

New records of moths (Insecta, Lepidoptera) from urban gardens on Terceira Island with new data on recently introduced species to the Azores

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The urban Duque da Terceira Garden, in the main town of Angra do Heroísmo (Terceira, Azores), was investigated to describe the species composition of moths (Insecta, Lepidoptera). Moths were sampled with two methods: SLAM traps (between April and September 2017) and light trapping (two sessions in the summer of 2017). A total of 42 taxa were sampled with the addition of 19 new records for Duque da Terceira Garden, five of which were also new records for Terceira Island. The five species recorded as new for Terceira were subjected to an exhaustive taxonomic analysis. In addition, we revised the colonization status of some species. Our results show that urban gardens may help the establishment of exotic species and that it is necessary to monitor and control how these species established in urban environments.

Key words: Lepidoptera, Azores, exotic, new records, urban gardens, invasive.

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INTRODUCTION

Azores have a unique arthropod fauna, which is reflected in the presence of about 266 endemic species and subspecies (Borges et al. 2010). However, during 600 years of human occupation the Azorean archipelago has been extremely impacted by human activities, mainly associated with the synergistic effects of dramatic land-use changes (only about 5% of the original forests still remain; Triantis et al. 2010), habitat degradation, and the introduction of exotic and invasive species (Cardoso et al. 2010; Triantis et

al. 2010; Borges et al. 2013, Terzopoulou et al. 2015). The ongoing spread of exotic species, along with the relatively poor fauna of the Azorean archipelago when compared with the other Macaronesian archipelagos and a presumably higher number of empty niches may imply that Azorean ecosystems are highly susceptible to the impact of introductions. In fact, the flora and fauna in the Azores are dominated by introduced species (Borges et al. 2010) and the impact of invasive species in the Azores is well documented (Silva & Smith 2006; Silva et al. 2008 a, b). Many exotic invasive plants like *Hedychium*

gardnerianum, *Pittosporum undulatum* and *Hydrangea macrophylla* are threatening several fragments of native vegetation and consequently are directly affecting the communities of Azorean arthropods (Borges et al. 2017, Borges et al. 2018).

This contribution focuses on one of the most diverse insect orders, the Lepidoptera, integrating moths and butterflies (van Nieuwerkerken et al. 2011). In the case of the Azorean archipelago, while the number of endemic species has continued to increase with new species descriptions (e.g. Wagner 2014, 2015), some exotic species have also been recorded for the islands (Wagner & Hausmann 2014). In the last published list of Lepidoptera species found in the Azores (Vieira & Karsholt 2010), historical data were compiled and analysed, adding new records and reaching a total of 150 different species and subspecies. About one third of these taxa were interpreted and classified as being in the Azores as a consequence of human introductions (Vieira & Karsholt 2010), in which snout moths (Pylalidae), fungus moths (Tineidae) and leaf-rollers (Tortricidae) are the families with the highest number of introduced taxa. However, poor knowledge of the taxonomic status and biology of most microlepidoptera makes it difficult to interpret the colonization status of many species and the current list of Azorean Lepidoptera needs revising.

The present contribution lists and provides faunistic and ecological information on some Azorean Lepidoptera species with an emphasis on five new records for Terceira (Portugal, Azores). It will also analyse the fundamental role played by urban gardens since they host a high diversity of ornamental plants and are the source of many potential invasive insect species.

MATERIAL AND METHODS

STUDY SITE

The current study was performed in Terceira Island, the third largest island in the archipelago of the Azores, with a surface area of 400.6 km². The study was conducted in the urban Duque da Terceira Garden in the main town of Angra do Heroísmo, at coordinates 38° 39.414'N; 27° 13.065'W (see Appendix 1). The garden has a large number

of ornamental plants, from annual plants to trees or hedges of different species.

SAMPLING

Moths were sampled using two methods: i) SLAM trap (Sea, Land, and Air Malaise trap approximately 110 x 110 x 110 cm, a passive flight interception trap that operated for six months between April and September 2017. We used propylene-glycol as it persists for a long time without evaporating, and enables the collection of good quality specimens for posterior DNA extraction; ii) light trapping with a UV tube of 12 W, with two sessions in the summer of 2017. All collected moths were identified, catalogued, preserved in 96% ethanol and stored under the curation of Paulo A. V. Borges (paulo.av.borges@uac.pt). Species images were obtained from specimens deposited in Dalberto Teixeira Pombo Insect Collection at the University of the Azores and other were ceded by http://www.pyrgus.de/index_en.php (credit: Wolfgang Wagner).

The list of species in Table 1 includes all the species recorded in the literature, based on a consultation of the AZORESBIOPORTAL at <http://azoresbioportal.uac.pt/>, and our SLAM and light trap collections. It does not give all the synonyms after the species name; to consult the list of synonyms see Vives Moreno (2014).

RESULTS

OVERALL DATABASE DESCRIPTION

A total of 836 individuals (SLAM trap 711 and light trap 125) were collected in Duque da Terceira Garden, belonging to 41 species or subspecies (Table 1). This originated 19 new records of Lepidoptera for Duque da Terceira Garden, five of which were new records for Terceira Island. It should be highlighted that seven Azorean endemics and three Macaronesian endemics have been recorded so far in Duque da Terceira Garden (Table 1). Of those ten endemic species, three were only recorded in the literature, namely *Ascotis fortunata azorica* Pinker, 1971, *Mesapamea storai* (Rebel, 1940) and *Noctua atlantica* (Warren, 1905). The present sampling

Table 1. List of the species recorded in the urban Duque da Terceira garden (Terceira, Azores). It gives the records in the literature, based on the AZORESBIOPORTAL, and number of specimens captured in SLAM trap and Light trap.

