FIND YOUR DARK SIDE: INVITATION TO JOIN DISCOVER LIFE'S *MOTHING* PROJECT

BY

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Abstract – Here I give an overview of Discover Life's Mothing project and invite Southern Lepidopterists' Society members to join this effort and its educational component, *Moth Math*. Our goals are to study moth communities and to teach how to collect, analyze, and present data. By working across numerous study sites and with historical collections, we designed *Mothing* to understand how latitude, weather, land use, and other environmental factors affect moths and how their life history parameters, behavior, populations, and communities change over time. Discover Life seeks your participation at all levels. Please help us photograph and collect creatures that come to lights; integrate specimen data from existing collections, both public and private; build and test local annotated checklists and identification guides; provide taxonomic expertise in specimen identification, and last but not least, work with your local schools and nature centers to involve the public in natural history research and improve the teaching of science and quantitative skills.

Discover Life – www.discoverlife.org grew out of the Insect Diversity Project started in 1992. The mission of Discover Life is to assemble and share knowledge in order to improve education, health, agriculture, economic development, and conservation throughout the world. Its servers at the University of Georgia and University of New South Wales freely provide users with taxon pages, identification guides, maps, albums, labels, seasonality graphs, and other resources. Since inception, Discover Life has served over 3.5 billion pages and currently has approximately 800,000 users monthly. It integrates over 1.2 million species names, 650,000 species maps, 2 million images, and 500 identification guides contributed and maintained by organizations and individual participants. **(See Fig. 1 to the left)**

***Mothing* project** – www.discoverlife.org/ moth – After marginally successful attempts to develop citizen science projects to study ants, bees, lichens, goldenrod associates, and plants, Discover Life started to study moths in 2010. Simply, wow! Moths are arguably the best group of organisms on the planet for understanding environmental change. Everyone should be exposed to their beauty, diversity, and the mysteries about life that they are revealing. We have developed research protocols involving digital cameras and Discover Life's online tools to enable a network of people to work together efficiently to photograph specimens, identify them, and analyze results. *Mothing* has now collected 550,000 photographs from 22 study sites in eastern North America and one in Costa Rica, documenting over 3,000 moth species in total. **(Fig. 2)**

Fig. 2. Map of *Mothing's* current network of study sites in the United States, Canada, and Costa Rica. See www.discoverlife.org/moth/report.html for nightly updates of each site's effort and results. We hope to increase our coverage in North America and to expand to other countries, notably Ecuador and Mexico.

At our Blue Heron site in Clarke County, Georgia (33.8882° North, 83.2973° West), we have taken over 180,000 photographs to record the diversity of creatures that come to lights, including vertebrates and invertebrates alike. We have documented between-year differences in the abundance, size, and seasonality of 1,223 moth and 14 butterfly species that have come to lights over the past six years **(Fig. 3)**. The site has yielded approximately 300 species that are new state records and approximately 50 species that we think may be undescribed and new to science.

Fig. 1. This montage shows some of the beauty and diversity of the moths that we have photographed at our Blue Heron site in Clarke County, Georgia. It contains 154 species and one duplicate photograph. As you try to fine the duplicate, imagine the task of identifying and tabulating over 140,000 moth images that we have from this site. The montage contains only about an eighth of the total 1,237 Lepidoptera species we have photographed at the site's lights since we began *Mothing* there in 2010.

