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The year-round phenology of *Macroglossum stellatarum* (Linnaeus, 1758) at a Mediterranean area of South of Spain (Lepidoptera: Sphingidae)

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Abstract

Macroglossum stellatarum (Linnaeus, 1758) is a common moth species found in the Palearctic region. However little is known about their year-round phenology at southern areas of their distribution range. Here I present data on the year-round phenology of imagos recorded at three sites located at Cádiz area (South of Spain) during three years (2014-2016). All the plots were located at lowland sites (<80 m altitude) with a mild Mediterranean-type climate due to the seashore influence. Overall, a total of 206 imagos were recorded on 1307.3 km of BMS transects. Abundance was 0.09 moths/km (data of all sites and years pooled) and varied greatly among sites and years. The species was recorded all year round and exhibited three peaks of abundance (one late in the winter between February and March, in May and July) suggesting that the species is trivoltine in the study area. Abundance was however higher in May and July. The year-round phenology varied greatly both among study plots and also among years for the same study plot. Available data suggest that this species is an obligate day-active species in the study area. Despite the species seems to have a residence status in the area, the possibility that some imagos could have been recorded during their migratory movements in their Palearctic route remain open.
KEY WORDS: Lepidoptera, Sphingidae, *Macroglossum*, residence status, phenology, Spain.

El ciclo fenológico anual de *Macroglossum stellatarum* (Linnaeus, 1758) en un área mediterránea del sur de España (Lepidoptera: Sphingidae)

Resumen

A pesar de que *Macroglossum stellatarum* (Linnaeus, 1758) es una especie frecuente en la región Paleártica. Sin embargo es poco conocido su ciclo fenológico anual en las zonas más meridionales de su área de distribución. En este trabajo presentamos la fenología anual de los imagos registrados en tres localidades situadas al sur de la provincia de Cádiz (sur de España) durante tres años (2014-2016). Las parcelas estudiadas se localizaban en zonas de baja altitud (<80 m de altura s.n.m) y presentaban un clima mediterráneo suave (definido como submarítimo, cf. FONT TULLOT, 1983) debido a la influencia del océano. Se registraron un total de 206 imagos en 1.307,3 km recorridos siguiendo los transectos BMS. La abundancia registrada fue 0.09 polillas/km (datos agrupados para todos los sitios y años) y mostró grandes variaciones entre sitios y años. La especie fue registrada durante todo el año y se registraron tres picos de abundancia (uno al final del invierno entre febrero y marzo, otro en mayo y finalmente, otro en Julio) lo que sugiere que la especie es trivoltina en la zona de estudio. Sin embargo, la abundancia fue mayor en mayo y julio. La fenología anual varió significativamente entre las áreas de estudio y también, entre años para una misma área. La información disponible sugiere que es una especie diurna obligada en el área de estudio. A pesar de que los datos indican que la especie es residente en el área de estudio, no descartamos la posibilidad de que algunos imagos registrados en este estudio puedan corresponder a ejemplares migradores que han sido registrados durante sus movimientos en el Paleártico.

PALABRAS CLAVE: Lepidoptera, Sphingidae, *Macroglossum*, estatus residente, fenología, España.

Introduction

Many aspects of the natural history of nocturnal butterflies remain unknown. At most, studies refer their distribution range or their migratory status (e.g. MANLEY, 2015; MORRIS, 1933; LERAUT, 2006; ROTHSCHILD & JORDAN, 1903; ROUGEOT & VIETTE, 1978). Studies of these aspects for non-central European habitat are remarkably scarce (but see for instance REDONDO *et al*., 2015).

Macroglossum stellatarum (Linnaeus, 1758), is a common species widely distributed at the Palearctic (Europe and North Africa), central Asia, India and Indochina (HIGGINS & RILEY, 1973; MANLEY & ALLARD, 1970; ROTHSCHILD & JORDAN, 1903; SEITZ, 1906-1910; STAUDINGER & REBEL, 1901), Differently to other moths, is a day-active species (GÓMEZ DE AIZPURÚA, 2002; HERRERA, 1992; KELBER, 1996; MORENO-BENÍTEZ, 2016) and imagos are remarkably easy to recognize while collecting nectar in front of the flowers on nervous and quick flights among plants. Under controlled laboratory conditions, the life-spam of imagos was 4-6 months (FARINA *et al.,* 1994; KELBER, 1996).

