A contribution to the knowledge of the larval ecology of the Azorean *Phlogophora* (Lepidoptera: Noctuidae) with taxonomic notes on the complex of *P. interrupta* (*P. interrupta jarmilae* Saldaitis & Ivinskis, 2006, stat. rev.)

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Abstract: The author recorded larvae of all known Azorean species of *Phlogophora* Treitschke, 1825 (*P. cabrali* Pinker, 1971, *P. furnasi* Pinker, 1971, *P. interrupta* (Warren, 1905), *P. kruegeri* Saldaitis & Ivinskis, 2006, *P. meticulosa* (Linnaeus, 1758)) in the wild in the islands of São Miguel, Flores and Pico. Observations on larvae, hostplants and habitats are provided; larval descriptions and illustrations are given. All endemics are mainly found in the fog zones (400–1000 m elevation). Not two endemic and sympatric species have the same habitat requirements and main hostplant (*P. cabrali: Rubus, P. furnasi: Calluna vulgaris, P. interrupta* and *P. kruegeri:* ferns). All ecological factors which have been so far identified are described. *P. interrupta* can be devided into two subspecies: *P. interrupta* (Warren, 1905) in the central islands group of the Azores (type locality São Jorge) and *P. interrupta jarmilae* Saldaitis & Ivinskis, 2006 **stat. rev.** in São Miguel (eastern group).

Ein Beitrag zur Larvalökologie azoreanischer *Phlogophora* (Lepidoptera: Noctuidae) mit taxonomischen Anmerkungen zum Komplex von *P. interrupta* (*P. interrupta jarmilae* Saldaitis & Ivinskis, 2006, stat. rev.)

Zusammenfassung: Der Autor konnte Raupen von allen bekannten Arten von *Phlogophora* Treitschke, 1825 der Azoren (*P. cabrali* Pinker, 1971, *P. furnasi* Pinker, 1971, *P. interrupta* (Warren, 1905), *P. kruegeri* Saldaitis & Ivinskis, 2006, *P. meticulosa* (Linnaeus, 1758)) im Freiland nachweisen (Inseln São Miguel, Pico und Flores). Hier werden Beobachtungen über die Raupen, ihre Freiland-Nahrungspflanzen und die Larvalhabitate vorgestellt. Die endemischen Arten sind meist auf Höhenlagen zwischen 400 und 1000 m Höhe beschränkt (Nebelzone). Nicht zwei endemische und auf der gleichen Insel vorkommende Arten haben dieselben Habitatansprüche und Hauptnahrungspflanzen (*P. cabrali: Rubus, P. furnasi: Calluna vulgaris, P. interrupta* und *P. kruegeri:* Farne). Alle bislang erkannte ökologische Faktoren werden dargestellt. *P. interrupta* kann in zwei Unterarten gegliedert werden: *P. interrupta* (Warren, 1905) in der Zentralgruppe der Azoreninseln (Typenfundort auf São Jorge) und *P. interrupta jarmilae* Saldaitis & Ivinskis, 2006 **stat. rev.** auf São Miguel (Ostgruppe).

Introduction

The Azores in westernmost Europe are a group of nine islands of mainly volcanic origin in the Atlantic between Portugal and North America, politically belonging to Portugal. The islands are arranged in three groups. São Miguel is the largest island and belongs to the eastern group of islands, some 1500 km from the Portuguese mainland, some 1700 km from the African coast and about 3600 km from the United States east coast. Pico Island is the second largest island and located in the central group with a distance of 246 km to São Miguel. Flores belongs to the smaller islands and the western group of islands, some 511 km away from São Miguel and some 265 km from Pico.

Climatic conditions are quite balanced and humid in the Azores with nearly subtropical lowlands (Ponta Delgada in São Miguel: more than 1000 mm precipitation per year and monthly mean temperatures from 14°C in winter up to 22° in summer) and cooler, very wet mountains (precipitation up to several thousand mm per year, e.g. 3000 mm in São Miguel and 5000 mm in the western islands) generally raising up to elevations of 1000 or 1100 m above sea line and thus being located in the fog cloud zone (these clouds considerably contribute to total precipitation). Only Mount Pico with its altitude of 2351 m is above the general fog zone and thus drier. In winter, occasional frosts can occur above 400 m, but are rare and mild up to 1100 m. Only Mount Pico has more regular frosts and even snow in its upper zones.

Natural vegetation would involve large-scale laurel woodland (Laurisilva), Atlantic heath with *Calluna vulgaris* (L.) Hull (Ericaceae) and locally bogs. But these natural habitats have been largely influenced and destroyed by man. In São Miguel, lowlands and medium-high altitudes are transformed into cattle grazing fields, allochthonous coniferous forests or settlements. But the mountain ranges bear some nature reserves with more or less autochthonous vegetation that is so far saved from cattle. In Pico Island, pressure is generally lower, but the big problem is that there is no strict separation between cattle fields and laurel woodland and heaths. This means that cows reach almost all parts of the island with only few exceptions and cause great damage as Azorean native vegetation is very sensitive. Thus degradation stages dominate. Flores is somewhat intermediate.

Another problem are invasive plants introduced by man. For example, the Australian *Pittosporum undulatum* Ventenant (Pittosporaceae) is a real pest species in lower altitudes and so is the Himalayan ginger lilian *Hedychium gardnerianum* (Zingiberaceae) all over the islands.

In general, the nine islands are quite species-poor due to their isolation and volcanic origin. But for example among the occurring noctuid species, about one third are endemic to these islands, among them a couple of *Phlogophora* species.

Phlogophora Treitschke, 1825 is mainly a subtropical to tropical genus with only two species occurring in mainland Europe. But there are 4 endemic species (adults see in Figs. 11, 35, 54, 75–76) – *Phlogophora interrupta* (Warren, 1905), *P. cabrali* Pinker, 1971, *P. furnasi* Pinker, 1971 and *P. kruegeri* Saldaitis & Ivinskis, 2006 – known so far in the Azorean archipelago, besides the widespread *P. meticulosa* (Linnaeus, 1758). Another recently described taxon (*P.*

jarmilae Saldaitis & Ivinskis 2006) has been synonymised with *P. interrupta* by Fibiger & Hacker (2007).