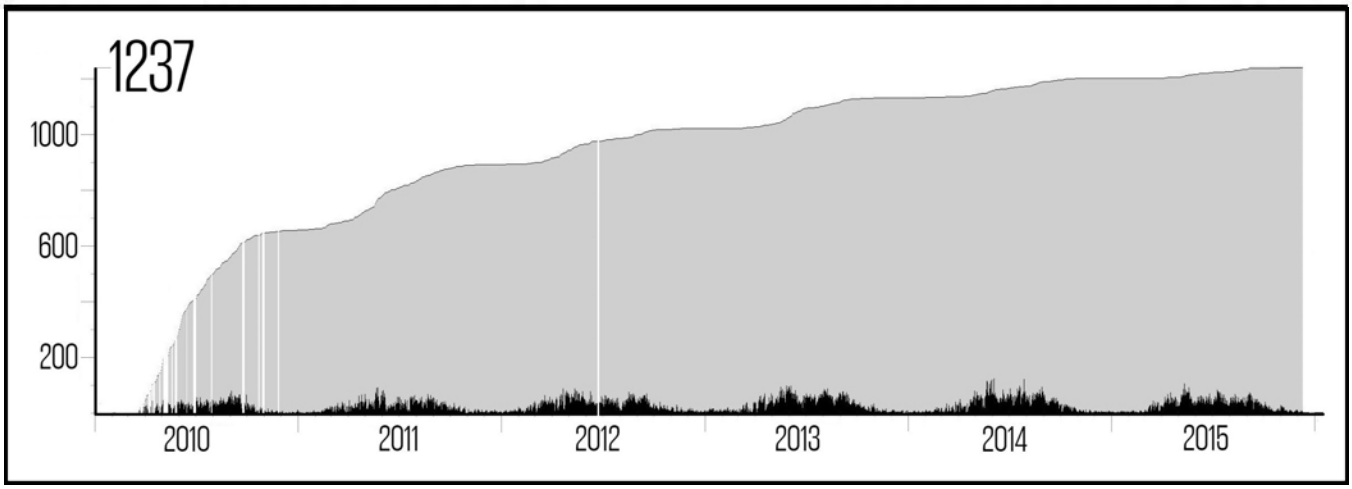

Fig. 3. Nightly moth species at Blue Heron Site, Clarke County, Georgia, starting 2010.
Gray – The 1,237 accumlated species is based on 139,638 identifications, including 1,310 specimens identified to 58 morphospecies and 5,758 identified to 47 species groups. We have identified 97.2% of the site's moth images; 4,073 images are still unidentified.
White bands – Data not taken.
Black – Number of species photographed each night. See http://ww.discoverlife.org/mp/20m?plot=3&la=33.9&lo=-83.3 for the site's most current data. This link is interactive and enables you to view the count of species for a selected date or between any two dates. [Note: the gap in data at the end of October, 2010, was because of a heart attack that I had at 6:00AM, after an exciting morning with my moths. This focused my life goals and I decided to moth nightly. I recommend that you do the same but skip the heart attack.]

Research protocol and workflow – *Mothing* has developed and tested a research protocol and identification tools, to manage, identify, and analyze data rapidly and accurately from images and datasets uploaded to Discover Life. So as to ensure the accuracy of where and when we record observations, participants take photographs of the time and date on cell phones. Similarly, for geographical information, they photograph porch lights, street signs, and latitude and longitude coordinates on smartphones and GPS devices. After participants upload images to albums, they tag them with geographical and other data. They and others then start the identification process, first grouping photographs into "buckets," such as "moth Geometridae gray," "moth Geometridae Macaria," "moth micro," and "moth Pterophoridae plume." As we identify moths further, either to species, species group, or morphospecies, automated programs tabulate and graph them nightly.

Specimen identification – Identifying specimens accurately from photographs is our greatest challenge. There are over 12,000 species of Lepidoptera in North America and possibly over 20,000 in Costa Rica. When we started *Mothing*, it took us 18 months to identify our first 10,000 photographs to species. We didn't know what we were doing, hadn't built identification guides customized by location, and only had the ability to label up to 100 specimens from one album at a time. After we assembled reference photographs, built site specific identification guides and annotated checklists, and wrote software to better manage the flow of images through "buckets" and examine up to 6,000 images at a time, it took us only 6 weeks to determine our second 10,000 images. Our experts can now determine over 500 specimens in a few hours.

Identification guides – Discover Life has an online identification guide to 12,000 moths that occur in the United States and Canada. By continually refining species checklists to states, counties, and other locations, we allow users to customize this guide and filter out species that are unlikely because of their known geographical range. Our guide also allows users to select species by size, month, color, wing pattern, family, genus, and other characters. Once it narrows possible taxa to below 100 kinds, users can view images of the species with the selected character states. For access to guides by state see www.discoverlife.org/moth/identification.html. Building a filter to a specific location is simple, it requires a list of the species in text format, one 'Genus species' binomial per line.

Annotated checklists – In partnership with Moth Photographers' Group, Discover Life uses the guide filters to build annotated checklists for sites. Such checklists are under 'Study sites', www.discoverlife.org/nh/cl. For example, see the one for Clarke County, Georgia: www.discoverlife.org/mp/20p?see=nh/cl/US/GA/Clarke/moth.cl&res=120 which rapidly presents over 1,200 thumbnails grouped by its index. When called at res=240 instead of 120, this shows up to six, larger images per species, but takes longer to download. These checklists, along with local guides, greatly speed our identification process.

Data management and availability – All *Mothing's* images, associated data, and analyses are available online. Automated programs tabulate results each night and make the images and associated data available immediately. Each night Discover Life mirrors information across its network of servers. It currently maintains 7 copies in the United States and Australia. We will share data with other sites, such as BISON, run by the United State Geological Survey.

Tools available through *Moth Math* enable users to build customized graphs and download records with associated moon phase, temperature, precipitation, and barometric pressure for further analysis. **Fig. 4** shows an example of a seasonality graph that *Moth Math's* tools generated.