At the Iberian Peninsula, the species is amply distributed ranging from the sea level to high mountains (MORENO-BENÍTEZ, 2016; REDONDO *et al.,* 2015) including city parks and gardens (MANLEY, 2015; MORENO-BENÍTEZ, 2015). At least at lowland sites, imagos are observed all year round (MORENO-BENÍTEZ, 2016) including winter months on days when the ambient temperature is favorable. Furthermore, the species is bivoltine (CORBET, 2002) because it completes two overlapping generations between May and October (GÓMEZ DE AIZPURÚA, 2002; ZAPATA-SIERRA, 1982). Many other aspects of their natural history remain unknown. In addition, many studies have considered *Macroglossum* as a migratory species in the Palearctic with seasonal movements between the Mediterranean area to central and northern Europe (GÓMEZ DE AIZPURÚA, 2002; MANLEY, 2015; PITTAWAY, 1993).

In this paper, I explore the year-round phenology of *Macroglossum* at three Mediterranean sites located in Cádiz (S of Spain) for three years to clarify their phonological status of this species in the area. The aims of this study were as follows: (1) to study the year-round phenology of imagos and (2) to compare the abundance of moths among sites and years. To my knowledge, this is the first time that these aspects are studied for a Mediterranean site of S Europe.

Material and methods

Butterfly counts

I used the BMS (Butterfly Monitoring Scheme, cf. VAN SWAAY *et al.,* 2012) procedure to count butterflies. The BMS procedure counts the number of butterflies intercepted by the observer in a volume of space (5 m width or 2.5 m at both sides, 5 m tall and 5 m in front of the observer) while walking slowly through the itinerary. Local time, ambient temperature, cloud cover (in a scale ranging from 0 to 8) and wind speed (by using a 0-5 code of the Beaufort scale) were noted twice at the beginning and the end of the itinerary (cf. VAN SWAAY *et al.,* 2012). Counts were performed on days with no rain and ambient temperature > 13º C between 1000 and 1900 h local time. For this study, it was not necessary to capture any specimen. When necessary, a 10x40 Zeiss binocular was used to identify individual butterflies at a distance. Photos of 10 *Macroglossum* photographed by the author during BMS transects are available from www.biodiversidadvirtual.org (accessed by 23-III-2017).

Study sites

I performed year-round BMS butterfly counts at 3 study plots located around Cádiz Bay (Cádiz,

southern Spain). All these plots were located at low altitude (< 80 m a.s.l., distance between sites < 25 km) near the Atlantic Ocean sea shore. Climate of the area was typically Mediterranean with hot summers and mild winters. Rainfall during the winter and summer was extremely low. However, due to the low altitude and the proximity to the sea both winter and summer temperatures were less extreme than is typical for this climate-type. Thus, this climate-type is defined as "Mediterráneo submarítimo" (or sea-influenced Mediterranean climate, cf. FONT-TULLOT, 1983).

At each study plot, an itinerary (within 570 m - 2.6 km in length) that passed among the preferred butterfly sites was selected. According to BMS methodology, the itinerary was divided into 2-8 sections (between 200 and 800 m distance each). The characteristics of plots and the field work period were as follows:

1. Jerez (Jerez de la Frontera, Cádiz, 36.689009, -6.150112). The study area was located at the gardens of Zoobotánico Jerez, a typical zoological park (6.5 ha in size) settled at the western part of Jerez city. The whole area was covered by dense vegetation composed by more than 400 plant species (including trees, palms and bushes). Some trees were remarkably old (> 25 m tall and > 150 years). Animal enclosures were surrounded by trees, bushes and herbs where *Macroglossum* were recorded. The whole area was surrounded by roads and buildings. To perform the BMS censuses, I selected a 2 km, itinerary divided in 8 sections (between 200 and 350 m each). Field work was performed 1-7 days per week. Standard BMS censuses (see above), were performed from January 2014 to December 2016. Total distance covered on the BMS censuses was 954 Km (290 in 2014, 310 in 2015 and 354 in 2016).
2. Punta del Boquerón (Parque Natural Bahía de Cádiz, 36.407491, -6.218390, San Fernando, Cádiz). The study area was a nature reserve located at the sea shore, 4 km south of San Fernando city. The study plot was a sandy spit area surrounded by water (the Atlantic Ocean and the marsh area around "Caño Sancti Petri"). No roads or buildings were present in the area. Vegetation of the dune area was composed by shrubs of *Retama monosperma* (L.) Boiss. and typical sandy soil herbs (e.g. *Malcolmia littorea* L. R. Br., *Echium gaditanum* Boiss., *Anthemis maritima* L., *Lotus creticus* L.). The vegetation of the marsh area was composed of salt-adapted plants (e.g. *Limoniastrum monopetalum* L. Boiss., *Arthrocnemum macrostachyum* Moric. Moris, *Inula crithmoides* L., *Suaeda vera* Forssk. ex J. F. Gmel, *Limonium algarvense* Erben, *Sarcocornia perennis* Mill. A. J. Scott). The selected itinerary (2.6 km in distance) was linear and it was divided into 6 (300-800 m) sections that extended in a NW - SE direction, parallel to the seashore. BMS censuses were performed at least twice a month, from June 2014 to December 2016. Total distance covered on the BMS censuses was 309.4 km (23.4 in 2014, 88.4 km in 2015 and 197.6 in 2016).
3. Ecohuerto (El Marquesado, Cádiz, 36.460569, -6.117232). The area was devoted to low-intensity ecological agriculture composed of fruiting tree and orchards combined with seasonal vegetables in a typical heterogeneous mosaic-like landscape. The density of buildings in the area was very small. The study plot (1.7 ha in size) included tomatoes, beans, potatoes, cucumber, water melon etc. and isolated fruiting trees (e.g. *Punica granatum* L., *Olea europaea* L.) on an ecological production regime. The itinerary (distance = 0.92 km) was divided into 4 sections that elapsed through different crops of the area. Field work was performed at least once a month from March to December 2016. Total distance covert on the BMS censuses was 43.9 Km.

Data analysis

At each site, the overall number of *Macroglossum* recorded during BMS censuses and the distance walked per month were pooled before calculations. An abundance index based on the number of butterflies recorded per kilometer and month was then calculated. Overall, total distance

walked on BMS censuses was 1307.3 km: 954 at Jerez, 309.4 at Punta del Boquerón and 43.9 at "Ecohuerto".

RESULTS

Year-round phenology: A total of 206 *Macroglossum* imagos were recorded during BMS censuses. Of them, 130 were counted within the BMS transect (or 0.09 moths/km, Appendix 1) and 76 were recorded out (data of all years and sites pooled). The year-round abundance based on the overall number of moths recorded (N=206, Fig. 1) showed that (1) the species was recorded all year round at the study area, (2) the distribution showed three well-defined periods where the species was more abundant: one at the end of the winter (February-March), May and July and finally (3) the abundance of the species was higher from May to July (Fig. 1).