Colonization status as follows: MAC- endemic from Macaronesia; END – endemic in the Azores; n – native to the Azores; m – migratory species; I – introduced species; nat – naturalized. * – updated status MF at DTP – Code number in the Azorean Dalberto Teixeira Pombo insect collection at the University of Azores.

	Global N	Literature	SLAM trap	Light trap	Sex Ratio (M/F)	Colonization Status	MF at DTP	New island
Lepidoptera								
Moths								
FAMILIES								
BLASTOBASIDAE								
<i>Blastobasis desertarum</i> (Wollaston, 1858)	321	not recorded	320	1	166/154	MAC	1330	
<i>Blastobasis maroccanella</i> Amsel, 1952	92	2	83	7	32/51	MAC	918	
CHOREUTIDAE								
<i>Tebenna micalis</i> (Mann, 1857)	3	2		1	1/0	n*	731	
COSMOPTERIGIDAE								
<i>Pyroderces argyrogrammos</i> (Zeller, 1847)	1	not recorded		1	1/0	n*	1339	NEW TER
CRAMBIDAE								
<i>Euchromius ocella</i> (Haworth, 1811)	2	2		not found		n		
<i>Eudonia interlinealis</i> (Warren, 1905)	1	not recorded	1		1/0	END	1293	
<i>Eudonia melanographa</i> (Hampson, 1907)	8	4	4		3/1	END	1331	
<i>Herpetogramma licarsialis</i> (Walker, 1859)	24	not recorded	8	16	11/13	i*(nat)	1320	NEW TER
<i>Nomophila noctuella</i> (Denis & Schiffermüller, 1775)	3	2		1	1/0	m*	1344	
<i>Palpita virealis</i> (Rossi, 1794)	9	4		5	2/3	n	1324	
<i>Udea ferrugalis</i> (Hübner, 1796)	8	4	3	1	2/2	n	1135	
GELECHIIDAE								
<i>Aproaerema anthyllidella elachistella</i> (Stainton, 1859)	4		3	1	1/3	MAC*	562	
<i>Phthorimaea operculella</i> (Zeller, 1873)	2	not recorded		2	2/0	i	1327	
<i>Platyedra subcinerea</i> (Haworth, 1828)	3	2		1	0/1	i	1329	

GEOMETRIDAE									
<i>Ascotis fortunata azorica</i>	Pinker, 1971	2	2	2	not found		END	176	
<i>Costaconvexa centrostrigaria</i>	(Wollaston, 1858)	2	2	2	not found		n		
<i>Gymnoscelis ruffasciata</i>	(Haworth, 1809)	20	4	2	11	4/9	n	1290	
<i>Nycterosea obstipata</i>	(Fabricius, 1794)	8	2	1	5	2/4	n	42	
<i>Xanthorhoe inaequata</i>	Warren, 1905	1	not recorded		1	1/0	END	414	
GLYPHIPTERIGIDAE									
<i>Glyphipterix diaphora</i>	Walsingham, 1894	2	not recorded	2		1/1	MAC	1340	
NEPTICULIDAE									
<i>Stigmella aurella</i>	(Fabricius, 1775)	3	not recorded	3		2/1	i	1334	
NOCTUIDAE									
<i>Agrotis ipsilon</i>	(Hufnagel, 1766)	3	2	2	1	1/0	i*(nat)	337	
<i>Agrotis segetum</i>	(Denis & Schiffermüller, 1775)	4	4	4	not found		i*(nat)	105	
<i>Autographa gamma</i>	(Linnaeus, 1758)	3	2	2	1	1/0	m*	126	
<i>Chrysodeixis chalcites</i>	(Esper, 1789)	2	2	2	not found		m*		
<i>Ctenoplustia limbirena</i>	(Gueneé, 1852)	6	6	6	not found		n		
<i>Galgula partita</i>	Gueneé, 1852	6	2	2	4	1/3	n	1342	
<i>Helicoverpa armigera</i>	(Hübner, 1808)	1	not recorded	1	1	0/1	i*(nat)	1338	
<i>Hypena lividalis</i>	(Hübner, 1790)	2	not recorded	2	2	1/1	n	1323	NEW TER
<i>Hypena obsitalis</i>	(Hübner, 1813)	5	2	2	3	1/2	n	1335	
<i>Mesapamea storai</i>	(Rebel, 1940)	2	2	2	not found		END	389	
<i>Mythimna unipuncta</i>	(Haworth, 1809)	11	6	6	5	2/3	n	10	
<i>Noctua atlantica</i>	(Warren, 1905)	2	2	2	not found		END		
<i>Noctua pronuba</i>	(Linnaeus, 1758)	5	4	4	1	0/1	n	220	
<i>Peridroma saucia</i>	(Hübner, 1808)	2	2	2	not found		n	565	
<i>Sesamia nonagrioides</i>	(Lefèbvre, 1827)	2	2	2	not found		i		

