Conservation Matters: Contributions from the Conservation Committee

Moth decline in the Northeastern United States

David L. Wagner

Ecology and Evolutionary Biology, University of Connecticut, Storrs, CT 06268 **david.wagner@uconn.edu**

The matter of moth decline in the Northeast and southern Canada, particularly of larger moths, has been of concern for a half century (Muller 1968-1979, Hessel 1976, Schweitzer 1988, Goldstein 2010). Below I offer an assessment, based on my 23 years in New England. Mine is a prospective piece meant to raise the issue of moth decline to a larger audience—it is a call for study, a research agenda—offered in the absence of the quantitative data needed to make rigorous species-by-species status assessments. As a caveat to what I outline below, I should add that local, regional, and continental biota changes are the norm and that all animal and plant distributions change through time. Ranges and abundances may, in fact, be inherently much more dynamic than is generally understood. At issue here, is not change, but the rate and nature of changes.

Lepidoptera and other herbivores are under considerable evolutionary pressures from below and above, fated to be in never-ending battles with their hostplants (the bottom-up forces) and natural enemies (the top-down forces). Parasitoids, and no doubt birds, are particularly relevant to the persistence of any lepidopteran population. Lepidoptera (and other fecund taxa) live on a knife's edge: in each clutch of eggs only a single pair need survive to replace the previous generation: greater than 95% mortality is the norm, and in taxa with more than 200 eggs mortality rates would be expected to approach or even exceed 99%. Even modest changes in climate, local ecology, natural enemy complexes, etc. could doom a population's persistence.

Connecticut's moth fauna may rank as the best known in North America, given the state's small size, homogeneous landscape, and density of sampling. Sydney Hessel, Alexander Barrett Klots, Herman Wilhelm, Ben Williams, and Charles Remington were long-term resident moth collectors; additional collectors of note include Douglas Ferguson and Dale Schweitzer, who held positions at Yale University. I have collected micro and macrolepidoptera since my arrival in 1988. Perhaps more than any other, Connecticut is a good state by which to assess the "health" or status of the moth and butterfly fauna of a small region (state), even in the absence of quantitative, long-term data.

The most general but least documented observation is that numbers, especially those of larger moths, seem to be diminishing. This conclusion is echoed by virtually all who have run lights in their yards for more than a decade: Tony Roberts in Maine; Warren Kiel in New Hampshire; Mark Mello, Ed Peters, and Darryl Willis in Massachusetts; Sam Adams and Tim McCabe in New York; Don Lafontaine in Ottawa; and Ben Williams and myself in Connecticut.

Hickory horned devil (*Citheronia regalis*). Members of the genus *Citheronia* were among the first moths to disappear from New England. The last *C. regalis* record for the region was Syd Hessels's 1956 collection from Washington, CT (Ferguson, 1971).

A phenomenon upon which there is broad agreement is the collapse of the region's saturniid and sphingid faunas with most species seemingly less common than decades before. In my state of Connecticut, we had 15 resident Saturniidae (including one introduced species): four of these have been extirpated and no less than four others are in marked decline (Table 1). Just in the past decade, many former locales for the io (*Automeris io*) have stopped supporting this moth. The late Robert Muller (in litt.) wrote to me of the days when he was a boy growing up in southeastern Connecticut (in the 1930s and early 1940s) when he and his father used to go cocoon collecting in the winter and would carry a shopping bag to hold all the promethea (*Callosamia promethea*) and cecropia (*Hyalophora cecropia*) cocoons that they found. He lamented that by the time he had kids of his own, numbers had started to wane. I recall seeing promethea cocoons on my drives to work when I first started working at the University of Connecticut in the late 1980s. I have not seen a viable cocoon of either promethea or cecropia anywhere in the state on any drive in more than decade--where leaves are absent from our trees for six months of the year. Don Adams, who has

been collecting, rearing, and mostly releasing saturniines in southeastern Massachusetts since the 1950s reports considerably reduced numbers of cecropia and promethea cocoons over the past six decades. (I suspect that much of this decline of promethea, cecropia, and even the disappearance of cynthia (*Samia cynthia*), is due to bird predation on cocoons.)

