in this study are deposited in the McGuire Center for Lepidoptera & Biodiversity, Gainesville, FL.; additional specimens remain in the author's collection.]

Range: Confined to eastern Long Island, New York (Fig. 16). Most frequently observed in the Westhampton Dwarf Pine Plains Preserve and in the Edgewood Oak Brush Plains Preserve. Additional populations are in southeastern New England, Cape Cod, Martha's Vineyard and Nantucket, which are of the same phenotype, are often referred to as the same taxon.

Habitat: Primarily pitch pine barrens, scrub oak plains and maritime shrublands or sandplains where the hostplant *Quercus ilicifolia* abounds. Selfridge *et al.* (2007) state that *H. maia* is restricted to remnant *Pinus rigida* (Pitch Pine)/*Quercus ilicifolia* (Scrub Oak) habitat in the northeastern United States. This habitat is becoming more fragmented and threatened by multiple factors, thus bringing conservation attention to the nominotypical subspecies. Fire suppression in the fire-dependent habitat is a threat and requires considerable management considerations.

Flight period: NY (Long Island): Oct. 4 to 28. Southeastern New England: Sept. 27 to Oct. 25.

Hosts: *Quercus ilicifolia* (Scrub Oak) on Long Island, N.Y., Plymouth County, MA. and Martha's Vineyard, MA. Also on *Quercus prinoides* (Dwarf Chinquapin Oak). Haggerty (2006) reared larvae on *Q. alba* (White Oak) and *Q. stellata* (Post Oak). Larvae are known to wander to additional, non-*Quercus*, hosts in the later instars, such as *Salix* (Willow sp.) and *Populus* (Aspen sp.) (NatureServe Explorer, 2020). In Edgewood, N.Y., I have found them frequently on *Prunus serotina* (Black Cherry) in July. In West Greenwich, R.I., I once found a clutch of first instar larvae on *P. serotina* but could not locate an egg ring to confirm oviposition on that host.

Description: Male FW length 21-28 mm., female FW length 28-30 mm. The smallest of all *maia* populations. Forewings slightly more rounded than other subspecies as described. Wings generally with a variable dark gray appearance, darker toward the outer margin, and highly translucent (thinly-scaled)

[text can be read through the wings when placed against the wings]. Median bands primarily white with a bare hint of yellow tint in some specimens. The forewing band directly intersects the discal streak which usually breaks the band into two segments in most examined specimens. The posterior portion of the median band may be partially faded in many individuals. Females are more uniformly gray than males, and have a distinct black wing margin. The Long Island, N.Y. population has larvae characterized by having a distinct yellow lateral line.

***Hemileuca maia sandra* Pavulaan, 2020 – New Subspecies**
Eastern Buckmoth

ZooBank registration: [urn:lsid:zoobank.org:act:9EDBE62F-2415-4EC0-BE24-6E2C4BB20712](https://zoobank.org/urn:lsid:zoobank.org:act:9EDBE62F-2415-4EC0-BE24-6E2C4BB20712)

This taxon (Figs. 3, 4 & 12) represents interior continental (inland) populations. Insufficient published or available collected material makes it difficult to ascertain the full extent of its distribution. Common name Eastern Buckmoth per NatureServe Explorer (2020) reflects distribution throughout the interior eastern United States. The New York Natural Heritage Program (2020) refers to this as Inland Barrens Buckmoth and considers this the nominal subspecies because adults are determined to fall within the range of variation of southern populations. The subspecies is named in honor of my older daughter, who provides invaluable field assistance in all my lepidoptera studies.

Type locality: Holotype (male): Oct. 15, 2019, ex-larva, Chatsworth, Woodland Township, Burlington Co., New Jersey, leg. I. Osipov. 24 paratypes (20 males, 3 females) from same location. Holotype, allotype (female) and 8 paratype specimens (6 males, 2 females, from TL) are deposited in the McGuire Center for Lepidoptera & Biodiversity, Gainesville, FL.; the remainder in the author's collection. A series of 32 southern Indiana specimens (males) were analyzed for morphological comparison and matched the range of variation in the New Jersey series [10 specimens from Mishawaka and West Lafayette, IN. are deposited in the McGuire Center for Lepidoptera & Biodiversity, Gainesville, FL.; the remainder in the author's collection.]