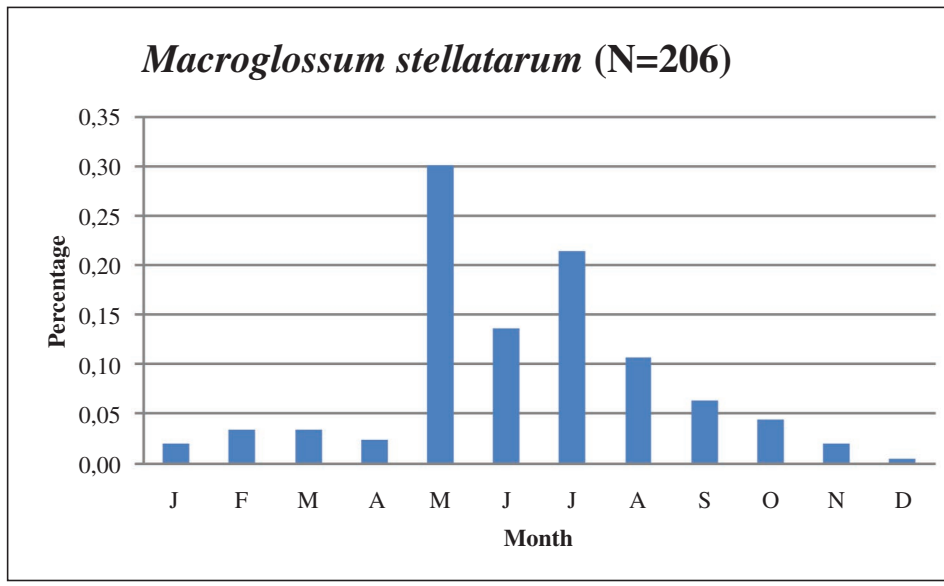

Figure 1.– Monthly distribution of the number of *Macroglossum stellatarum* (L.) imagos found during field work. Abundance was measured as the percentage of individuals recorded in each month. Data of three study sites and three years (2014-2016) were pooled for calculations. Overall, the total number of individuals recorded was 206.

Variation in the abundance among sites: Number of *Macroglossum* and their abundance index recorded on BMS censuses varied greatly among sites: 54 at Jerez (or 0.06 moths/km), 47 at Punta del Boquerón (or 0.15) and 29 at Ecohuerto (or 0.66). Monthly abundance of *Macroglossum* according to BMS censuses showed great differences among sites and years (Fig. 2). The species was univoltine at one site (Punta del Boquerón) and bivoltine at another (Ecohuerto) being recorded respectively, from May to July and from June to December. At Jerez however, the number of generations was unclear and two (probably more) generations were recorded (Fig. 2). Similarly, the abundance was remarkably different among years. For instance, abundance index at Punta del Boquerón was 0.34 in 2015 (N=30) and 0.06 in 2016 (N=12). Similar differences were recorded at Jerez site (Fig. 2).

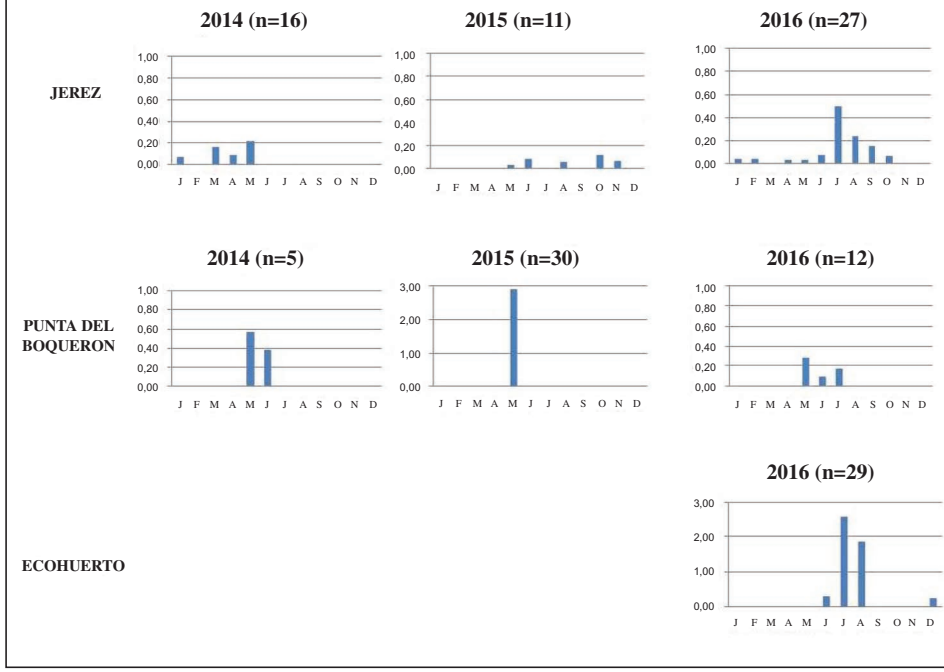

Figure 2.– Monthly abundance of *Macroglossum stellatarum* imagos recorded at the study plots from 2104 to 2016. Abundance represents the number of butterflies recorded per km and month according to BMS (Butterfly Monitoring Scheme, cf. VAN SWAAY *et al.,* 2012). Notice that the y-axis scale was different at Punta del Boquerón (year 2015) and Ecohuerto (year 2016).