<i>Spodoptera littoralis</i> (Boisduval, 1833)	7	not recorded	7	1/6	i*(nat)	1321
<i>Thysanoplusia orichalcea</i> (Fabricius, 1775)	4	4	not found		n	
<i>Xestia c-nigrum</i> (Linnaeus, 1758)	5	4	1	0/1	n	315
NYMPHALIDAE						
<i>Vanessa cardui</i> (Linnaeus, 1758)	2	2	not found		n	
PTEROPHORIDAE						
<i>Amblyptilia acanthodactyla</i> (Hübner, 1813)	1	not recorded	1	1/0	n	1345
PYRALIDAE						
<i>Aglossa caprealis</i> (Hübner, 1809)	1	not recorded	1	1/0	i	1333
<i>Cryptoblabes gniatella</i> (Millière, 1867)	16	not recorded	16	7/9	i	1322 NEW TER
<i>Phycitodes albatella pseudonimbella</i> (Bentinck, 1837)	4	not recorded	1 3	2/2	n	1328
SPHINGIDAE						
<i>Agrius convolvuli</i> (Linnaeus, 1758)	2	2	not found		n	
TINEIDAE						
<i>Eudarcia atlantica</i> Henderickx, 1995	6	2	4	3/1	END	1337
<i>Monopis crocicapitella</i> (Clemens, 1859)	3	2	1	1/0	i	1341
<i>Niditinea fuscella</i> (Linnaeus, 1758)	6	2	1 3	2/2	i	1326
<i>Oinophila v-flava</i> (Haworth, 1828)	240	not recorded	238 2	72/168	i	96
<i>Opogona omoscopa</i> (Meyrick, 1893)	25	4	17	10/11	i	852
<i>Opogona sacchari</i> (Bojer, 1856)	19	4	12	4/11	i	1332
TORTRICIDAE						
<i>Bactra lancealana</i> (Hübner, 1799)	2	2	not found		n	
<i>Bactra venosana</i> (Zeller, 1847)	2	not recorded	2	1/1	n	1343
<i>Crociosema plebejana</i> Zeller, 1847	16	2	7	4/10	i	1325
<i>Cydia molesta</i> (Busck, 1916)	2	2	not found		i	
<i>Epiphyas postvittana</i> (Walker, 1863)	3	not recorded	3	3/0	i	1336 NEW TER
<i>Selania leplastriana</i> (Curtis, 1831)	2	2	not found		n	

has added the presence in Duque da Terceira Garden of two Azorean endemics, *Eudonia interlinealis* (Warren, 1905) and *Xanthorhoe inaequata* Warren, 1905, and two Macaronesian endemics, *Blastobasis desertarum* (Wollaston, 1858) and *Glyphipterix diaphora* Walsingham, 1894.

TAXONOMIC DESCRIPTION

Cosmopterigidae

Pyroderces argyrogrammos (Zeller, 1847)

COMMON NAME: Cosmet moth.

TAXONOMIC NOTES: *Pyroderces argyrogrammos* was described in the genus *Cosmopterix* by Zeller (1847) but was reassigned to the genus *Pyroderces* by Herrich-Schäffer (1853). *Pyroderces argyrogrammos* does not present sexual dimorphism in the wing pattern and is distinguished from other species of genus *Pyroderces* by the following characters: orange-brown terminal cilia in the forewing on the upper side and male genitalia more robust in general with a complex uncus or a short phallus.

REMARKS: *Pyroderces argyrogrammos* can be distinguished externally from the other member of the family Cosmopterigidae in the Azores, *Cosmopterix pulchirimella* Chambers, 1875, by the wing pattern. However, *P. argyrogrammos* presents external similarities with two members of the family Gracillariidae: *Micrurapteryx bistrigella* (Rebel, 1940) and *Phyllonorycter messaniella* (Zeller, 1846). The main external difference is the presence of a black spot near the apex of the forewing.

EXAMINED MATERIAL: Portugal, Azores, Terceira, Angra do Heroísmo, public garden of Duque da Terceira, 33 m, Light Trap, 29 Sep 2017 (♂), J.V. Pérez Santa-Rita, P.A.V. Borges, R. Gabriel and A. Ros-Prieto.

DISTRIBUTION: Native range: Palearctic. The species occurs in central Europe, Mediterranean areas, part of Asia, North Africa and the Channel Islands (Sterling et al. 2004; Koster & Sammut 2006). In Macaronesian areas, it occurs in Madeira and the Azores islands (only cited for Pico by Vieira & Karsholt 2010) and is now recorded for Terceira.

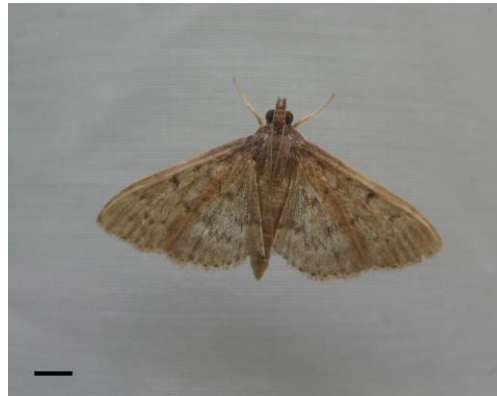
STATUS OF THE SPECIES: This species was considered introduced to the Azores (Vieira & Karsholt 2010), but we have changed it to native species in the Azores and Macaronesia region.

HABITAT: The species occupies dry habitats in Palearctic region, areas with a dominance of steppe (Huertas-Dionisio 2008). In the Azores the species mainly occurs in low altitudes particularly in garden areas, where ornamental plants can be their host plants.

BIOLOGY AND ECOLOGY: Larvae of *Pyroderces argyrogrammos* feed on seed heads of Asteraceae plants. The imago is considered a bivoltine species, since according to the literature it has two generations per year, one generation in June and another in August. The fully developed larva is about 7 mm long. The larvae feed on the flower heads of a number of plants such as thistle (*Carlina* sp.) and knapweed (*Centaurea* sp.), but are cited in other host plants (Koster & Sammut 2006; Huertas-Dionisio 2008). Global knowledge of natural enemies of *P. argyrogrammos* is limited.