Range: Known to be common in parts of the southern New Jersey Pine Barrens region. N.J. phenotype matches specimens from Virginia, Georgia, southeastern Ohio, southern Indiana, northern Alabama and northern Mississippi. This subspecies likely ranges west to Oklahoma (Fig. 16). It is likely that inland populations in New York, from the Shawangunk Mountains to Albany are represented by this taxon.

Habitat: In New Jersey and inland New York, primarily Pitch Pine/Scrub Oak barrens but also in dry, mixed forest dominated by *Quercus*. In northern Virginia, mixed deciduous forest with presence of different species of *Quercus*, but apparently *Q. ilicifolia* is absent. Reportedly associated with pine barrens and sand barrens in other northern states: NY (inland sites), GA, OH, PA, VA, WV. In the Appalachian Mountains, the habitat is mixed, dry *Quercus*-dominated woodland and granite balds. In the southeastern coastal plain, the habitat is described as sandhills. Fragmentation and fire suppression of Pitch Pine/Scrub Oak habitat in northern portions of the species range are a threat to the habitat.

Flight period: Southern IN: Sep. 27 – Nov. 2. NY (populations around Albany, believed to be this subspecies): Sept. 25 – Oct. 5. NJ: Sep. 27 – Nov. 1. PA: Sept. 25 – Nov. 1. MD: Oct. 25 - Nov. 12. VA: Oct. 17 - Nov. 12. WV: Oct. 8 – Oct. 19. NC: Nov. 4 – Dec. 26. SC: Jan. 1. Southeastern OH: Oct. 18 – Nov. 4. KY: Oct. 3 – Nov. 14. TN: Nov. 14 – Nov. 30. GA: Nov. 4 - Dec. 2. Northern AL: Nov. 7 – Dec. 3. Northern MS: Dec. 7.

Hosts: *Quercus alba* (White Oak), *Q. bicolor* (Swamp White Oak), *Q. falcata* (Southern Red Oak), *Q. hemisphaerica* (Darlington Oak), *Q. ilicifolia* (Scrub Oak), *Q. laevis* (Turkey Oak), *Q. marilandica* (Blackjack Oak), *Q. montana* (Chestnut Oak), *Q. muehlenbergii* (Chinquapin Oak), *Q. prinoides* (Dwarf Chinquapin Oak), *Q. rubra* (Red Oak), *Q. stellata* (Post Oak) and *Q. velutina* (Black Oak). Larvae are

known to wander to additional, non-*Quercus*, hosts in the later instars, such as *Prunus cerasus* (Sour Cherry). In Clifton, VA found on *Rosa multiflora* (Multiflora Rose) in July; in KY and MD, found on cultivated *Fragaria* (Strawberry sp.). In laboratory experiments, Smith (1974) successfully reared larvae from eggs collected on *Q. ilicifolia* in Colonie, N.Y. on alternate hosts *Q. chrysolepis* (Canyon Live Oak) and *Salix hindsiana* (Sandbar Willow). Leeuw (1974) reported rearing them on *Salix babylonica* (Weeping Willow). Many other hosts are listed in Tietz (1952, 1972) and Heppner (2003), but they do not specify what states or regions these records are from.

Description: Male FW length 24-31 mm., female FW length 29-36 mm. Larger than ssp. *maia*. Wings black, opaque [text cannot be read through the wings when placed against the wings]. Median bands white but with slightly more yellow tint than in ssp. *maia*. Forewing median band intersects the discal streak which breaks the band into two segments in less than half of individuals, but in most specimens the median band is located exterior to the discal streak, thus maintaining a continuous band. Indiana and Virginia specimens tend to have the continuous median band (inner edge of the median band intersects the discal streak) and the bands are clearly cream-colored. Specimens from northern Alabama and northern Mississippi are deep black, matching northeastern populations, and do not possess the brownish-black color of the nearby Gulf Coast population.