Diminished numbers of sphingids were mentioned by all ten collectors listed above. Of Connecticut's 35 resident or formerly resident sphingids: two are extirpated; one is historic and likely gone; and at least 14 others are in decline with some of these evidently close to extirpation (Table 1). Formerly common and widespread species like the hog sphinx (*Darapsa myron*) are noticeably less abundant. The genus *Sphinx* seems to be especially hard hit, which indicates that there is a phylogenetic component to the collapse, which itself is suggestive that something in the natural enemy complex of the genus has changed. Numbers of *Ceratomia*, too, have fallen off markedly. The waved sphinx (*C. undulosa*), one of Connecticut's most common large moths historically, is markedly down from previous years. Numbers of all the eyed sphinxes are falling. The demise is on-going, with numbers diminishing appreciably with each passing decade.

Presently, 65 species of butterflies and moths (out of a state total just over 2300) are thought to be extirpated or historic for Connecticut. Reasons for the losses can be ascribed for many of these: habitat destruction, loss of early successional habitats and afforestation, coastal development, overgrazing by deer, climate change, etc. Light proliferation, and in particular, elevated bat predation by night, and bird predation by day, likely has had some impacts (Muller 1979 and Doug Ferguson personal communication), although there is little if any data to support claims that light pollution has been a major cause of moth decline (Eisenbeis 2006, Frank 2006, Schweitzer et al. 2011). Many losses are simply a matter of natural changes in forest type: Connecticut is transitioning from a largely agricultural to a largely forested landscape. There is little argument that development in, and mismanagement of, the state's pitch pine-scrub oak barrens accounts for a great fraction of losses, but it is the unexplained declines of formerly common species that prompted this article. The linden looper (*Erannis tiliaria*) was a widespread geometrid across Connecticut through the 1990s, but it has become scarce and in some areas undetectable. The red-humped caterpillar (*Schizura concinna*) was a widespread occasional pest of orchard crops and ornamentals—I have not seen its caterpillar in years, and its congener *Schizura apicalis* has become rare enough to warrant treatment in Schweitzer et al. (2011). I am unaware of any sightings of the zebra caterpillar (*Melanchra picta*) in more than 10 years. Both the latter two and the imperial moth (*Eacles imperialis*) (Goldstein 2010) remain common on some offshore islands in Massachusetts, a situation that suggests, again, a natural enemy (or a suite of natural enemies) on the mainland is affecting survivorship of all three. The nearly simultaneous disappearance of Harris' checkerspot (*Chlosyne harrisi*) and silvery checkerspot (*C. nycteis*) butterflies--the first a wet meadow obligate and the second a woodland and trap-rock ridge denizen--is also suggestive of a shared common enemy. Other unexplained losses and declines include the chain-dot geometer (*Cingilia catenaria)* and our datana moths; even the once ubiquitous yellow-necked caterpillar (*Datana ministra*) has become uncommon. The spotted datana (*D. perspicua*) has not been seen in 50 years. The contracted datana (*D. contracta*), has in fact contracted from its former range, and is now highly localized in Connecticut, Massachusetts, and Rhode Island (it remains common southward and westward).