Crambidae

Herpetogramma licarsisalis (Walker, 1859)
(Figures 1, 2).



Figs. 1, 2. Grass webworm *Herpetogramma licarsisalis*. (Scale bars 2 mm)

COMMON NAMES: Grass webworm, Sod webworm, Tropical grass webworm moth.

TAXONOMIC NOTES: *Herpetogramma licarsisalis* was described in the genus *Bothys* by Walker (1859), but is currently assigned to the genus *Herpetogramma*. Males and females of *H. licarsisalis* are almost similar, but the differences are in the antennae of the male, which are short, and in the wing colour, which is darker in males than in females (Goater & Knill-Jones 1999). *Herpetogramma licarsisalis* is distinguished from other species of genus *Herpetogramma* by the following characters: shape of the valva, rounded at the apex, and the length of the phallus that presents a complex of different cornuti, one at the basal part and another at apex in male genitalia and the length of ductus bursae, thickened, and the morphology of signum, elongated (Goater & Knill-Jones 1999).

REMARKS: There are no similar species in the Azores.

EXAMINED MATERIAL: Portugal, Azores, Terceira, Angra do Heroísmo, public garden of Duque da Terceira, 33 m, SLAM Trap, 21 July 2017 (♂, ♀), P.A.V. Borges and A. Ros-Prieto; Light Trap, 20 Nov 2017 (6♂, ♀10), J.V. Pérez Santa-Rita, P.A.V. Borges, R. Gabriel and A. Ros-Prieto; 29 Nov 2017 (4♂, ♀4), J.V. Pérez Santa-Rita, P.A.V. Borges, R. Gabriel and A. Ros-Prieto.

DISTRIBUTION: Native range: Tropical Africa,

Asia and Australia (Old World tropical). Introduced Range: The species is almost cosmopolitan, cited as

introduced species in many parts of the world (Davis 1969; Hardwick et al. 2000). In the Macaronesia region there are records of the presence of *H. licarsisalis* in Madeira and the Canary Islands (Aguilar & Karsholt 2006; Goater & Knill-Jones 1999). In the Azores it was only cited on Pico and São Miguel (Vieira & Karsholt 2010) and is now recorded for Terceira.

STATUS OF THE SPECIES: This species was considered a native species to the Azores (Vieira & Karsholt 2010), but we have changed it to introduced species for the Azores (subcategory naturalized).

HABITAT: Originally it is adapted to tropical habitats with dominance of grass plants. It has expanded to habitats where its host plants (family Poaceae) occur, and may also be observed in turf and pastures (Davis 1968). In the Azores there is a dominance of pastures where this species is abundant (J.V. Pérez Santa-Rita, unpubl.). Other types of habitat for *H. licarsisalis* are cultivated areas and gardens, where ornamental plants can become their host plants.

BIOLOGY AND ECOLOGY: *Herpetogramma licarsisalis* is a polyphagous moth. The imago is considered a multivoltine species in warm areas and it has a flight period that is uninterrupted practically all year (case of the Azores). The fully

developed larva is about 20 mm long. The larva lives on the foliage and culms of its host plants. There are numerous host plants for the larva of *H. licarsisalis*; the majority belong to the family Poaceae, which includes grasses and important crops such as rice, maize and millets (Davis 1968; Hardwick et al. 2000). Global knowledge of natural enemies of *Herpetogramma licarsisalis* is well reported. A large number of generalist predators are cited attacking the larva, such as spiders, ants and syrphid flies, but there are also specialist predators such as hymenopteran parasitoids (braconids, ichneumonids, scelionids and encyrtids) or tachinid flies attacking the larval and egg states (Davis 1968).

Gelechiidae

Aproaerema anthyllidella elachistella (Stainton, 1859) (Figure. 3).



Fig. 3. Twiler moth *Aproaerema anthyllidella elachistella*. (Scale bars 2 mm).

COMMON NAMES: Twiler moth.

TAXONOMIC NOTES: *Aproaerema anthyllidella elachistella* was described by Stainton (1859) as *Gelechia elachistella*. This taxon was synonymized by Walsingham (1907) and the individuals in Macaronesia were grouped within the subspecies range. It is necessary to reanalyse the taxon from the description of male and female genitalia and DNA barcode to determine whether the species occurring in the Azores is conspecific with the populations in Madeira and the Canary Islands.

REMARKS: There are no similar species in the Azores.

EXAMINED MATERIAL: Portugal, Azores, Terceira, Angra do Heroísmo, public garden of Duque da Terceira, 33 m, SLAM Trap, 21 August 2017 (♂, 3♀), P.A.V. Borges and A. Ros-Prieto.

DISTRIBUTION: Native Range: Macaronesian region. Species cited only in the Canary Islands, Madeira, Porto Santo and Desertas (Stainton 1859; Walsingham 1907). In the Azores it has been registered on Pico, Graciosa, Terceira, São Miguel and Santa Maria but described as *A. anthyllidella* (Vieira & Karsholt 2010). We have now identified and cited the Macaronesia subspecies *A. anthyllidella elachistella* for Terceira.

STATUS OF THE SPECIES: In the Canary Islands, Madeira, Porto Santo and Desertas the species is considered a Macaronesian endemic species. In the Azores it was considered an introduced species (Vieira & Karsholt 2010) but now we have changed its status to a Macaronesian endemic subspecies.