The larvae and their ecology are poorly known in all four endemics (Hacker & Schmitz 1996, Fibiger & Hacker 2007). A bit more data is only available for the common species *P. interrupta* which has already been reared from egg several times (e.g. Pinker 1971, including description of larva). But even in that species obviously nobody searched for larvae in the field to reveal the ecology. For *P. cabrali,* there is the short statement by Pinker (1971) that he had managed to bring a *P. cabrali* larva up to the third instar with *Rosa* flowers in an ex ovo rearing from a captured female. Because of this he concluded that the larva would feed on *Rubus* (also Rosaceae) in the wild. Moreover, this young larva showed an unnatural pale white colour with a red touch, surely because of the unusual rose flower diet. A few other rearing attempts (ex ovo from captured females) have been realized (Herbert Beck, pers. comm.), but larvae always failed to reach the last instar. The larvae of the other two species – *P. furnasi* and the most recently described *P. kruegeri* (see Saldaitis & Ivinskis 2006) – are still completely unknown.

Fibiger & Hacker (2007) write on both *P. cabrali* and *P. furnasi* that "the early stages and food plants are described by Pinker (1963)". This is an error, not only because these species had been described not until 1971, but furthermore because there are no hints in Pinker's publications (also from 1971 and later) or in any other ones that would exceed my above citations of Pinker (1971). Pinker's Macaronesian publications (1962, 1963, 1965, 1969, see Lödl & Imb 1988) of the 1960s only dealt with the Canaries, as well as those after 1971 (e.g. 1974), with exception for 1983 (description of *Noctua carvalhoi* from Azores).

Material and methods

Larvae and eggs (the latter only in *P. interrupta*) have been searched in the field by visual investigation of the plants, especially the lower side of the leaves, during daytime, by beating the plants carefully with a stick and an umbrella (daytime) and by searching with a torch at night. Prior to knowing the exact hostplants of the species, I searched every available plant species that complied with following requirements: herby or smaller woody plant with year-round availability of green leaves. In the case of *P. interrupta* I had already the idea that this species should live on ferns because I know the Madeiran sister species *P. wollastoni* (Bethune-Baker, 1891) which shows a certain polyphagous behaviour in rearing, but is indeed found often on ferns in the field.

I observed the following numbers of larvae and eggs in the field: *Phlogophora cabrali:* 32 larvae, *P. furnasi:* more than 115 larvae, *P. interrupta:* more than 170 larvae and 40 eggs, *P. kruegeri:* 22 larvae, *P. meticulosa:* more than 80 larvae

With *P. interrupta* and *P. kruegeri,* additionally a breeding was realized with reared adults.

The mandibles can easily be studied by dissecting the empty head capsules after larval moults (for younger instars) and especially after pupation for the mature larva.

Results

Phlogophora cabrali

(Figs. 1–13, 15, 19.)

Eight larvae have been beaten from *Rubus* in March 2013 (Serra Devassa, São Miguel). In the same island 21 larvae can be recorded from *Rubus* both by beating and searching with a torch in December 2014. In Pico Island, three larvae have been beaten from *Rubus* in December 2014 (northern slopes of Cabeço do Caveiro). All larvae occurred between 400 and 800 m elevation.

Description of larva

L_1 larva yellowish green (after feeding) with more or less distinct darker pinacula.

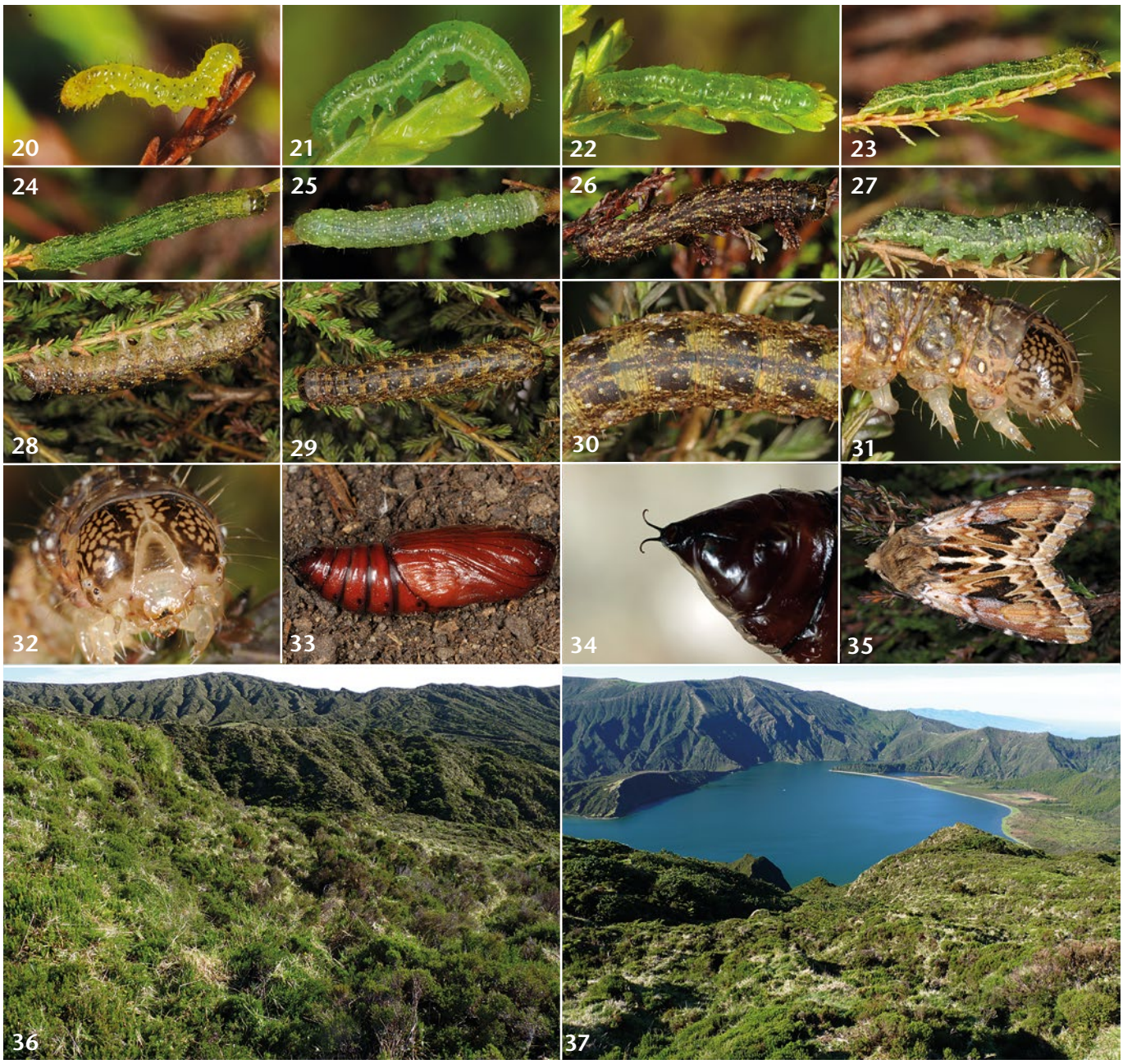
L_2 larva (Fig. 1) usually light grass-green with prominent yellowish, most often interrupted subdorsal lines and whitish, but not conspicuous bristle points. Dorsal line most often faint, only marked by darker green heart, but in some cases more conspicuous as an interrupted white line (most complete on throrax).