One suspect is *Compsilura concinnata*, a tachinid fly that was introduced from Europe to control two exotic lymantriine tussock moths: the gypsy moth (*Lymantria dispar*) and the brown-tail moth (*Euproctis chrysorrhoea*), as well as the native range caterpillar (*Hemileuca oliviae*), and others (see Elkinton and Boettner 2012). (There have been multiple introductions of this polyphagous parasitoid beginning in 1906—continuing at least through 1986 (Sanchez 1996.) In addition to these two introduced pests, this tachinid is known to attack more than 200 native species of Lepidoptera from more than a dozen families (Webber and Schaffner 1926, Schaffner and Griswold 1934, Schaffner 1959, Arnaud 1978, Clausen 1978, Boettner et al. 2000, Strazanac et al. 2001). During gypsy moth outbreaks, *Compsilura* densities can reach 10,000 adult flies per hectare (Gould 1990, William et al. 1992). Because gypsy moths are only present for the fly's spring generation, *Compsilura*'s second, third, and fourth generations must seek out and parasitize native caterpillars. Boettner et al. (2000) demonstrated staggeringly high mortality rates from this tachinid in two native giant silkmoths in

Compsilura concinnata. Females of this tachinid parasitoid insert their larvae directly into the host larva, which enables it to circumvent the host encapsulation-immune system. Typically death follows in as few as 5 to 7 days. Photo: Mike Thomas & D. Wagner.

Table 1: Status of Saturniidae and Sphingidae in Connecticut

SATURNIIDAE	
Eacles imperialis	extirpated; woodland and oak scrub habitats
Citheronia regalis	extirpated; woodlands
Dryocampa rubicunda	abundant
Anisota stigma	extirpated; oak woodlands, but esp. oak barrens in Northeast
Anisota senatoria	oak woodlands; increasingly localized, but still occasionally (infrequently) abundant locally
Anisota virginiensis	declining drastically; now very local
Hemileuca maia	state endangered; rare and exceedingly local; larvae at Killingly and Oneco recently
Hemileuca lucina	declining; nowhere known to be common; wetlands and powerline ROW's
Automeris io	declining; becoming increasingly localized
Antheraea polyphemus	common; more common than a decade ago
Actias luna	evidently stable; second-generation adults becoming increasingly frequent
Samia cynthia	extirpated; formerly New Haven on ailanthus
Callosamia promethea	declining; markedly less common than in past times, but an early successional species
Callosamia angulifera	not enough data to stay; still locally common
Hyalophora cecropia	declining; becoming increasingly localized especially in wildlands; often in suburbs
SPHINGIDAE	
Agrius cingulatus	fall migrant
Manduca sexta	no longer common at lights
Manduca quinquemaculata	very rare; may no longer be resident, but certainly was previously
Manduca jasminarium	extirpated; last seen around 1960s
Dolba hyloeus	common; numbers dramatically up relative to previous three decades
Ceratomia amyntor	very scarce; significantly down in recent years
Ceratomia undulosa	recently common; becoming infrequent; marked decline over past decade
Sphinx canadensis	rare and local in northwest section of state
Sphinx chersis	in rapid decline; much scarcer than a decade ago
Sphinx kalmiae	formerly common, becoming scarce
Sphinx gordius	still locally common
Sphinx lucitiosa	extirpated; Britton 1920; northern; fens and riparian areas
Sphinx drupiferarum	historic and probably extirpated
Lintneria eremitus	uncommon as adult; more commonly reported as a larva
Lapara coniferarum	very local in pine barrens; worthy of state protection
Lapara bombycoides	locally common
Smerinthus jamaicensis	formerly widespread and common; evidently declining
Smerinthus cerisyi	mostly Litchfield County
Paonias excaecatus	our most common sphingid but declining
Paonias myops	formerly widespread and common; markedly less common
Paonias astylus	locally common but numbers dropping
Laothoe juglandis	common
Pachysphinx modesta	declining
Erynnis ello	stray
Hemaris thysbe	very common to abundant
Hemaris gracilis	very local; state threatened
Hemaris diffinis	very common to abundant
Eumorpha pandorus	evidently declining
Eumorpha achemon	rare; perhaps no longer resident
Eumorpha fasciata	stray; being seen with increasing regularity
Eumorpha vitis	stray
Sphecodina abbottii	common but less so in recent years
Deidamia inscripta	common but less so in recent years
Amphion floridensis	common but less so in recent years
Darapsa versicolor	locally common
Darapsa myron	common but less so than in previous decades
Darapsa choerilus	common (formerly known as *D. pholus*)
Xylophanes tersa	stray
Hyles gallii	very common
Hyles lineata	infrequent; perhaps not even a long-term resident