HABITAT: The species is adapted to habitats with dominance of herbaceous plants. The host plant in which it was originally cited is *Lotus glaucus*, abundant in low coastal areas (Walsingham 1907). In the Azores, the species can be found in coastal habitats with abundance and dominance of *Lotus creticus*, but also in cultivated and garden areas, where *Lotus* is growing.

BIOLOGY AND ECOLOGY: *Aproaerema anthyllidella elachistella* is a monophagous moth. The imago is considered a bivoltine species. The fully developed larva is from 7 to 9 mm long. The first generation of larval stage is a leafminer, while the second generation feeds on flowers and within sewn leaves. In the Azores the larvae of this species seems to be confined to *Lotus* species. However, in Madeira the larvae were reported feeding *Bituminaria bituminosa* (Aguiar & Karsholt, 2006). In continental Europe and North Africa larvae were reported attacking plants of Fabaceae like *Anthyllis* sp., *Coronilla* sp., *Cytisus* sp., *Lathyrus* sp., *Lotus* sp., *Trifolium* sp., *Medicago* sp. or *Vicia* sp. (Huertas Dionisio 2005). Global knowledge of natural enemies of *A. anthyllidella elachistella* is scarce.

Noctuidae

Hypena lividalis (Hübner, 1790) (Figures 4, 5).



Figs. 4, 5. Chevron snout moth *Hypena lividalis* (5. Photo: Wolfgang Wagner). (Scale bars 2 mm)

COMMON NAMES: Chevron snout moth, Snout moth.

TAXONOMIC NOTES: *Hypena lividalis* was described in the genus *Pyralis* by Hübner (1790). Subsequently, it was synonymized with the genus *Hypena* by Walker (1859). As regards the diagnosis, *Hypena lividalis* does not present sexual dimorphism in the wing pattern. It is distinguished from other species of genus *Hypena* by the following characters: unique wing pattern with the presence of an oblique white line in the forewing on the upper side that extends from costa to dorsum, delimiting the half of the wing near the apex with a brownish-greyish coloration and the other half of the wing with a brownish ochre coloration (Carvalho et al. 1999). Morphological characters of genitalia are very similar between species of the subgenus *Hypena*.

REMARKS: *Hypena lividalis* can be distinguished externally from the other member of the genus *Hypena* in the Azores, *Hypena obsitalis* (Hübner, 1813) by the wing pattern.

EXAMINED MATERIAL: Portugal, Azores, Terceira, Angra do Heroísmo, public garden of Duque da Terceira, 33 m, Light Trap, 20 Sep 2017 (♂, ♀), J.V. Pérez Santa-Rita, P.A.V. Borges, R. Gabriel and A. Ros-Prieto.

DISTRIBUTION: Native range: Paleotropical and subtropical part of Africa (Carvalho et al. 1999). The species also occurs in the Mediterranean areas of Europe (occasionally migrating further northwards in Europe) and it has colonized some Macaronesian islands (Canaries, Azores and Madeira). In the Azores it was only cited for São Miguel (Vieira & Karsholt 2010). This is the first record for Terceira.

STATUS OF THE SPECIES: This species is considered a native species to the Macaronesia region (Vieira & Karsholt 2010).

HABITAT: Originally it was adapted to tropical and subtropical habitats. It expanded to habitats with a dominance of host plants (*Parietaria* sp.) which could be observed in ruderal terrain such as walls, rocks and often coastal sites (Carvalho et al. 1999). Other types of habitat for this species are cultivated areas and gardens.

BIOLOGY AND ECOLOGY: *Hypena lividalis* is an oligophagous moth. The imago is considered a polyvoltine species in warm areas and it has a flight period that is uninterrupted practically all year (case of the Azores). The host plants of the larva are primarily species of genus *Parietaria* and sometimes *Urtica* spp. Records of feeding on other plants, such as lamb's quarters



Figs. 6, 7. Cotton worm *Spodoptera littoralis* (7. Photo: Wolfgang Wagner). (Scale bars 2 mm)

(*Chenopodium album*) or spinach (*Spinacia oleracea*) (Carvalho et al. 1999), require confirmation. Global knowledge of natural enemies of *H. lividalis* is scarce.

Spodoptera littoralis (Boisduval, 1833) (Figures 6, 7)

COMMON NAMES: African cotton leaf worm, Cotton worm, Mediterranean brocade, Mediterranean climbing cutworm, Egyptian cottonworm, Egyptian cotton leaf worm.

TAXONOMIC NOTES: *Spodoptera littoralis* was described in the genus *Hadena* by Boisduval (1833) but subsequently was reassigned to the genus *Spodoptera* by Viette (1963). Regarding the diagnosis, *Spodoptera littoralis* presents sexual dimorphism in the wing pattern, with an ochreous median area on the forewing between the antemedial and postmedial line in males. It can only be distinguished from other species of genus *Spodoptera* by the genitalia characters, because the wing pattern is similar and almost indistinguishable from other related species. Male genitalia present a juxta quadrate and ampulla robust and female genitalia present a distal margin of ventral plate with straight ostium and short ductus bursae (Popue 2002).

REMARKS: *Spodoptera littoralis* can be distinguished externally from the other members of the family Noctuidae in Azores. Although there are similar species like *Hadula trifolii* (Hufnagel, 1766) and

Xestia c-nigrum (Linnaeus, 1758), they are easily distinguishable from the wing pattern.