***Hemileuca maia warreni* Pavulaan, 2020 – New Subspecies
Florida Buckmoth**

ZooBank registration: [urn:lsid:zoobank.org:act:281A5C71-A821-47B4-BDA6-CFDBF4A5E251](https://zoobank.org/act:281A5C71-A821-47B4-BDA6-CFDBF4A5E251)

This taxon (Figs. 5, 6 & 13) represents peninsular Florida populations and was only recently thought to be a distinct subspecies. The subspecies is named in honor of Dr. Andrew D. Warren, Senior Collections Manager, McGuire Center for Lepidoptera & Biodiversity, who provided considerable information regarding Florida populations.

Type locality: Holotype (male): Jan. 24, 1984. Deltona, Volusia Co., Florida, leg. L. C. Dow. 50 paratypes from Alachua (Archer, Gainesville), Clay (Camp Blanding), Duval (Jacksonville), Putnam (Katherine B. Ordway Preserve), Seminole, Taylor (Steinhatchee) and Volusia (Deltona, Cassadaga) Counties. [Holotype, allotype (female) and all paratype specimens deposited in the McGuire Center for Lepidoptera & Biodiversity, Gainesville, FL.]

Range: Primarily peninsular Florida (Fig. 16): Duval to Palm Beach counties along the east coast, west to Taylor County.

Habitat: Pine-Oak scrub.

Flight period: Dec. 25 - Feb. 4 (peak flight in Jan.).

Hosts: *Quercus laevis* (Turkey Oak) reported from northern parts of Florida (e.g. western Marion, Alachua, Clay counties), *Quercus myrtifolia* (Myrtle Oak) reported from southeastern portions (e.g. Marion Co. (Ocala National Forest), Palm Beach Co.).

Description: Male FW length 23-28 mm., female FW length 27-35 mm. [Holotype (male) FW length is 23.7 mm.] Smaller than the other subspecies except ssp. *maia*. Forewings have a slightly more elongated appearance than other subspecies. In many individuals, the forewings are decidedly more pointed than other subspecies. Wings black to dark brownish-black, solid opaque. Median bands cream-white with a tendency for the forewing bands to be quite narrow in most specimens. Some individuals have the posterior portion of the forewing median band faded or reduced to small white patches. In some, the posterior portion of the band is absent and the anterior portion reduced to a small white triangle adjacent

to the discal streak, leaving the forewing almost all black. The forewing median band is positioned exterior to the discal streak in most specimens, thus maintaining a continuous band (inner edge of the median band intersects the discal streak). The discal streak is enlarged in most specimens, more so than in other subspecies.

***Hemileuca maia orleans* Pavulaan, 2020 – New Subspecies**
Gulf Coast Buckmoth

ZooBank registration: [urn:lsid:zoobank.org:act:EB65773F-B937-45F5-A58D-9C30478A8281](https://zoobank.org/urn:lsid:zoobank.org:act:EB65773F-B937-45F5-A58D-9C30478A8281)

This taxon (Figs. 7, 8 & 13) represents Louisiana populations, mainly around New Orleans and the Mississippi River delta. This is a unique phenotype with a variable brownish-black ground color.

Type locality: Holotype (male): Dec. 11, 2003. 4.2 mi. NE of Abita Springs, sec. 24.T6.SR12E, St. Tammany Parish, Louisiana, leg. V. Brou. 45 paratypes (males) from St. Tammany Parish, 1 paratype (female) from Ascension Parish. [Holotype, allotype (female) and 16 male paratype specimens deposited in the McGuire Center for Lepidoptera & Biodiversity, Gainesville, FL., the remainder in the author's collection.]

Range: Primarily southern portions of Louisiana around New Orleans and adjacent portions of Mississippi (Fig. 16). Range into eastern Texas requires morphological examination of specimens, but all viewed images of eastern Texas *maia* are black. Some Texas records may be confused with *H. peigleri* but adult morphology is very different.

Habitat: Known to be an urban pest on host trees in New Orleans and Baton Rouge, experiencing heavy infestations, leading to mass defoliation of city trees (Martinat *et al.*, 1997).

Flight period: LA (New Orleans region): Nov. 15 ó Jan. 9. Eastern TX records are: Dec. 4 ó 17 but may not be ssp. *orleans*.