Massachusetts (see also Kellogg et al. 2003). The declines of many Saturniidae, Sphingidae, some Notodontidae, and others mentioned here could well trace to *Compsilura* (see discussion in Schweitzer et al. 2011), but one can't be sure without more study. One observation that strongly points to a parasitoid such as *Compsilura* is that a sweeping percentage of the species at issue here are gregarious as larvae, including *Anisota*, *Callosamia*, *Datana*, *Hemileuca*, *Schizura concinna*, and *Melanchra picta*, as well as both checkerspot butterflies. Large body size and/or longer development times also seem to be risk factors (Dale Schweitzer personal communication). In sum, many of the declines appear to relate more to natural enemy complexes than to development, afforestation, light or chemical pollution, climate change, and other threats. But without more data, it would be premature to assign blame to *Compsilura*. As easily, introduced lady beetles such as the Asian Lady beetle (*Harmonia axyridis*) or other enemies (both native and exotic) are at play.

Not all species are declining. Many southern species are establishing. For example, Connecticut added two new, year-round resident swallowtail butterflies in just the past decade: the pipevine swallowtail (*Battus philenor*) and most recently the giant swallowtail (*Papilio cresphontes*). Last fall, a fresh individual of *Glenoides texanaria*, a widespread southern geometrid, was taken for the first time. Some newly established exotics such as the large yellow-winged dart (*Noctua pronuba*) are enjoying extraordinary ecological release. Formerly rare species are now routinely encountered, e.g., the white-m hairstreak (*Parrhasius m-album*) and shivering pinion moth (*Lithophane querquera*). There is indication that datanas have rebounded somewhat from their numbers of a decade ago (Dale Schweitzer personal communication). Even some larger moths seem to be more numerous than in past decades: both luna (*Actias luna*) and especially polyphemus (*Antheraea polyphemus*) are being seen in greater numbers, which may be tied to the ever-increasing proportion of second generation adults (which were quite scarce in Connecticut prior to the turn of the century). The longer growing season and warmer summer temperatures of the last decade have even led to first reports of a facultative second generation of promethea in Massachusetts, beginning about ten years ago (Don Adams personal communication).

An important aspect of this mystery is the variation across the Northeast. Some areas still are reporting high saturniid diversity: e.g., Joe Garris in Stillwater, New Jersey is seeing good numbers of cecropia, luna, tulip tree silkmoths, and others species that have declined elsewhere. With the exception of *Ceratomia*, Steve Johnson has not noted appreciable declines in the moth diversity in southern Pennsylvania. Coastal Massachusetts seems to be less affected than central counties (Goldstein 2010, Mark Mello personal communication). But on the whole, moth biomass at sheets and in blacklight traps is waning. The region's human population is not growing fast enough for either habitat loss or light pollution to be the core causes for the decline. At Ben Williams's rural property in Pomfret, Connecticut, where he has been light trapping for six decades, there has been little difference in urbanization, agricultural practices, light pollution, or other tangible human impacts--decline has been steady and on-going with the most noticeable changes and losses accruing over the past decade. Across many parts of the Northeast, previously occupied habitat now sits empty. Something is amiss.