Discussion

This study reports some interesting findings as follows. Firstly, *Macroglossum* was recorded all year round (including winter months) with three well-defined picks of abundance (February-March, May and July). Consequently, the species is trivoltine at our study area. Our results are different to other studies that suggested bivoltinism, with two overlapping generations between May and October (GÓMEZ DE AIZPURÚA, 2002; ZAPATA-SIERRA, 1982). On the contrary, our results were very like that reported by MORENO-BENÍTEZ (2016b) who gathered a total of 378 sporadic observations from a larger area (Málaga province, S Spain) between 2006 and 2015. In Málaga, the species show three generations with peaks of abundance in March, May and July, very like the phenology found in this study (MORENO-BENÍTEZ, 2016b: 338), Table I.

And secondly, the year-round phenology varied greatly both among study plots and among years for the same study plot. In fact, data suggest that *Macroglossum* was univoltine at Punta del Boquerón, bivoltine at Ecohuerto and probably, trivoltine at Jerez. In addition, the residence status was remarkably constant year after year at one site (Punta del Boquerón) but varied greatly at Jerez. To conclude, the species seem to be trivoltine at lowland sea-influenced habitats of Southern Spain with a variable and in some plots, unpredictable residence status among study sites and years.

I found little evidence of the migratory status of *Macroglossum* in my study area. In fact, the year-round phenology found in our study was remarkably different to that expected for a migratory butterfly

species. For instance, *Vanessa atalanta* (L.), a well-known migratory but diurnal species between the Mediterranean area and Scandinavia (BRATTSTRÖM *et al.,* 2008; BITZER, 2016; LARSEN, 1993; LUNDMARK, 2010; MIKKOLA, 2003; STEFANESCU, 2001)) was bivoltine with two peaks of abundance, one in late winter (February) and another in autumn (November) presumably coinciding to their migration north during the spring to reproduce and south in autumn to overwinter (Cuadrado, unpub. data). Similar results have been found in *Vanessa cardui* (L.) another migratory diurnal species in the area (cf. CUADRADO, 2016; STEFANESCU *et al*., 2016; TALAVERA & VILA, 2016 for the description of their migratory behavior in the Palearctic). Interestingly the years round phenology of resident but diurnal butterfly species (e.g. *Papilio machaon* L., *Iphiclides podalirius* (Duponchel), *Pararge aegeria* (L.) or *Pieris* spp.) showed three or more overlapping generations being recorded for more than seven months in a year (CUADRADO, 2016). In fact, *Macroglossum* was more abundant from May to July, the most favorable period for diurnal butterflies in my study area (CUADRADO, 2016). To support the residence status of *Macroglossum* in my study areas, I could record three females while egg laying at two of the study plots. In all cases, the plant selected was *Rubia peregrina* L.

However, the possibility that some *Macroglossum* imagos were recorded during their migration still remains open. It is important to remark that the whole area is near the Gibraltar Strait, a well-known hot spot for many migratory species. This might be more evident at Punta del Boquerón, a nature reserve close to sea shore where the migration of many bird species (storks, swifts, swallows and many others), dragonflies and also some butterflies and moths (e.g. *Autographa gamma* (L.), *Utetheisa pulchella* (L.) or *Vanessa cardui* (L.)) have been extensively recorded. If some (or all) *Macroglossum* recorded at Punta del Boquerón were imagos on migration, the logical question is why did I never record the same pattern during their post-reproduction migration in autumn? More data are needed to clarify this point.

My study also remarks the idea that *Macroglossum* is an obligate day-active species. In fact, I failed on recording the species neither in the evening nor by night (see also HERRERA, 1992). Other lines of evidence support this view. Firstly, the species was never recorded by night in the proximity of artificial lights at favorable areas (e.g. MORENO-BENÍTEZ & GALLEGO-DOMÍNGUEZ, 2016, MORENO-BENÍTEZ *et al.,* 2016a). Secondly, the species was never sampled on night light traps for moths (ANONIMOUS, 2016; MORENO-BENÍTEZ *et al.,* 2016b; David Barros and Miguel Olvera pers. comm.). And finally, thirdly, the species was often recorded while resting at favorable sites during the day (MORENO-BENÍTEZ & GALLEGO-DOMÍNGUEZ, 2016).