L_3 larva (Fig. 2) similar, but white bristle points now much more marked by black spots and angulated dashes on inner side. Subdorsal lines can be faint. Lateral lines broad yellow, interrupted, most complete on thorax and especially rear abdomen.

In penultimate (Figs. 3, 4) and last instar (Figs. 5–8) the black short dashes are much more numerous and not restricted to inner sides of bristle points (but here the most compact). They are curved to wavy, narrow and largely orientated in longitudinal lines. Dorsal line inconspicuous, but often with black intersegmental markings. Subdorsal line usually not visible. Lateral line as in L_3 broad yellow, interrupted and not sharply confined. Spiracles black with only very narrow light gap, light yellowish coronated. White bristle points are bordered darkish very narrowly. Head greenish yellow or greenish light brown, reticulate pattern present but most often indistinct, coronal stripes faint and usually only marked by indistinct darker colour. Outer sides of prolegs with large yellow flecks (most conspicuous in penultimate instar). Full-fed about 44–49 mm long, still light green, often more or less whitish breathed. Only a few individuals turn basic colour to light rosy-brownish or brown in last instar (Fig. 8).

There are only small white spots above SD1 in thoracic segments 2 and 3.

Figs. 1–13: ***Phlogophora cabrali,*** São Miguel. **Figs. 1–9:** larvae found on Monte Escuro in XII. 2014. **Fig. 1:** L_2. **Fig. 2:** L_3. **Figs. 3–4:** Penultimate instar, dorsal (**3**), lateral (**4**). **Figs. 5–8:** Last instar, normal green morph, dorsal (**5**), lateral (**6**), head (**7**); brown morph, dorsal (**8**). — **Figs. 9–10:** pupa; ventral (**9**), cremaster details (**10**). **Fig. 11:** ♀ imago. **Fig. 12:** *Rubus* thickets, Monte Escuro, 750 m, XII. 2014. **Fig. 13:** *Rubus* thickets, Serra Devassa, 750 m, III. 2014. — **Figs. 14–18:** *Phlogophora* larval mandibles (from empty larval skins after pupation), species from left to right. **Figs. 14–15:** *P. furnasi, P. cabrali* (both São Miguel). **Figs. 16–18:** *P. kruegeri* (Flores), *P. interrupta interrupta* (Pico), *P. interrupta jarmilae* (São Miguel). — **Fig. 19:** Larval habitat of *P. cabrali*, *P. furnasi* and *P. interrupta* with *Calluna, Erica, Rubus* and ferns: Pico Island, eastern part, north-facing-slopes in about 700 m, XII. 2014.



Figs. 20–37: ***Phlogophora furnasi,*** São Miguel, Serra de Àgua de Pau, larvae found in XII. 2013, Figs. 24–35 under rearing conditions. — **Fig. 20:** L_1. **Figs. 21–22:** L_2; (**21**) lateral view, (**22**) dorsal. **Figs. 23–25:** half-grown larva; (**23**) dorsal view, (**24**) lateral, (**25**) light form. **Figs. 26–27:** penultimate instar, different colour forms. **Figs. 28–32:** last instar; (**30**) dorsal detail, (**31**) head detail, lateral, (**32**) head frontal. **Figs. 33–34:** pupa; **34:** cremaster. — **Fig. 35:** ♂ imago. — **Figs. 36–37:** *P. furnasi,* large-scale habitat with *Calluna,* **36:** ca. 750 m, XII. 2013; **37:** both around Lagoa do Fogo, São Miguel, ca. 600–850 m.

Ecology

Larvae could be recorded on both *Rubus hochstetterorum* Seub. (endemic to the Azores) and *Rubus ulmifolia* Schott (naturalized in the Azores) in São Miguel and Pico. While younger larvae live underneath a leaf, older ones (at least in last instar) usually hide away in moss or litter under the plants and feed only at night. When moulting, the larvae sometimes not only spin a seat pad, but spin together some leaflets for a loose moulting cavity. Mature larvae construct a very weak cocoon in the ground, litter or moss and pupate immediately without dormancy (rearing observation).