Hosts: *Quercus virginiana* (Live Oak). Martinat *et al.* (1997) conducted host suitability studies to determine alternate host suitability. They report that late-instar larvae have been found on almost any type of foliage but it was unknown whether they can complete development on non-*Quercus* species. In their study, 1st through 4th instar larvae were raised on *Quercus nigra* (Water Oak), then switched to various alternate hosts in the 5th instar, while others were successfully reared to pupation on *Q. nigra*. Suitable alternate hosts included: *Q. velutina* (Black Oak), and *Prunus serotina* (Black Cherry). Lower survival rates occurred on *Lagerstroemia indica* (Crape Myrtle), *Liquidambar styraciflua* (Sweetgum), and *Salix nigra* (Black Willow).

Description: Male FW length 25-32 mm., female FW length 35 mm. The largest of all *maia* populations. Wings decidedly brownish-black, solid opaque. The brownish tint is variable. While some individuals are black, a small percentage are clearly brown. Median bands are cream-colored. The forewing median band is located exterior to the discal streak in most specimens, thus maintaining a continuous band (inner edge of the median band intersects the discal streak). Some individuals have the posterior portion of the forewing median band faded or reduced to small white patches

***Hemileuca maia menyanthevora* Pavulaan, 2020 – New Subspecies**
Bogbean Buckmoth

ZooBank registration: [urn:lsid:zoobank.org:act:B7D0030D-1C45-4733-A1CE-79B6515AC4E1](https://zoobank.org/urn:lsid:zoobank.org:act:B7D0030D-1C45-4733-A1CE-79B6515AC4E1)

This taxon (Figs. 9, 10 & 15) represents a small grouping of wetland-associated populations in northern New York State, around Ottawa, Ontario and in southeastern Wisconsin. Rubinoff & Sperling (2004) found no marked genetic divergence from *H. maia* populations nearby in New York State, lending to its status as a recent postglacial taxon. Long considered to be a unique ecological form of *H. maia*, adapted to use of a particular hostplant (*Menyanthes trifoliata*), but the lack of an adequate description and naming hinders conservation efforts. In the absence of formal description, and to further conservation efforts in New York and Ontario, the Evolutionary Significant Unit (ESU) concept was employed. Fraser & Bernatchez (2001) define the ESU concept as: “Segments of species whose divergence can be measured or evaluated by putting differential emphasis on the role of evolutionary forces at varied temporal scales [within a species]”.

The present paper resolves at least one issue, that of formal description and naming. One of the most difficult hindrances to the study of this taxon is locating any specimens able to serve as types. Only the McGuire Center for Lepidoptera and Biodiversity had institutional specimens, which serve as the holotype and paratypes. Ross Layberry provided information on specimens collected in Ontario in 1984 (pre-act). Additional analysis of New York, Wisconsin, and Ontario phenotypes came from many internet resources and published works (Handfield, 2011). It is not clear whether the New York, Wisconsin and Ontario populations all represent the same exact taxon. COSEWIC (2009) states that genetic exchange between U.S. and Canadian populations does not occur due to distance between population groupings. Further research is warranted. This may actually represent a full species. The Bogbean Buckmoth was granted state protection as threatened in 1999 in New York State, though it has not been formally described or named. It is also protected as endangered in Canada as of 2009, and also in Ontario under the Endangered Species Act, 2007.

Common name Bogbean Buckmoth (*Hemileuca* sp. 1) per New York Natural Heritage Program (2020) and NatureServe Explorer (2020).

Type locality: Holotype (male): Sep. 22, 1985. Brennan Beach Camp, Pulaski, Oswego Co., N.Y. Leg. P. Savage. Allotype (female), 9 male paratypes and 4 female paratypes, same data as holotype. All specimens deposited in the McGuire Center for Lepidoptera & Biodiversity, Gainesville, FL.

Range: Confined to six known fens in Oswego County, N.Y. and in four fens near Ottawa, Ontario (Fig. 16). Kruse (1998) provides detailed information on two sites in Marquette and Ozaukee Counties in Wisconsin.