Data are needed. Long-term monitoring data are best, even if only for a subset of species: e.g., for all saturniids, sphingids, many notodontids, and perhaps a pre-selected group of common species that represents a wide range of taxa and ecological niches. There is ample reason to use sentinel egg and larval studies (where lab-reared early stages are placed out in the wild for a time and re-collected for lab rearing of natural enemies) to obtain field measures of key mortality factors. Good candidates for "sentinel species" would be those that show marked differences in abundance on the mainland versus Massachusetts's nearshore islands (as for example red-humped caterpillar and the contracted datana). Sphingids, and especially *Sphinx*, *Ceratomia*, or the various eyed sphinxes, could prove to be telling sentinel taxa. If anyone knows of existing data sets or records that could be used to assess the status of the region's moths and especially historical abundances, please contact me. Such data would help document the decades over which the decline occurred, and in so doing help identify likely causes.

Acknowledgements

This article grew from numerous conversations with Dale Schweitzer, Tim McCabe, Ben Williams, Jeff Boettner, Don Lafontaine, and many others—many offered unpublished observations, especially Dale and Tim. Dale also helped with literature and provided a five-decade perspective on the phenomenon of moth decline in the Northeast. Persons mentioned in the fourth paragraph gave permission for inclusion of their name. Much of the work documenting the importance of Massachusetts's offshore islands as refugia for saturniids and other regionally rare species was carried out by Paul Goldstein. Some text on *Compsilura* was reproduced from Wagner et al. 2011, which was much dependent on information passed along by Jeff Boettner. Don Adams and Steve Johnson sent helpful information on their experiences. Stan Malcolm, Robert Pyle, Jane O'Donnell, Mike Nelson, Eric Metzler, Jeff Boettner, John Snyder, and John Calhoun made suggestions which improved the article.

Literature Cited

Arnaud, P. H., Jr. 1978. A host-parasite catalog of North American Tachinidae (Diptera). Publication 1319. U. S. Science and Education Administration, Washington, DC.

Boettner, G. H., J. S. Elkinton, and C. J. Boettner. 2000. Effects of a biological control introduction on three non-target native species of saturniid moths. Conservation Biology 14: 1798-1806.

Clausen, C. P. (ed.). 1978. Introduced parasites and predators of arthropod pests and weeds: A world review. Handbook 480. U. S. Agricultural Research Service, USDA, Washington, DC.

Eisenbeis, G. 2006. Artificial night lighting and insects: Attraction of insects to streetlights in a rural setting in Germany. Pp. 281–304. In: C. Rich and T. Longcore (eds.). Ecological consequences of artificial night lighting. Island Press, Washington, D. C.

Elkinton, J. S. and G. H. Boettner. 2012. Benefits and harm caused by the introduced generalist tachinid, *Compsilura concinnata*, in North America. Biological Control 57: 277–288. DOI 10.1007/s10526-011-9437-8.

Ferguson, D. C. 1971. Bombycoidea. Saturniidae (Part). The Moths of America North of Mexico, Fascicle 20.2A. E. W. Classey Limited and R. B. D. Publications, Inc., London.

Frank, K. 2006. Effects of artificial night lighting on moths. Pp. 305–344. In: C. Rich and T. Longcore (eds.). Ecological consequences of artificial night lighting. Island Press, Washington, D. C.

Goldstein, P. Z. 2010. Life history of the imperial moth *Eacles imperialis* (Drury) (Saturniidae: Ceratocampinae) in New England, U.S.A.: distribution, decline, and nutritional ecology of a relictual islandic population. Journal of the Lepidopterists' Society 42: 34-49.

Gould, J. R., J. S. Elkinton, and W. E. Wallner 1990. Density-dependent suppression of experimentally created gypsy moth, *Lymantria dispar* (Lepidoptera: Lymantriidae), populations by natural enemies. Journal of Animal Ecology 59: 213-233.

Hessel, S. A. 1976. A preliminary scan of rare and endangered Nearctic Moths. Atala 4: 19–21.

Kellogg, S. K., L. S. Fink, and L. P. Brower. 2003. Parasitism of native luna moths, *Actias luna* (L.) (Lepidoptera: Saturniidae) by the introduced *Compsilura concinnata* (Meigen) (Diptera: Tachinidae) in central Virginia, and their hyperparasitism by trigonalid wasps (Hymenoptera: Trigonalidae). Environmental Entomology 32: 1019–1027.