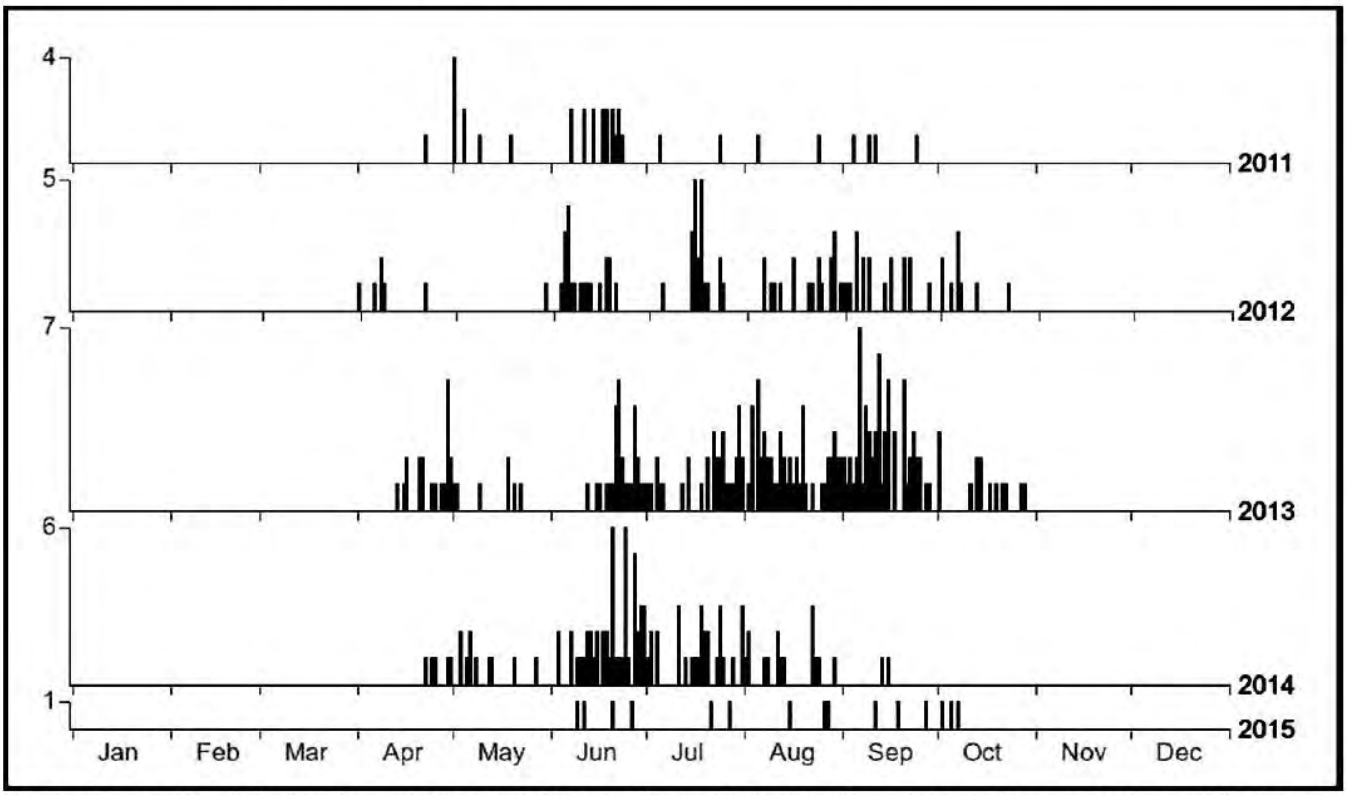

Fig 4. Seasonality of *Pselnophorus belfragei*, Belfrage's Plume Moth, based on nightly photography from 2011 through 2015 (except 22 June, 2012, oops!) at our Blue Heron site, Clarke County, Georgia. Debbie Matthews, at the McGuire Center for Lepidoptera and Biodiversity, University of Florida, identified most specimens. This species does not exhibit strong synchronous flights of each generation but flies almost continuously throughout its March through October season. It flew earlier in 2012, presumably in response to the exceptionally warm winter that year. For unknown reasons, its numbers declined in 2015. For more information on this species, see its taxon page on Discover Life: www.discoverlife.org/mp/20q?search=Pselnophorus+belfragei

Results and future directions – *Mothing* has a huge trove of data online which we have begun to analyze. We have published one paper on a regional outbreak and subsequent collapse of the Black-dotted Brown, *Cissusa spadix*, a noctuid (Coyle et al., 2013. *American Entomologist* 59: 78-90). We have novel findings that show how the body size of a species can change between generations and years, how smaller moths are relatively less active than larger moths at colder temperature, and how moths with larvae that feed on lichens may be more detrimentally affected by urbanization than other species.