Habitat: Described as minerotropic [stream or spring-fed] fens at the east edge of Lake Ontario and open graminoid fens (New York Natural Heritage Program, 2020); open, low-shrub fens (Government of Canada Species Profile, 2020), and open, calcareous, graminoid and low shrub fens in Ontario (COSEWIC, 2009). COSEWIC (2009) gives the habitat description of the two groupings of New York as: (1) a complex of several discrete, rich, shrub-dominated fen openings behind barrier dunes on Lake Ontario at one site, and (2) an inland complex of edge-dominated floating peat mats on lake edges. This subspecies (or species) is extremely vulnerable to extirpation in New York, because its habitat is rapidly degrading and is significantly threatened (New York Natural Heritage Program, 2020). Habitat threats include succession by invasive *Typha angustifolia* (Narrowleaf Cattail), *Phragmites australis* (Common Reed), *Lythrum salicaria* (Purple Loosestrife), and *Frangula alnus* (Glossy Buckthorn); hydrologic alteration resulting in lowering of the Lake Ontario water level; nutrient pollution run-off from surrounding areas; surface flooding at two fen sites; and parasitoid wasps and other predators. Pesticide

application in the habitat could be disastrous. In Ontario, there are nearly identical threats to the habitat (COSEWIC, 2009).

Flight period: Sept. 9 to Oct. 12.

Hosts: A rather complicated series of choices (COSEWIC, 2009; Government of Canada Species Profile, 2020) across a broad range of suitable hostplants. In Ontario, females were observed depositing egg rings mostly on *Myrica gale* (Sweet Gale), *Betula pumila* (Bog Birch), but also other low shrubs such as *Spiraea alba* (Narrow-leaved Meadowsweet), *Salix petiolaris* (Slender Willow), *Salix bebbiana* (Bebbø Willow) and odd choices such as *Phragmites australis* (Common Reed), *Muhlenbergia glomerata* (Marsh Muhly), *Solidago* (Goldenrod sp.), *Aster* (Aster sp.), and *Scirpus* (Rush sp.) [The primary host *Menyanthes trifoliata* has already dried by the time females are looking to oviposit]. Many of these plants are unsuitable for larval development. Newly-hatched larvae in the following year seek out *Vaccinium macrocarpon* (Bog Cranberry), later switching to *M. trifoliata* as it leafs out. Late instars disperse widely, being found on *B. pumila*, *S. petiolaris*, *S. bebbiana*, *Salix pedicellaris* (Bog Willow), and *Spiraea alba* (Narrow-leaved Meadowsweet).

In a New York study (Pryor, 1998), similar observations were obtained of ovipositions on *M. gale*, *Acer rubrum* (Red Maple), *Woodwardia* (= *Anchistea*) *virginica* (Virginia Chain Fern), *Alnus incana rugosa* (Speckled Alder), *Carex* (Sedge sp.), *Chamaedaphne calyculata* (Leatherleaf), *Salix pedicellaris* (Bog Willow), *S. alba*, and *Cornus sericea* (= *stolonifera*) (Red Osier Dogwood). Likewise, many of these plants are unsuitable for larval development. Larvae have been observed leaving unsuitable plants and seeking out *V. macrocarpon* and later switching to *M. trifoliata* as it leafs out. Larvae were further found throughout summer feeding on: *A. incana rugosa*, *Aronia melanocarpa* (Black Chokeberry), *Carex* (Sedge sp.), *C. calyculata*, *Ilex verticillata* (Common Winterberry), *M. trifoliata*, *Quercus* (Oak sp.), *S. pedicellaris*, *S. alba*, and *V. macrocarpon*. [The name Buckbean Buckmoth might thus be a misnomer.]

Description: FW length: males 22-32 mm; females 26-36 mm. [Holotype (male) FW length is 27.6 mm.] Despite published claims, this subspecies is very distinct and nearly identical to *H. lucina*. Larger than ssp. *maia*. Wings light gray and highly translucent, with the cream-tinted median bands nearly transparent [text can easily be read through the wings when placed against the wings]. The median bands on both sets of wings are much wider than in all other *maia* subspecies, generally completely enclosing the forewing median discal streak and covering about 1/3 of the interior of the wings. The basal third of the forewings are darker than the outer third. Female wings are not as broad as the other *maia* subspecies, the wings are more rounded and possess a dark gray wing margin on both sets of wings. The median band pattern in females is remarkably similar to *H. nevadensis* females.