Larval habitats (Figs. 12, 13, 19) are most often shady to half-shady, humid, wind-protected places at woodland edges, road cuts, depressions or clearings between 400 and 800 m (presumably up to 1000 m; humid fog zone). Denser growing *Rubus* stands are preferred to sparse, single twines. The species is not dependent on a certain type of surrounding vegetation. Larvae occur in and around allochthonous coniferous forests dominated by *Cryptomeria japonica* (L. F.) D. Don (Cupressaceae), in hedges between still more extensively managed cattle fields, in laurel woodland and also Atlantic heath dominated by *Calluna vulgaris*, *Erica azorica* and *Rubus* sp.

Phlogophora furnasi

(Figs. 20–37.)

In São Miguel, more than 40 young to half-grown larvae have been recorded mainly by carefully beating *Calluna*

vulgaris shrubs in the Serra de Água de Pau (600–900 m, especially Lombadas and Pico da Barrosa near the summit) during daytime in December 2013 and another 50 half-grown to mature larvae in the same places in March 2014, but then at night with a torch. In March, additionally 8 larvae could be observed in Serra Devassa, 6 of which on *Rubus*. 26 larvae have been reared on *Calluna vulgaris* in glasses under humid and dark conditions at about 17°C.

In December 2014, 16 young larvae were beaten from *Calluna vulgaris* in Pico Island (northern slopes of Cabeço do Caveiro, 850 m, northern slopes of Pico, 800–1000 m). One larva was recorded on *Rubus* in last instar at Monte Escuro in São Miguel feeding at night.

Description of larvae

L_1 larva (Fig. 20) is quite short (shorter, compacter than other species), yellowish green with black pinacula and quite long and comparatively dense hair.

In L_2 (Figs. 21–22) white, interrupted subdorsal lines appear as well as usually broad, conspicuous white lateral lines (stripe). Bristle points still blackish, sometimes a bit light coronated.

From L_3 onward, the then very small dark bristle points are broadly white coronated and dorsal line is more and more visible usually as a narrow, interrupted light line which is bordered on both sides by broader darkish stripes. Sometimes additional small, narrow white dashes appear on body surface. Ground colour is quite variable until penultimate instar (Figs. 23–25): grass-green, blue-green or brownish. Between L_3 and penultimate instar, more and more larvae shift from green to brown. At first, dark elements increase, especially the darkish bars at the inner sides of subdorsal lines in the front part of each segment.

In last instar (Figs. 28–32) finally all larvae have changed in ground colour to lighter or darker brown. Each larva then shows three different colours: white in coronae of bristle points, in stigmata and around ocelli on head. Light greenish or yellowish ochre (remnant of former green ground colour, lighter on ventral and sub-spiracle lateral side) and dark to blackish brown. The latter predominates on anal and thoracic shield which otherwise show only light bristle points and in case of the thoracic shield also the narrow light dorsal line. The dark colour is moreover concentrated dorsally in more or less inconsistent triangular, large flecks on both sides of the dorsal line with broad base near subdorsal line and tip towards dorsal line. Finally, other dark elements are located irregularly across the body, especially concentrated in spiracular level. Spiracles themselves are white, narrow black bordered. Above SD1 there are white spots in thoracic segments 2 and 3. But because of the other white bristle points and spiracles they are very inconspicuous.

Head (Figs. 31–32) light brown with dark reticulate pattern and coronal stripes well developed.

Full-fed, the larva is about 36–48 mm long.

Ecology

Phlogophora furnasi primarily feeds on *Calluna vulgaris*. Only a few (6) larvae could be found on *Erica azorica* Hochst. ex Seub. (a close relative of *Erica scoparia* L.), which also belongs to the Ericaceae family. Altogether 10 larvae could be recorded on *Rubus,* but in 8 cases *Calluna* grew between the *Rubus* stands. Only two larvae were found at *Rubus* with *Calluna* being absent within a 10 m radius. In rearing, *Erica* was preferred to *Calluna* probably because of its softer leaves.

Typical larval habitat (Figs. 19, 36–37) of *P. furnasi* is open, unused Atlantic heathland with plenty of *Calluna* in higher altitudes. It penetrates into open woodlands together with its hostplant (e.g. at embankments, clearings, rocks, road side verges etc.), but largely lacks in denser ones. Primarily, it is not a typical species of dark woodland. The larvae occurred in highest density in humid, shadowy, north-facing slopes in higher altitudes (usually above 500 m) with open heathland consisting of mosses, grasses (*Festuca francoi*) and small *Calluna vulgaris* shrubs. There it is sometimes syntopic with *Apamea sphagnicola* Wagner, 2014, but is generally much more widespread than the *Apamea*. A lower density was recorded in more sunny locations where higher growing *Calluna* or *Erica* had been interspersed with laurel forest or allochthonous conifers. Isolated stands of *Calluna* in lower regions most often lack the species. Generally, the higher the altitude of the site, the higher is larval density under otherwise comparable conditions (recorded between 500 and 900 m). On Pico da Barrosa (north side), the small *Calluna* shrubs were so densely inhabited by young larvae, that almost each shrub hosted one or more young larvae. In lower altitudes, only every 10th to 15th plant delivered a larva.

Beating on other shrubs in and near the habitats (e.g. *Viburnum, Vaccinium*, *Frangula* and other species of laurel forest formation) did not succeed in larvae.

The young larvae stay on the hostplant during the day, but the older ones leave it and hide on the ground in some depth in the moss, similar to many other noctuids. The larvae need much humidity and did not grow well in rearing when kept too dry. Pupation at least partly occurs in the moss layer as the observation of five empty pupal skins in *Sphagnum* moss show (place of high larval abundance, no ferns or *Rubus*). The mature larvae create a weak cocoon. Most larvae went into dormancy prior to pupation. Larvae that had been mature in spring always entered this prepupal dormancy which lasted from a few weeks to months. One larva found mature in December 2014 did pupate, however, without such a dormancy.

Phlogophora interrupta

(Figs. 38–57.)