EXAMINED MATERIAL: Portugal, Azores, Terceira, Angra do Heroísmo, public garden of Duque da Terceira, 33 m, Light Trap, 20 Nov 2017 (5♀), J.V. Pérez Santa-Rita, P.A.V. Borges, R. Gabriel and A. Ros-Prieto; 29 Nov 2017 (♂, ♀), J.V. Pérez Santa-Rita, P.A.V. Borges, R. Gabriel and A. Ros-Prieto.

DISTRIBUTION: Native range: Tropical and subtropical part of Africa. Introduced Range: The species occurs in introduced areas of the rest of Africa, southern Europe and Asia Minor (Popue 2002). In the Macaronesia region the presence of *Spodoptera littoralis* is recorded for Madeira, Porto Santo and Azores (to date only cited on Faial, São Miguel and Santa Maria by Vieira & Karsholt 2010). This is the first record for Terceira.

STATUS OF THE SPECIES: In Madeira and Azores it was considered a native species (Vieira & Karsholt 2010). We have changed it from native to introduced species in the Macaronesia region (subcategory naturalized).

HABITAT: Originally, it was adapted to tropical and subtropical habitats. It has expanded to habitats with a dominance of scrub, such as a Mediterranean maquis habitat, cultivated areas or gardens and parks with presence of ornamental plants. In the Azores, it occurs preferably in cultivated areas and gardens but it possibly occurs

in native forest surroundings and grassy clearings as well as along sunlit forest roads in exotic coniferous forests.

BIOLOGY AND ECOLOGY: *Spodoptera littoralis* is a polyphagous moth. The imago has a flight period that is uninterrupted all year. Masses of eggs are put on the lower leaf surface of plants, and walls. Eggs are laid in batches covered with orange-brown hairs. The fully developed larva is from 35 to 45 mm long. There are numerous host plants for the larva. It is cited in the literature attacking plants in 44 different families including grasses, legumes, crucifers and deciduous fruit trees. In the Azores, the larva has been observed feeding on tobacco (*Nicotina tabacum*), beet (*Beta vulgaris*), pepper (*Capsicum* spp.), cabbage (*Brassica oleracea*) and different ornamental plants. Life cycle lasts from 19 to 144 days (Salama et al. 1971). Global knowledge of natural enemies of *Spodoptera littoralis* is well reported (Gerling 1969; Delvare & Rasplus 1994). A large number of hymenopteran parasitoids (braconids, ichneumonids and encyrtids) or tachinid flies attack the larval and egg stages.

Pyalidae

Cryptoblabes gnidiella (Millière, 1867) (Figure 8)

COMMON NAMES: Honeydew moth, Christmas berry webworm, Citrus pyralid, Earhead caterpillar, False blossom moth, Lemon borer moth.

TAXONOMIC NOTES: *Cryptoblabes gnidiella* was described in the genus *Ephestia* by Millière (1867). Subsequently, it was transferred to the genus *Cryptoblabes* by Ragonot (1893). As regards diagnosis, *C. gnidiella* presents sexual dimorphism. Females are smaller than males and the females have darker forewings, due to the low intensity in the transversal lines, of which one is more visible in males (greyish coloration). *Cryptoblabes gnidiella* is distinguished from other species in the genus *Cryptoblabes* by the forewing pattern being greyish-brown with the presence of interspersed red-brownish scales. At the level of genitalia, it is only distinguished by the male genitalia characters since females at

genitalia level are very similar to other females in the genus. The males have a broad, robust and



Fig. 8. Honeydew moth *Cryptoblabes gnidiella*. (Scale bars 2 mm).

elongated uncus compared to the other species and a characteristic phallus with a developed cornutus.

REMARKS: *Cryptoblabes gnidiella* can be distinguished externally from the other members of the family Pyralidae in the Azores. Although there are similar species, like *Ephestia elutella* (Hübner, 1796), *Ephestia kuehniella* Zeller, 1879 and *Phycitodes albatella pseudonimbella* (Bentinck, 1936), it is easily distinguishable by the wing pattern as *Cryptoblabes gnidiella* has interspersed red-brownish scales in the forewing.

EXAMINED MATERIAL: Portugal, Azores, Terceira, Angra do Heroísmo, public garden of Duque da Terceira, 33 m, Light Trap, 20 Nov 2017 (5♂, 8♀), J.V. Pérez Santa-Rita, P.A.V. Borges, R. Gabriel and A. Ros-Prieto; 29 Nov 2017 (3♂), J.V. Pérez Santa-Rita, P.A.V. Borges, R. Gabriel and A. Ros-Prieto.

DISTRIBUTION: Native range: Mediterranean. Introduced range: The species is almost cosmopolite, introduced in numerous areas like Asia, Africa, Caribbean, Oceania and South America (Dawidowicz & Rozwalka 2016). In the Macaronesia region there are records of the presence of *Cryptoblabes gnidiella* in Madeira, Porto Santo, Canary Islands and the Azores (to date only cited on Pico and São Miguel by Vieira

& Karsholt 2010). This is the first record for Terceira.

STATUS OF THE SPECIES: In Madeira the species was considered a native species and in the Canary Islands and Azores an introduced species (Vieira & Karsholt 2010). We have changed it from native to introduced species in the Macaronesia region.

HABITAT: Originally it is adapted to Mediterranean habitats with scrub dominance but it expanded to cultivated areas (Dawidowicz & Rozwalka 2016). In the Azores it occurs preferably in cultivated and garden areas with a presence of ornamental plants.