This subspecies is the most unique of all the *maia*-complex populations and likely represents a different species-level taxon. It appears to be nearly identical in morphology to *H. lucina*. Handfield (2011) describes it as *Hemileuca* sp. near *lucina* due to great similarity to *H. lucina*. Legge *et al.* (1996) suggest this taxon is an evolutionarily significant unit, possibly a separate species. Crandall *et al.* (2000) consider this an evolutionarily significant unit (ESU), based on ecological and genetic data, and further suggest that these are more relevant for conservation efforts. They consider the evolutionary heritage of ESUs based on ecology will better foster conservation management. Buckner *et al.* (2014) state that Bog Buckmoth populations are not consistently distinguishable from other *H. maia* populations on the basis of any diagnostic set of color or other morphological characters. This paper presents a different conclusion.



Fig. 1. *Hemileuca maia maia* Drury (1773). Neotype. Oct. 21, 2017, Edgewood, Long Island, N. Y. Leg. H. Pavulaan Male. Dorsal view.



Fig. 2. *Hemileuca maia maia* Drury (1773). Neotype (same specimen), ventral view.



Fig. 3. *Hemileuca maia sandra* Pavulaan (2020). Holotype. Chatsworth, Woodland Township, Burlington Co., N.J., leg. I. Osipov.



Fig. 4. *Hemileuca maia sandra* Pavulaan (2020). Holotype (same specimen), ventral view.



Fig. 5. *Hemileuca maia warreni* Pavulaan, 2020. Holotype. Jan. 24, 1984. Deltona, Volusia Co., FL. Leg. L. C. Dow. Male. Dorsal view.



Fig. 6. *Hemileuca maia warreni* Pavulaan, 2020. Holotype (same specimen), ventral view.



Fig. 7. *Hemileuca maia orleans* Pavulaan, 2020. Holotype. Dec. 11, 2003. 4.2 mi. NE of Abita Springs, sec. 24.T6.SR12E, St. Tammany Parish, LA., leg. V. Brou. Male. Dorsal view.



Fig. 8. *Hemileuca maia orleans* Pavulaan, 2020. Holotype (same specimen), ventral view.



Fig. 9. *Hemileuca maia menyanthevora* Pavulaan, 2020. Holotype. Sep. 22, 1985. Brennan Beach Camp, Pulaski, Oswego Co., N.Y. Leg. P. Savage. Male. Dorsal view.



Fig. 10. *Hemileuca maia menyanthevora* Pavulaan, 2020. Holotype (same specimen), ventral view.



Fig. 11. *Hemileuca maia maia* Drury (1773). Female. Westhampton, N.Y. Ex-larva, em: Oct. 4, 2017. Leg. H. Pavulaan. Dorsal view.



Fig. 12. *Hemileuca maia sandra* Pavulaan, 2020. Allotype female. Chatsworth, Woodland Township, Burlington Co., N.J. Ex-larva, em: Sep. 28, 2017. Leg. I. Osipov. Dorsal view.



Fig. 13. *Hemileuca maia warreni* Pavulaan, 2020. Allotype female. Jan. 26, 1985. Deltona, Volusia Co., Florida. Leg. L. C. Dow. Dorsal view.



Fig. 14. *Hemileuca maia orleans* Pavulaan, 2020. Allotype female.
Dec. 10, 1998. Ascension Parish, LA. Dorsal view.



Fig. 15. *Hemileuca maia menyanthevora* Pavulaan, 2020. Allotype female.
Sep. 22, 1985. Brennan Beach Camp, Pulaski, Oswego Co., N.Y. Leg.
P. Savage. Dorsal view.