More than 160 larvae and 40 eggs of *P. interrupta* have been found by all three methods mainly on ferns (in November–December 2013, March 2014 and December

2014) in various parts of São Miguel between 400 and 900 m (Lagoa do Canario and Serra Devassa in the west, Monte Escuro and surroundings, east of Furnas, Nordeste). 40 larvae have been collected and reared at home under similar conditions as *P. cabrali,* but on ferns of the genus *Dryopteris,* namely *D. carthusiana* (Vill.) H. P. Fuchs and *D. filix-mas* (L.) Schott.

Some 16 larvae were recorded in Pico Island (eastern part) on ferns in December 2014.

The egg (Fig. 38) is small, creamy and shows ca. 30 ribs on lateral side. Some days after oviposition, a reddish ring and a fleck on apex appear.

Description of larvae

Pinker (1971) gives a good description of the larvae, but the variability is not considered satisfactorily. Thus a supplementary description is provided here.

L_1 (Figs. 39–40) yellowish on hatching, but light green after feeding, with small light bristle points which are broader dark coronated (pinacula).

L_2 and most L_3 of green ground colour with medium-sized dark pinacula that are sometimes light coronated and/or accompanied by irregular white spots. Dorsal, subdorsal and lateral lines either absent or variable in broadness, white and usually interrupted, the lateral line most often being broadest. Sometimes the field between dorsal and subdorsal line is darker filled, appearing as two stripes which are darker confined on outer side.

From L_3 to last instar (Figs. 41–51) more and more larvae shift ground colour to brownish. Finally only about 5% remain green in last instar (in nature and breeding).

In penultimate and last instars, the few green larvae show whitish to light bordered bristle points with inconspicuous pinacula, an in density very variable net of small, irregular light yellowish to whitish spots, yellowish segment transitions and a variable intensity of dark markings (borders of pinacula and lines, other irregular spots and dashes).

The majority, which shifted to brown, shows following pattern: body with an irregular net of lighter spots, more or less light bristle points with more or less dark to black pinacula, a narrow light dorsal line which is bordered with black, a often lighter brown to ochre dorsal field with irregular lighter markings, an usually hardly visible subdorsal line, on inner side bordered by more or less distinct, interrupted and slightly transversal dark bars (in each segment diverging towards head). Ventral side in general lighter than dorsal side.

Spriacles from light brown to black, always black bordered. Dark thoracic shield with lighter bristle points, the narrow light dorsal line and light frontal spots where the hardly visible subdordsal lines should reach the head. Head variable greenish brown to brown with well developed reticulate pattern and variable coronal stripes.

Full-fed about 38–43 mm long (São Miguel) respectively up to 47 mm (Pico Island).

Larvae from São Miguel always show quite large white spots directly above bristle SD1 on thoracic segments 2 and 3 (Figs. 50–51). These spots are much more conspicuous than in the other species. Larvae from Pico Island, however, only show small, quite inconspicuous white spots there (Figs. 58–60).

Ecology

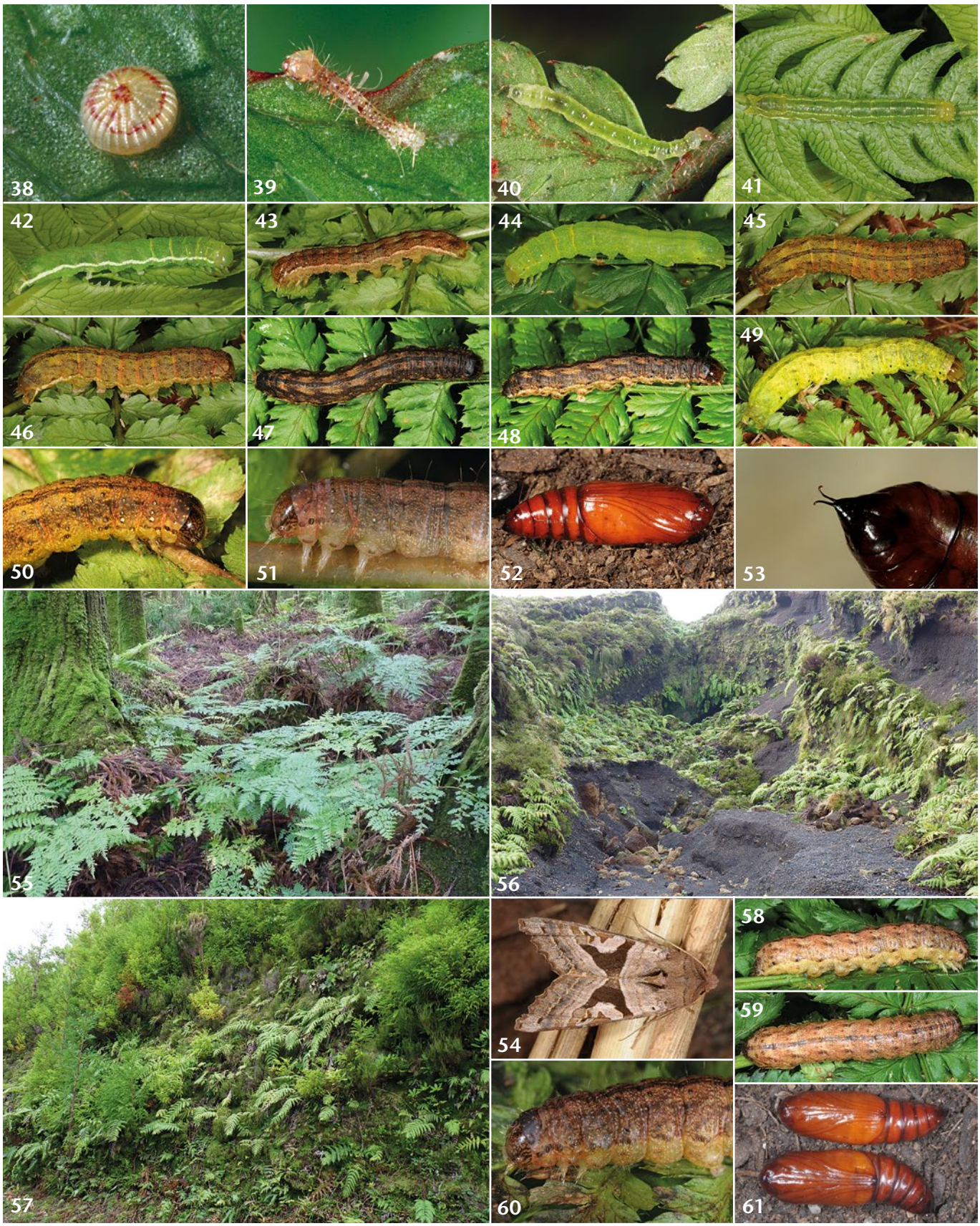
Phlogophora interrupta has been recorded as egg and young larva mostly on ferns of various genera [order in more or less decreasing importance]: *Dryopteris aemula* (Aiton) O. Kuntze, *Dryopteris affinis* (Lowe) Fraser-Jenk, *Osmunda regalis* L., *Dryopteris azorica* (Christ) Alston, *Athyrium filix-femina* (L.) Roth., *Woodwardia radicans* (L.) Sm., *Dryopteris crispifolia* Rasbach, Reichstein & Vida, *Oreopteris limbosperma* (All.) Holub, *Blechnum spicant* (L.) Roth. and a few undetermined others (families: *Dryopteris* = Dryopteridaceae; *Osmunda* = Osmundaceae; *Athyrium* = Woodsiaceae; *Woodwardia, Blechnum* = Blechnaceae; *Oreopteris* = Thelypteridaceae).