BIOLOGY AND ECOLOGY: *Cryptoblabes gnidiella* is a polyphagous moth. In Mediterranean climates, this species has three to four periods of adult flight activity. Eggs are laid usually singly or in small batches in a host plant. The fully developed larva is 12 mm long (Bagnoli & Lucchi 2001). There are numerous host plants for the larva; the common host plants are *Citrus* spp. (including orange, grapefruit and lemon), *Persea americana* (avocado), *Punica* spp. and *Vitis* spp. The life cycle of adults is 5 weeks, but it depends on temperature and host plant availability (Dawidowicz & Rozwalka 2016). Global knowledge of natural enemies of *C. gnidiella* is scarce but hymenopteran parasitoids (braconids, ichneumonids and encyrtids) have been reported predated the eggs and larval state (Bisoto et al. 2007).



Tortricidae

Epiphyas postvittana (Walker, 1863) (Figures. 9, 10)

COMMON NAMES: Light brown apple moth, often abbreviated to LBAM.

TAXONOMIC NOTES: *Epiphyas postvittana* was described in the genus *Teras* by Walker (1863). Subsequently, it was designated as genus *Austrotortrix* by Bradley (1956) but finally an exhaustive analysis meant that it was synonymized with the genus *Epiphyas* by Common (1961). Regarding diagnosis, *E. postvittana* presents sexual dimorphism and a high variation within each sex in the wing pattern. Besides, the wing pattern of other *Epiphyas* species in Australia resembles *E. postvittana*, which makes identification difficult. It is distinguished from other species in genus *Epiphyas* by the male genitalia characters, because the female genitalia are very similar to other species of the tribe Archipini. The male genitalia have a spatulate uncus and membranous lobe on the apex of the valva, a unique character in the genus (Brown et al. 2010).

REMARKS: *Epiphyas postvittana* is difficult to differentiate from another species in the family Tortricidae, *Pandemis heparana* (Denis & Schiffermüller, 1775). *Epiphyas postvittana* presents great variation in the wing pattern, and some morphotypes are similar to *P. heparana*.



Figs. 9, 10. Light Brown apple moth *Epiphyas postvittana* (10. Photo: Shane Farrell). (Scale bars 2 mm)

The main differences are found internally. Although both species are members of the Archipini tribe, differences in genitalia can be found. The male genitalia of *E. postvittana* presents a narrow uncus basally and membranous projections in the area of the cucullus of the valva.

EXAMINED MATERIAL: Portugal, Azores, Terceira, Angra do Heroísmo, public garden of Duque da Terceira, 33 m, Light Trap, 20 Nov 2017 (3♂), J.V. Pérez Santa-Rita, P.A.V. Borges, R. Gabriel and A. Ros-Prieto.

DISTRIBUTION: Native range: Southeastern region of Australia. Introduced Range: The species is introduced in numerous areas, cited in all biogeographic regions except for Antarctica (Brown et al. 2010). In the Macaronesia Region there are records of the presence of *Epiphyas postvittana*, but in the Azores to date it was only cited on São Miguel by Vieira & Karsholt 2010 and Pico (V. Vieira unpubl.). This is the first record for Terceira.

STATUS OF THE SPECIES: This species is considered introduced to the Macaronesia region (Vieira & Karsholt 2010).

HABITAT: *Epiphyas postvittana* is adapted to apple-growing areas in the south-eastern part of Australia (indigenous areas) (Brown et al. 2010). In the Azores it occurs preferably in cultivated and garden areas.

BIOLOGY AND ECOLOGY: *Epiphyas postvittana* is a polyphagous moth. The imago has 2 or more generations per year; it is a multivoltine species. This variation depends on temperature and latitude. Masses of eggs are laid on surfaces of host plants, including leaves, stems and fruits. The fully developed larvae have a length from 10 to 20 mm. In the first stages, the larva feeds on the undersides of leaves within a silk chamber, later it continues to feed on leaves, leaf rollers, or perforate and enter the fruit. The larva has been reported feeding and developing on more than 500 plant species, in 120 different families, although it has a preference for herbaceous plants. The common host plants are fruits such as apples,

blueberry, peach, pear and grapes or vegetables such as cabbage, corn, pepper and tomato. The life cycle of adults lasts 2 to 3 weeks, depending on temperature and host plant availability (Brown et al. 2010). Global knowledge of natural enemies of *Epiphyas postvittana* is well reported (Adler, 1991; Wearing et al. 1991; Hogg et al. 2013) and some spiders, chrysopids and mirids are cited as predators of larvae. Additionally, a large number of hymenopteran parasitoids (braconids, ichneumonids and encyrtids) or tachinid flies attack the larval and egg stages.

DISCUSSION

We have analysed five new moth records for Terceira Island, contributing data on their taxonomy, distribution, colonization status, biology and ecology. In general, we can affirm that there is a lack of information about the life cycle for many species, biased towards the microlepidoptera. In addition, we need more information about the beneficial auxiliary fauna that occurs in the Azorean islands. Regarding the status of colonization of the species treated in the present work, we must separate the changes into four groups (without any taxonomic value).

Firstly, the group of migratory species, in which the owlet moths (Noctuidae), along with hawk moths (Sphingidae) and diurnal butterflies, are the migrants *par excellence* in the order Lepidoptera (Dingle 2014). We have modified the status of *Autographa gamma* (Linnaeus, 1758), which occurs practically in the entire Macaronesian region (Ormi et al. 1978; Vieira 2002; Vieira et al. 2003) and was categorized as a native species in Azores, Madeira and Porto Santo (Borges et al. 2010). We have changed its status to migrant species as many studies state the migratory capacity of *A. gamma*, known as mass-migration events (Chapman et al. 2008a; b). The observation of *A. gamma* larvae is possible practically throughout the year (Carvalho et al. 1999), but the presence of adults is surely a mixture of both resident individuals plus individuals received from migrations. In addition, we have reported the presence of two migratory species from North Africa, whose adults are

reported during spring and autumn coinciding with their migration periods (García et al. 1992; Carvalho et al. 1999). The moths are a noctuid moth *Chrysodeixis chalcites* (Esper, 1789) (golden twin spot moth) and a grass moth *Nomophila noctuella* (Denis & Schiffermüller, 1775) (rush vaneer).