Muller, J. 1968. Additions to the supplemental list of Macrolepidoptera of New Jersey. Journal of the New York Entomological Society 76: 303-306.

Muller, J. 1973. Second addition to the supplemental list of Macrolepidoptera of New Jersey. Journal of the New York Entomological Society 81: 66–71.

Muller, J. 1976. Third addition to the supplemental list of Macrolepidoptera of New Jersey. Journal of the New York Entomological Society 84: 197–200.

Muller, J. 1979. Fourth addition to the supplmental list of Macrolepidoptera of New Jersey. Journal of the Lepidopterists' Society 33: 174–178.

Sanchez, V. 1996. The genetic structure of northeastern populations of the tachinid *Compsilura concinnata* (Meigen), an introduced parasitoid of exotic forest defoliators of North America. Ph. D. thesis, University of Massachusetts, Amherst.

Schaffner, J. V., Jr. 1959. Microlepidoptera and their parasites reared from field collections. USDA Miscellaneous Publication 767. USDA, Washington, DC.

Schaffner, J. V., Jr. and C. L. Griswold. 1934. Macrolepidoptera and their parasites reared from field collections in the north eastern art of the United States. USDA Miscellaneous Publication 188. USDA, Washington, DC.

Schweitzer, D. F. 1988. Status of Saturniidae in the northeastern USA: A quick review. News of the Lepidopterists' Society 1 (January/February): 4–5.

Schweitzer, D. F., M. C. Minno, and D. L. Wagner. 2011. Rare, Declining, and Poorly Known Butterflies and Moths Lepidoptera) of Forests and Woodlands in the Eastern United States. U.S. Forest Service, Forest Health Technology Enterprise Team, FHTET-2011-01. USDA Forest Service, Morgantown, West Virginia. 517 pp.

Strazanac J. S., C. D. Plaugher, T. R. Petrice, and L. Butler L. 2001. New tachinidae (Diptera) host records of eastern North American forest canopy Lepidoptera: baseline data in a *Bacillus thuriengiensis* variety *kurstaki* nontarget study. Journal of Economic Entomology 94: 1128–1134.

Wagner, D. L., D. F. Schweitzer, J. B. Sullivan, and R. C. Reardon. 2011. Owlet Caterpillars of Eastern North America. Princeton University Press. Princeton, New Jersey. 576 pp.

Webber, R. T. and J. V. Schaffner, Jr. 1926. Host relations of *Compsilura concinnata* Meigen, an important tachinid parasite of the gipsy moth and the brown-tail moth. Bulletin No. 1363. USDA, Washington, DC.

William, D. W., R. W. Fuester, W. W. Metterhouse, R. J. Balaam, R. H. Bullock, R. J. Chianese, and R. C. Reardon. 1992. Incidence and ecological relationships of parasitism in larval populations of *Lymantria dispar* (Lepidoptera: Lymantriidae). Biological Control 2: 35-43.

Hyalophora columbia gloveri Spring Mountains, Nevada

continued from p. 41

Figure 2: adult male, Hyalophora columbia gloveri, dorsal surface, from larva illustrated in figure 1.

Acknowledgements

We thank Andrew D. Warren and Jacqueline Y. Miller for critically reviewing, and their suggestions to improve, the manuscript.

Literature Cited

Niles, W.E., P.J. Leary. 2007. Annotated Checklist of the Vascular Plants of the Spring Mountains, Clark and Nye Counties, Nevada. *Mentzelia, The Journal of the Nevada Native Plant Society* 8:1-72.

Tuskes, P.M., J.P. Tuttle M.M. Collins. 1996. *The Wild Silk Moths of North America: A Natural History of the Saturniidae of the United States and Canada*. Cornell University Press. 250 pp.