We are modelling how the moon, latitude, and weather variables affect the flight of species across sites and over time. We need longer time series and data from more sites to better understand how these factors, especially rainfall patterns, affect moths.

We are investigating how coloration affects flight patterns in aposematic and cryptic species, showing that the former have more synchronized flights with sharper peaks. This newly discovered phenomenon may affect the genetic structure of populations along a latitudinal gradient, leading to possible '*temporal vicariance*' between northern and southern populations of aposematic species that have more than one flight per year. Brian Wiegmann at North Carolina State University has started molecular work to compare the genetic structure of populations from northern versus southern sites.

In 2016, with the help of Alex Cherkinsky, a physicist at University of Georgia, we will start examining whether moths have a '*pupa bank*' similar to the '*seed bank*' of plants. We plan to measure radioactive carbon isotopes in museum specimens to determine when their larvae fed. If we find that moth species can remain in a *pupa bank* for years, it will have profound implications for our understanding of how their populations may respond to potential droughts and other threats from climate change.

How can you help?

Record moths at new sites – We hope that many of you will join *Mothing* and use its protocol to record species at your lights. If you wish to do so, please consider the following levels of commitment: 1) new mooner – you photograph moths for two mornings as close to each new moon as you can; 2) weekenders – you photograph for two mornings each weekend that you can; 3) all nighters – you photograph most mornings, ideally finding other naturalists to cover for you when you go on vacation or are too sick to enjoy your moths' company. Discover Life will set you up with an album to manage your photographs and provide training and technical support. Our albums are not restricted to photographs of insects. You can use them to build a digital life list and map all species that you photograph. Our most accomplished photographer, Malcolm Storey, who lives in England, now has over 4,750 species in his album, approximately a tenth of the British flora and fauna. We want to compare rural and urban sites, so even if you live in a city with few moths, please join us.

Integrate data from collections – We plan to photograph 30 - 50 focal species in as many collections as possible, thus capturing historical data. So far we have taken approximately 30,000 photographs of specimens and labels from 13 museums (see www.discoverlife.org/pa/ph/#e). We use optical character recognition, natural language processing, and crowdsourcing to capture information from such images. We seek your help taking photographs in collections and in crowdsourcing the labels, checking identifications, and measuring specimen wing lengths.

If you have existing images or datasets in tables, we wish to work with you to incorporate them into our collective information. It is Discover Life's policy that photographers retain copyright of their images.

Identification – We seek your help editing county checklists that we use to build local guides and checklists. For quality control, we want these lists to be based on photographs taken at lights or of specimens and their labels from collections. We find that local guides and checklists help us to identify species rapidly.

We are particularly in need of experts who will help us check all our identifications. We call such participation "blessing." If you know a taxon well, we find that it takes approximately 20 minutes to weed out misidentified specimens from up to 6,000 images. We also need help figuring out some of our species groups, ideally determining to species what we currently have in groups, such as *Crambidia pallida–uniformis*, *Melanolophia canadaria–signataria*, and *Hypagyrtis esther–unipunctata*.

Involving schools and the public – If you are a teacher or would like to help develop *Moth Math* to involve others in the scientific process, please join us. In addition to teaching quantitative skills, we hope that *Moth Math* participants will take photographs using smartphones of our '*dark dozen*' – a set of 12 easily-identified taxa, such as the Luna Moth, *Actias luna*; Rosy Maple Moth, *Dryocampa rubicunda*, and Painted Lichen Moth, *Hypoprepia fucosa* – and then upload them via Twitter and Instagram to our handle *@mothmath*. We hope that these extensive data will help us document the impact of urbanization on moth communities.

Please email Becka <dl@discoverlife.org> and/or me <pick@discoverlife.org> if you want to start a site or help in any other way. www.discoverlife.org/pa/ph explains how to get an album. I plan to give more details of *Mothing* and present more results in future issues of *SLS News*.

Acknowledgments – By its very nature of being a project of sharing, I cannot possibly list everyone whom I would like to thank for contributing to *Mothing*. There are so many of you – those who share and identify photographs, the support team at Discover Life, those of you who brainstorm ideas, inspire, volunteer time, and provide financial and logistic support. Thank you one and all. In particular, I thank Bob Patterson and the many contributors to MPG for making our moth identification possible, the museum community and collectors for historical information, the UGA Costa Rica program for support at their site, and the USGS for its support of Discover Life. My special thanks to Peter Burn, Sam Droege, Stella Guerrero, Jonathan Lochamy, Justin Long, Nancy Lowe, Tori Staples, Becka Walcott, Kevin Weick, and Brian Wiegmann.

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