Older larvae most often feed on these ferns, too. But seven larvae have been found feeding on *Rubus* at night. In most cases ferns had been interspersed with the *Rubus* shoots. In December 2014, one single egg was observed on the lower side of a *Rubus* leaf. Ferns grew in the vicinity, but a few decimetres away.

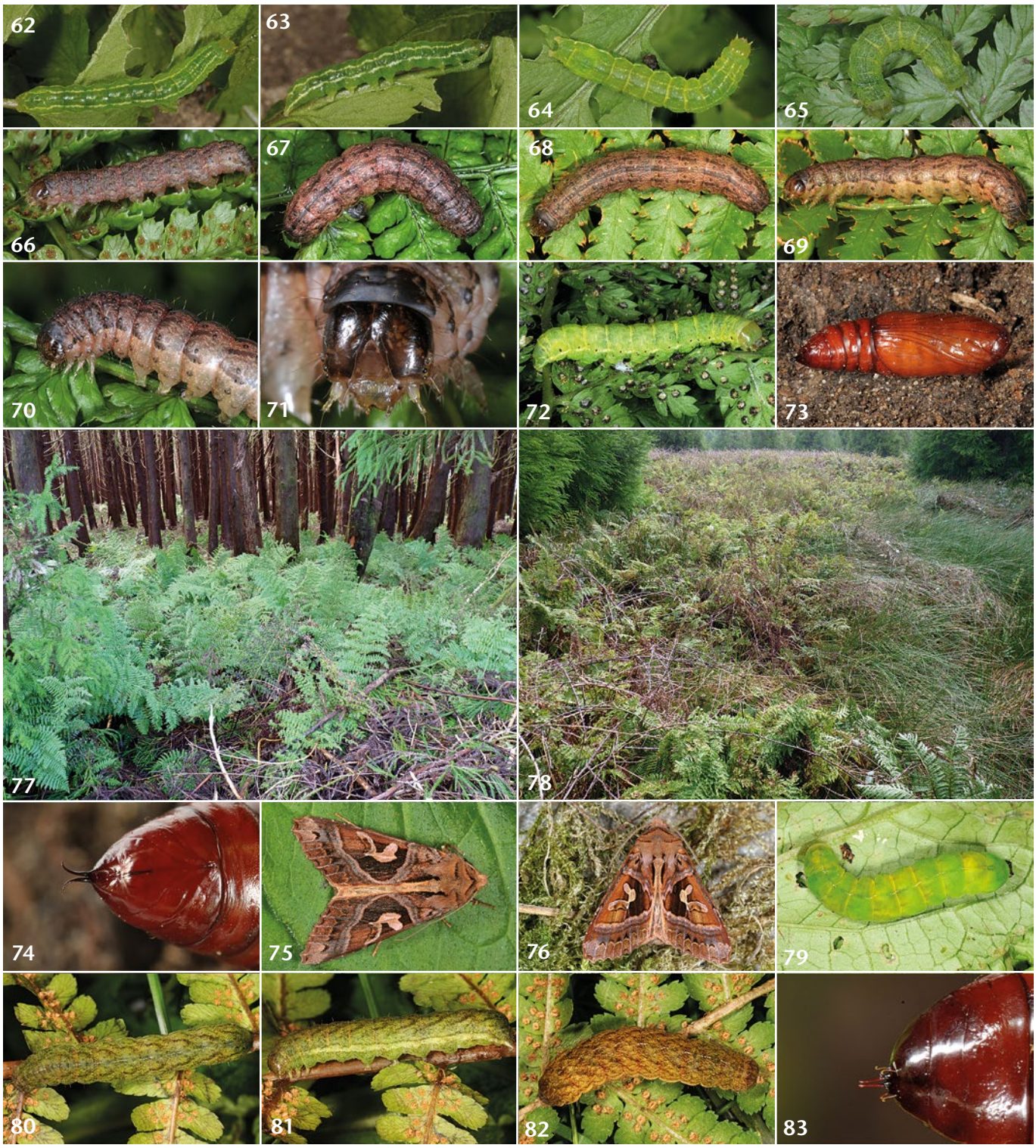
The species has a broad range of larval habitats (Figs. 19, 55–57) including dark and dense allochthonous coniferous forests with ferns in the understory, laurel forests, scrub, barrancos and open habitats as the Atlantic heathland. In the latter ones, north-facing slopes, ravines and depressions from pluvial erosion are preferred, but are not essential. But the species lacks completely on the nowadays widespread, over-fertilized cattle pastures, if they are not interspersed with wooded ravines, stony walls and other potential habitat, and in agricultural fields. The range in altitude is about 350 m to 1100 m. Lower reproduction sites are exceptional.

