Effect of climatic warming on the emergence date and flight period of Irish moth species

Bridget O'Neill[1]*, Angus Tyner[2] and Alison Donnelly[1]
[1]Centre for the Environment and Department of Botany, School of Natural Sciences, Trinity College Dublin, Ireland
[2]Moths Ireland, Ireland
*oneillb6@tcd.ie

Abstract

Temperatures in Ireland have been increasing due to anthropogenic-driven climate change. This increase in temperature has been shown to effect the phenological phases of plants and birds, but little is known about the effect on the phenophases of Lepidoptera. Observation records of the flight periods of 58 common species of Irish moths were obtained from a public monitoring group. These participants have been monitoring moth activity from eight to 39 years. Statistical analysis by generalized additive models (GAMs) showed that 49 out of 58 species are emerging significantly earlier (4-151 days) in the year now than when observation began in 1974 and that 45 out of 58 species have a significantly longer flight period (5-176 days). These changes varied across the country and by life history and were correlated with raising temperatures, primarily in the late spring/early summer. We discuss the possibilities of potential mismatches with their food plants and predators if warming continues as predicted.

Introduction

Recent changes in global climate, such as increasing temperature, have had notable effects on the phenology (timing of life cycle events) of plants and animals. The effects are variable across habitats and between species, but increasing temperatures have been shown to advance certain key phenophases of insects, such as first sighting in the spring after winter dormancy. Moths in particular are a useful group of insects to monitor for these changes. They are an important food source for birds and mammals, they can be important pollinators, they can be important crop pests and they are attractive to humans. Because of this, visual observations of moths are readily recorded and are available for analysis.

Methods

Fifty eight moth species were monitored nightly with the help of backyard light traps. There were up to 39 years of observations recorded between 1974 and 2009 at Raphoe, Ashford, Tramore, and Cork (Fig. 1). From the nightly counts, first, last, and median date of observation, total flight period and total numbers were calculated for each species and year. Each of these flight parameters for each species were weighted by total numbers observed and analyzed by generalized additive models (GAMs) in relation to year. Observations for each species were analyzed across the four sites, and also analysed separately by location and by life history parameters. Phenological parameters were correlated with meteorological parameters, mean, minimum and maximum air temperatures.

Acknowledgements

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Figure 1 - Locations where moth observations were taken

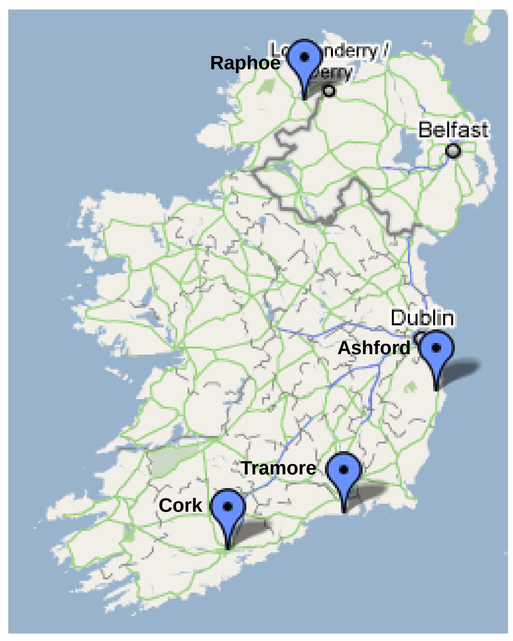

Table 1 - Significant changes in moth phenology across Ireland. Common name and significant *p* - values of phenophases (first, median and last sighting and the derived length of flight period) are listed. Blue shaded squares show significantly earlier sightings, red shaded squares are significantly increased flight period or later sightings.