To conclude, this species seems to exhibit a residence status in the area and probably, complete three generation with remarkable variations in the abundance among sites and also, among years for a particular site. Evidence to support their migratory status in the area is unclear and further studies are needed to clarify this point.

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Appendix 1.– Monthly abundance of Humming-bird Hawk-moth (Macroglossum stellatarum) imagos recorded at the study plots from 2104 to 2016. Data per month was pooled for calculations. Abundance represents the number of butterflies recorded per km and month according to BMS (Butterfly Monitoring Scheme, cf. VAN SWAAY *et al.,* 2012).

JEREZ	2014			2015			2016			Total		
Month	Km	No.	Abundance	Km	No.	Abundance	Km	No.	Abundance	Km	No.	Abundance
January	32	2	0.06	18	0	-	24	1	0.04	74	3	0.04
February	18	0	-	12	0	-	24	1	0.04	54	1	0.02
March	38	6	0.16	24	0	-	30	0	-	92	6	0.07
April	24	2	0.08	20	0	-	32	1	0.03	76	3	0.04
May	26	6	0.21	36	1	0.03	34	1	0.03	98	8	0.08
June	26	0	-	36	3	0.08	40	3	0.08	102	6	0.06
July	32	0	-	10	0	-	8	4	0.50	50	4	0.08
August	2	0	-	36	2	0.06	34	8	0.24	72	10	0.14
September	28	0	-	34	0	-	40	6	0.15	102	6	0.06
October	22	0	-	26	3	0.12	32	2	0.06	80	5	0.06
November	18	0	-	32	2	0.06	26	0	-	76	2	0.03
December	22	0	-	26	0	-	30	0	-	78	0	-
TOTAL	290	16	0.06	310	11	0.04	354	27	0.08	954	54	0.06
PUNTA DEL BOQUERÓN												
Month	Km	No.	Abundance	Km	No.	Abundance	Km	No.	Abundance	Km	No.	Abundance
January	-	-	-	5.2	0	-	10.4	0	-	15.6	0	-
February	-	-	-	2.6	0	-	2.6	0	-	5.2	0	-
March	-	-	-	2.6	0	-	10.4	0	-	13.0	0	-
April	2.6	0	-	2.6	0	-	18.2	0	-	23.4	0	-
May	5.2	3	0.58	10.4	30	2.88	20.8	6	0.29	36.4	39	1.07
June	5.2	2	0.38	5.2	0	-	20.8	2	0.10	31.2	4	0.13
July	5.2	0	-	5.2	0	-	23.4	4	0.17	38.8	4	0.12
August	2.6	0	-	10.4	0	-	10.4	0	-	23.4	0	-
September	2.6	0	-	10.4	0	-	18.2	0	-	31.2	0	-
October	2.6	0	-	13	0	-	26.0	0	-	41.6	0	-
November	-	-	-	10.4	0	-	15.6	0	-	26.0	0	-
December	5.2	0	-	10.4	0	-	20.8	0	-	36.4	0	-
TOTAL	23.4	5	0.21	88.4	30	0.34	197.6	12	0.06	309.4	47	0.15
ECOHUERTO												
Month	Km	No.	Abundance	Km	No.	Abundance	Km	No.	Abundance	Km	No.	Abundance
January	-	-	-	-	-	-	-	-	-	-	-	-
February	-	-	-	-	-	-	-	-	-	-	-	-
March	-	-	-	-	-	-	-	-	-	-	-	-
April	-	-	-	-	-	-	1.8	0	-	1.8	0	-
May	-	-	-	-	-	-	4.6	0	-	4.6	0	-
June	-	-	-	-	-	-	7.3	2	0.27	7.3	2	0.27
July	-	-	-	-	-	-	8.2	21	2.56	8.2	21	2.56
August	-	-	-	-	-	-	2.7	5	1.85	2.7	5	1.85
September	-	-	-	-	-	-	5.5	0	-	5.5	0	-
October	-	-	-	-	-	-	4.6	0	-	4.6	0	-
November	-	-	-	-	-	-	4.6	0	-	4.6	0	-
December	-	-	-	-	-	-	4.6	1	0.22	4.6	1	0.22
TOTAL	-	-	-	-	-	-	43.9	29	0.66	43.9	29	0.66