Larvae of this species have been recorded commonly in nearly any site that had been sampled. Oviposition occurs on the underside of fern leaves. The young larva rests there, too. From the third instar onward, more and more larvae become brown, especially early when feeding on ferns of poor quality (dead plant parts). But even in the penultimate and last instars, a few are still green and intermediate forms often occur. Older larvae rest superficially buried in the soil, litter or moss. At night, they climb on the plants (then mostly on the upper side of the leaves) in order to feed.

Mature larvae create a loose cocoon in the ground and most will pupate immediately or after a delay of a few days compared to the others. Only very few larvae (3) showed a dormancy of several weeks prior to pupation.



Figs. 38–57: ***Phlogophora interrupta jarmilae,*** São Miguel, Serra Devassa and Serra de Àgua de Pau; if not indicated otherwise, egg and all larvae found in the field in XI.–XII. 2013, but Figs. 45, 46, 49–54 in rearing. **Fig. 38:** egg. **Figs. 39–40:** L_1 directly after hatching (**39**) and end of this instar (**40**) (breeding from larvae found in the field in late 2013). **Fig. 41:** young larva. **Figs. 42–44:** half-grown larva with white lateral stripe (**42**); dark form (**43**), the typical and conspicuous white spots above SD1 on thoracic segments 2 and 3 (**44**). **Figs. 45–48:** last instar. **Fig. 49:** last instar, green form. **Figs. 50–51:** last instar, detail, typical and conspicuous white spots above SD1 on thoracic segments 2 and 3. **Fig. 52:** pupa. **Fig. 53:** cremaster. **Fig. 54:** ♀ imago. **Figs. 55–57:** São Miguel, larval biotopes with ferns. **Fig. 55:** understory of a dark coniferous forest, Serra Devassa, 800 m, XI. 2013. **Fig. 56:** shady gullies in open heathland, Serra Devassa, 700 m, XII. 2013. **Fig. 57:** *Osmunda* ferns in an embankment, east of Furnas, 600 m, XII. 2013. — **Figs. 58–60:** ***Phlogophora interrupta interrupta,*** Pico Island, eastern part, XII. 2014, from rearing; the white spots above/around SD1 on thoracic segments 2 and 3 are inconspicuous. — **Fig. 61:** comparison of average pupa size, **a** (top): *P. interrupta jarmilae,* São Miguel, **b** (bottom): larger pupa of *P. interrupta interrupta,* Pico.



Figs. 62–78: ***Phlogophora kruegeri,*** Flores, directly from larvae found in the field in III. 2014, or e.o. breeding from this material. Figs. 62–63: young larva. Figs. 64–65: half-grown larva. Figs. 66–72: last instar, different views, colour variation; 66–71: brown forms, 70: detail, white spots near SD1 on thoracic segments 2 and 3 inconspicuous, 71: head, 72: rare green form. Fig. 73: pupa. Fig. 74: cremaster. Figs. 75–76: imagos, ♀ (75), ♂ (76). Figs. 77–78: *P. kruegeri,* larval biotopes with ferns, central Flores, Ribeira Grande W Pico do Touro, 600 m, III. 2014. Fig. 77: understory of a dark coniferous forest. Fig. 78: wet clearing. — Figs. 79–83: ***Phlogophora meticulosa,*** São Miguel, for comparison. Figs. 79–82: last instar; green form (79), intermediate form (80), lateral view (81), brown form (82). Fig. 83: pupal cremaster.

Phlogophora kruegeri

(Figs. 62–78.)

In late March 2014 some 18 last-instar larvae of *P. kruegeri* could be observed on ferns (*Dryopteris aemula*, *D. azorica,* some indetermined others) in central Flores (Ribeira Grande W Pico do Touro, at about 600 m) especially at night, but four younger ones also by beating during the day.

Description of larvae

The larvae (Figs. 62–72) are similar to those of *P. interrupta*. The young, still green larva shows the same variability. In last instar, most larvae are dark (all larvae found in the field), but as in *P. interrupta* some may be still green (one larva in ab-ovo breeding). This green larva showed no obvious differences to *P. interrupta* from São Miguel except that the white spots above SD1 in thoracic

segments 2 and 3 are much smaller. It thus resembled *P. interrupta* from Pico Island.

The brown larvae obtained in the field are much more uniformous dark gray-brown and do not show the great variability of *P. interrupta*. Except for the lighter net of small spots no substantial ochre or light brown elements occurred in *P. kruegeri* larvae. But especially intersegmental a faint wine-red tinge is obvious in some individuals. Pinacula are always black. The head of grey-brown larvae is darker than in *P. interrupta*. The same applies for the thoracic shield which does not show light spots at frontal margin where subdorsal lines should end.

The full-fed larva is about 34–40 mm long.

Ecology

Larvae of this species were found on ferns in late March 2014 in Flores Island (Figs. 77–78). Most larvae occurred in and around a coniferous forest where they inhabited both quite dark understory and edges and clearings. Four larvae have also been observed in a more open mixture of heath vegetation, *Hortensia* and ferns near small streams. Young larvae live on the lower side of fern leaves, but older ones hide on the ground and feed at night where they climb ferns and often rest on upper sides of leaves. Mature larvae construct a loose cocoon and needed a few days longer to pupate than normal, but without a distinct dormancy.

Phlogophora meticulosa

(Figs. 79–83.)

About 80 larvae of this widespread species could be observed with all three methods in São Miguel Island at any time between sea level and 1000 m.