Species	First sighting	Median sighting	Last sighting	Length of flight period
Angle Shades	0.001	0.632	0.004	0
Bright-Line Brown Eye	0	0	0.563	0.015
Brimstone	0.02	0.112	0.024	0.001
Buff Ermine	0	0	0.899	0.002
Burnished Brass	0	0	0.034	0.02
Cinnabar	0.007	0.267	0.834	0.014
Clouded Border	0.004	0.492	0.001	0
Clouded Bordered Brindle	0.008	0.158	0.535	0.01
Clouded Drab	0.051	0.128	0.073	0.299
Common Carpet	0	0.127	0	0
Common Marbled Carpet	0.002	0.477	0.023	0.002
Common Quaker	0.07	0.014	0.876	0.358
Common Wainscot	0	0.347	0	0
Dark Arches	0	0.004	0.005	0
Dark-Barred Twin-Spot Carpet	0	0.234	0.017	0
Double-Striped Pug	0.044	0.336	0.106	0.015
Early Thorn	0.001	0.002	0.033	0
Elephant Hawk-Moth	0.004	0.071	0.281	0.412
Flame Carpet	0	0.005	0.033	0
Flame Moth	0	0.005	0.297	0.073
Flame Shoulder	0	0	0.196	0.001
Garden Carpet	0	0.285	0.132	0.005
Garden Tiger	0.038	0.035	0.359	0
Green Carpet	0.002	0.217	0.063	0.007
Grey Pine Carpet	0.042	0.978	0.145	0.048
Heart and Dart	0.005	0	0.562	0.063
Hebrew Character	0.009	0.41	0.217	0.001
July Highflyer	0	0.259	0.229	0
Large Yellow Underwing	0	0.075	0	0
Lesser Broad-Bordered Yellow Underwing	0.001	0.432	0.128	0.029
Lesser Yellow Underwing	0.085	0.301	0.019	0.015
Magpie Moth	0.002	0.198	0.291	0
Map-Winged Swift	0.064	0.262	0.066	0.075
Mottled Beauty	0.015	0.383	0.292	0.027
Peach Blossom	0.071	0.001	0.114	0.726
Pebble Prominent	0.019	0.034	0.058	0.008
Peppered Moth	0.002	0.154	0.036	0
Poplar Hawk Moth	0	0.031	0.208	0
Riband Wave	0.001	0.022	0.182	0.006
Rosy Rustic	0.027	0.287	0.001	0
Scalloped Hazel	0.069	0.188	0.307	0.148
Scalloped Oak	0	0	0.061	0.004
Silver-Ground Carpet	0	0	0.117	0.058
Single-Dotted Wave	0.006	0.073	0.055	0.018
Six-Spot Burnet	0.005	0.053	0.005	0.001
Small Fan-Footed Wave	0.001	0.975	0.001	0
Small Phoenix	0.027	0.027	0.203	0.142
Small Square-Spot	0.001	0.136	0	0
Small Wainscot	0.105	0.036	0.642	0.734
Smoky Wainscot	0.001	0.493	0.392	0.01
Snout Moth	0.001	0.002	0.087	0
Spectacle Moth	0	0	0.065	0.002
Spruce Carpet	0.042	0.857	0	0.007
Square-Spot Rustic	0.278	0.018	0	0
Swallow-Tailed Moth	0.032	0.149	0.805	0.16
True Lover's Knot	0.208	0.09	0.059	0.359
White Ermine	0	0	0.655	0.02
Willow Beauty	0.019	0.035	0.108	0.014

Results

Of the 58 moth species observed, 49 are emerging significantly earlier in the year now than they were at the start of the study period (Table 1). 45 species have a significantly longer flight period now than they had at the beginning of the study period as well (Table 1). The degree of early emergence and lengthening of flight period vary by several different ecological factors, some of which are presented in Table 2a-2b. The majority of the significant changes in phenology are correlated with rising temperatures in June. While first and last sighting are correlated with June maximum temperature, median sighting is correlated with June minimum temperature.

Discussion

In general, the majority of moth species examined in Ireland are emerging earlier and subsequently have a lengthened flight period as a result. There is a trend of increasingly advanced emergence the earlier in the year a species emerges. Moth species feeding on plants that exhibit more of a seasonal phenology in edible parts are emerging earlier than species feeding on grasses. The rising temperatures in June are having a large significant effect on moth emergence, potentially because most of the species studied emerge in June. There are several phenological mismatches possible. Earlier emergence could lead to potential larval starvation or slower growth as food plants may not be in the appropriate stage for feeding upon. Earlier emergence could also lead to mismatches with endangered predatory bats that depend on moths to replenish their fat stores after hibernation. More research is required to accurately predict climate-induced changes in interspecies relationships in Ireland.

Table 2a - Number of significant changes by time of year appearance. First column for each category is number of species showing the phenophase advancing/length of flight period longer. Second column is number of species showing the phenophase retreating/length of flight period shorter. Third column is number of species showing no change in phenophase. Direction of change is shown in parentheses.

Appearance period	Early Spring (March-April) – 5 species			Late Spring (May-June) – 37 species			Summer (July-August) – 16 species		
First Appearance	3 (-)	0	2	33 (-)	0	4	13 (-)	0	3
Median Appearance	2 (-)	0	3	16 (-)	0	21	3 (-)	3 (+)	10
Last Appearance	0	1 (+)	4	0	14 (+)	23	0	5 (+)	11
Length of Flight Period	0	3(+)	2	0	28 (+)	9	0	14 (+)	2

Table 2b - Number of significant changes by types of plants fed upon. Data is presented in the same format utilised in Table 2a.

Plant Type Fed Upon	Grasses – 5 species			Herbaceous plants – 29 species			Trees and shrubs – 24 species		
First Appearance	4 (-)	0	1	27 (-)	0	2	18 (-)	0	6
Median Appearance	2 (-)	0	3	14 (-)	1 (+)	14	5 (-)	2 (+)	17
Last Appearance	0	2 (2)	3	0	10 (+)	19	0	8 (+)	16
Length of Flight Period	0	4 (+)	1	0	23 (+)	6	0	18 (+)	6