SUBSPECIES RANGE MAP

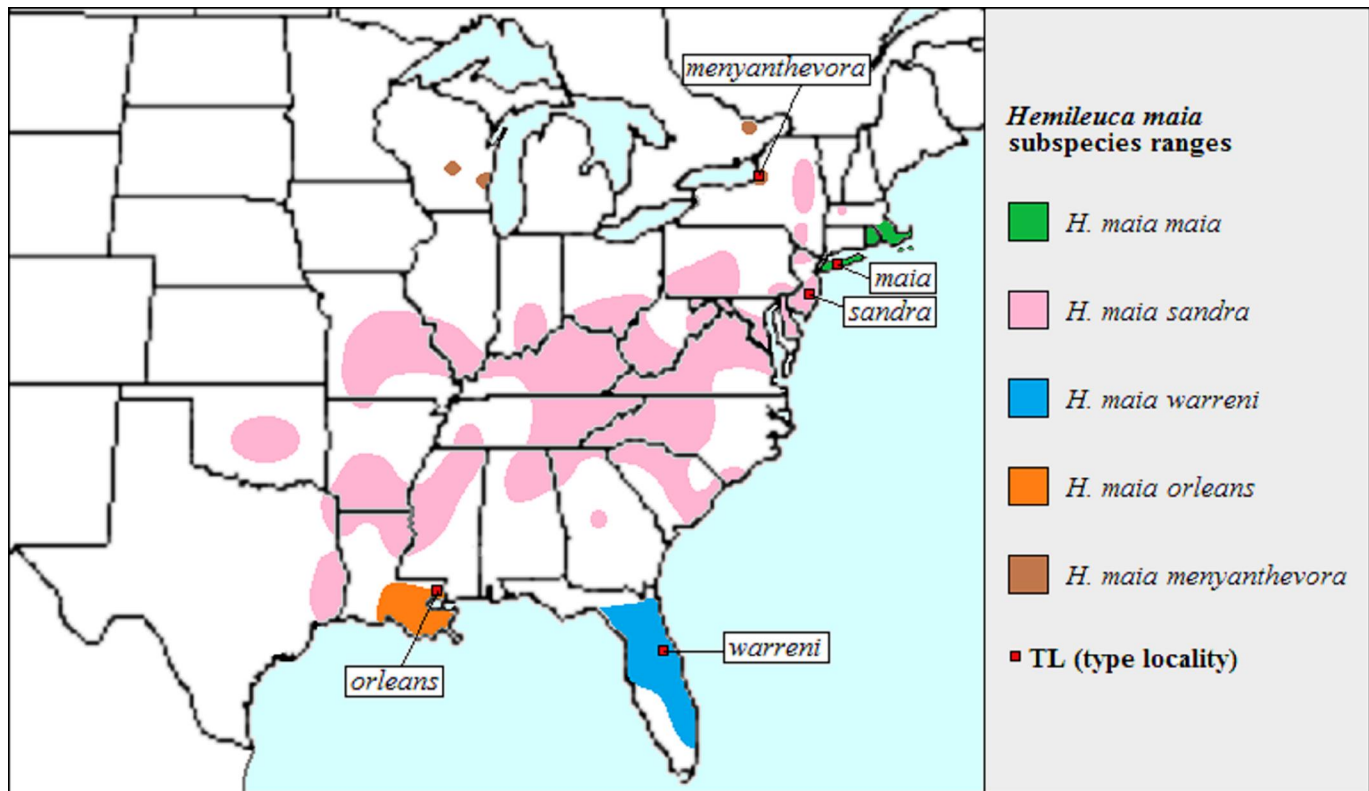


Fig. 16. Documented range of *Hemileuca maia* Drury (1773) and subspecies.

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ADDENDUM

While this paper was in review, an additional study was published (Tuttle *et al.*, 2020) that discussed the intrusion of a Xerothermic Period öprairie peninsulaö (Iftner *et al.*, 1992) across the upper Midwest and into Ohio. This broad prairie region presented a post-glacial barrier to the movement of many organisms between the glaciated Great Lakes region to the north and unglaciated regions south of the prairie. In Ohio, this is well-reflected by the presence of the Great Lakes Complex of *Hemileuca* populations north of the prairie peninsula utilizing *Salix* larval hosts and *Hemileuca maia* populations south of the prairie peninsula utilizing *Quercus* larval hosts. This post-glacial arrangement is maintained to the present day.

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