The next category is the native group, which is formed by species that were considered introduced to the Azores but we have changed the status to native for the Macaronesian region. The decision to change the status of the taxa in this group has been supported and always based on the following premises: they are species that originally had a Palearctic range, and have also been recorded on most islands in Macaronesia (Koster & Sinev 2003; Rota et al. 2014). In addition, the host plants of these taxa are native species of the Azores. The group is formed by one metalmark moth (Choreutidae) and one cosmet moth (Cosmopterigidae): *Tebenna micalis* (Mann, 1857) (small thistle moth) and *Pyroderces argyrogrammos* (Zeller, 1847).

Next, the Macaronesian group is formed by only one twirler moth (Gelechiidae): *Approaerema anthyllidella* (Hübner, 1813) (Figure 7). We analysed this case in detail, since in the Azores it was considered an introduced species (Vieira & Karsholt 2010), whereas in Madeira, Porto Santo, Desertas and the Canary Islands it was considered a Macaronesian endemic species as subspecies *elachistella*. It was reported living and feeding on *Lotus glaucus* in the Canary Islands (Klimesch 1984). The taxonomic study of the characters of genitalia in the individuals collected, in the present study, did not revealed differences between both subspecies (*elachistella* and *anthyllidella*). We assume that the individuals collected should be the subspecies *elachistella*, because they present a Macaronesian distribution, although a genetic analysis must be carried out to clarify the taxonomic identity of the subspecies present in the Azores.

The introduced group is formed by species that were considered natives but we have changed the status to introduced (subcategory naturalized) in the Macaronesian region. The group is formed by four noctuid moths: *Agrotis ipsilon* (Hufnagel, 1766) (black cutworm), *Agrotis segetum* (Denis & Schiffermüller, 1775) (common cutworm), *Helicoverpa armigera*

(Hübner, 1805) (cotton bollworm) and *Spodoptera littoralis* Boisduval, 1833 (cotton worm) (Figure 5, 6) and one grass moth *Herpetogramma licarsisalis* (Walker, 1859) (grass webworm) (Figure 1, 2). The four noctuids are important polyphagous pests; they have a wide range of host plants, affecting numerous economically important crops, including cotton, tobacco, tomato, rice, maize, potatoes, beans and chickpeas and a multitude of citruses (Hardwick 1965; Abdel-Megeed & Iss-Hak 1975, Busching & Turpin 1977, Drinkwater & Van Rensburg 1992). In contrast, *H. licarsisalis* is an important polyphagous pest of commercial and ornamental turf grasses but has been cited feeding on important crops (Tashiro 1976). The species has rapidly colonised the Macaronesian region, with the first records in the Algarve, Portugal and subsequently extending to the Canary Islands (Goater & Knill-Jones 1999), Madeira and Porto Santo (Borges et al. 2008). Before, it was only known on Pico and São Miguel (Vieira & Karsholt 2010), but it is now cited for Terceira and possibly will soon be recorded on all Azorean islands.

The absence of efficient monitoring of introduced products is the main cause of introduction of exotic species in the Azorean archipelago. In fact, food products or ornamental plants can harbour numerous species of larvae, including most species of Lepidoptera that are catalogued as introduced in the Azores. The application of quarantine and fumigation measures or improvement in the efficacy of inspection training of officials to detect symptoms of critical damage in the introduced products should be two of the mechanisms to be put in place to prevent future invasions (Borges et al. 2013). It should be noted that the results in the present study reflect the collecting methods that were used. The SLAM trap (Malaise trap), which was used during most of the research period, is less efficient to catch night flying Lepidoptera, compared to the much more efficient light trapping. However, the first method also collects flying insects during the day, and some of these are not – or only rarely – attracted to light. *Glyphipterix diaphora* Walsingham, 1894 is such a species. It is a northern Macaronesian endemic, which in the Azores is known only on Terceira (Vieira & Karsholt 2010).

Finally, there is the need to discuss the relative importance of urban gardens as repositories of insect diversity. The 19 new records for the public Duque da Terceira Garden include nine exotic species considered human introductions in the Azores, but also ten Azorean native species, including two Azorean endemics and two Macaronesian endemics (Table 1). Public urban gardens can be potential repositories of diversity (Agbogidi & Adolor 2013; Taylor & Lovell 2014) but in the Azores this still have to be confirmed by recording if larvae of the species in question complete their life cycles in the garden. However, urban gardens can also be a source of potential exotic insect species due to the introduction of new exotic plants. In our time, when nature – all over the world and in the Azores - is under pressure from urbanization or agriculture, urban gardens are increasingly becoming refugia for plants and animals. In many such gardens pesticides are no longer used, there is no hunting and prevails relative peace.

Summing up, Azorean biodiversity is increasing due to the establishment of exotic species (see also Borges et al. 2013), but it is necessary to monitor and control how these species established in urban environments affect native species that share the same habitat.

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Appendix 1. Panoramic photo with drone of the urban Duque da Terceira Garden (Photo: Agustín Jiménez Fernández Palacios).