Descriptions of larvae are given for example by Beck (1999) and Ahola & Silvonen (2008). In larvae of *P. meticulosa* (Figs. 79–82), a narrow white dorsal line is always visible. It is most often conspicuous (but only faint in some cases) and usually interrupted (best visible at segment borders). This line is never bordered by compact, large dark elements. Mature larvae can be green or brown with white bristle points, white spiracles with black border, a broad white lateral stripe and sometimes dark chevrons in dorsal field, diverging to the front.

There are only small and very inconspicuous white spots above SD1 in thoracic segments 2 and 3.

This polyphagous species could be observed on various ferns (including *Dryopteris* spp., *Pteridium aquilinum* and *Blechnum spicant*), on *Rubus, Fragaria, Scrophularia, Polygonum, Rumex, Erica* and others in all possible types of habitat (sea shore, gardens, parking lots, wasteland, woodland, Atlantic heath in the mountains). The older larvae hide on the ground during daytime and feed only at night.

Larval mandibles

Mandibles of the caterpillars of the four endemics are quite similar to each other (Figs. 14–18). They tend to be hemispheric to some extent through rotation of the lower (first tooth) and upper (cutting area beyond third tooth) margins to the inner side. Thus perspective must be taken into account when examining. There are usually three main teeth and an additional broader rounding (cutting area) beyond the third tooth. This rounding may be more or less differentiated into some smaller tips (small teeth).

P. interrupta from São Miguel and Pico differ only very slightly. The three teeth are more or less equal in size with only the first being a bit shorter. In larvae from São Miguel, the rounding beyond tooth 3 is losing height faster than in larvae from Pico.

P. kruegeri has very compact mandibles with strong marginal rotation and a dominant second tooth.

Mandibles of *P. furnasi* are larger than those of *P. interrupta*, but differ hardly in other characters.

P. cabrali has small and the most deviant mandibles with a very dominant and rotated first (lower) tooth and reduced teeth 2 + 3.

P. meticulosa has not been examined because there are already good figures in, e.g., Ahola & Silvonen (2008: 522). This species does not differ substantially with regard to mandibles from *P. interrupta* and *P. furnasi*.

Pupae

The pupae of all endemic species are very similar to each other. Cremasters show two large hooks which are curved outward in the outer part, but are often a bit parallel at basis (except for *P. furnasi*, where they are always V-shaped). Only the pupa of *P. meticulosa* differs: the two mainly parallel hooks are quite weak and accompanied by four very small hooks (material from São Miguel, Fig. 83).

The pupa of *P. cabrali* (Figs. 9–10) is a bit larger than those of the other species.

Male pupae of *P. furnasi* (Figs. 33–34) are characterized by the broad antenna sheaths.

Pupae of *P. interrupta* from São Miguel (Figs. 52–53) are smaller on average than those from Pico (comparison in Fig. 61), but otherwise indistinguishable from each other and from *P. kruegeri* (Figs. 73–74).

Discussion

Larvae

All species show a specific larval colouration and ornamentations and are thus easily separated at least from half-grown to mature instars (except complex of *P. interrupta*).

P. cabrali can be separated in last instar from all other species by the combination of uniform light green or more rarely pinkish brown ground colour with black spiracles, white bristle points and a pattern of short, narrow black dishes.

P. furnasi has a very characteristic ornamentation, white bristle points and white spiracles.

P. interrupta, which is very variable as a moth, is also very variable as a larva (dark and light elements). It is separable by the combination of a narrow dorsal line with dark borders, light brown to black spiracles with black borders and the white spots above SD1 in thoracic segments 2 and 3, even if these are not as conspicuous in individuals from Pico (and presumably other islands of central group) as in those from São Miguel.

P. kruegeri is superficially hardly separable from *P. interrupta*, at least from the Pico population. I only observed a certain uniform grey-brown larval form which does not occur in *P. interrupta.* But *P. kruegeri* larvae have been recorded in much lower numbers than *P. interrupta* and there may be forms that are more colourful. Green larvae are obviously undistinguishable anyway. But mandibles are different and allow determination.

P. meticulosa has white spiracles and a white, broken and narrow dorsal line with no massive dark borders.

Mature larvae of *P. cabrali* and *P. furnasi* are more or less equal in size, though the variability is higher in *P. furnasi* (some larvae smaller). The moths of *P. cabrali* are the largest of the genus in the Azores. This can be explained by the dormancy of *P. furnasi:* larvae shrink much more prior to pupation than in *P. cabrali.*

While most *P. cabrali* and about 60–70% of *P. meticulosa* remain green in last instar, the majority of individuals of other species turn brown. This corresponds to the behaviour of the larvae and the specific density of foliage and quality of hostplants. Young larvae permanently live on the hostplant (lower sides of leaves) and are thus very well camouflaged. Older larvae hide on the ground during daytime and feed at night. Thus a brown colour is favourable then. Half-grown brown larvae for example of *P. interrupta* correspond with poor food quality. Most younger brown larvae have been recorded on ferns with high proportion of dead, brown leaf parts.

Tab. 1: Host plants of endemic Azorean *Phlogophora* in the field. ++: main hostplant; +: hostplant of secondary importance; ?: possible hostplant, but lack of sufficient data; — not observed as natural hostplant so far.

	***Rubus* spp.** (Rosaceae)	***Calluna vulgaris*** (Ericaceae)	***Erica azorica*** (Ericaceae)	**Ferns** (various species)
P. cabrali	++	—	—	—
P. furnasi	+	++	+	—
P. interrupta	+	—	—	++
P. kruegeri	?	—	—	++

Host plants

(See Tab. 1.)

Phlogophora cabrali seems to be restricted to *Rubus* (blackberry). All larvae have been recorded on this plant genus and larvae refused both ferns and *Calluna* in rearing to a large extent. It is not known if other Rosaceae species are accepted at least secondarily (for example *Fragaria*) in the field. By chance, Pinker (1971) guessed right that the larvae should live on *Rubus*. But if he would have used *Urtica* instead of *Rosa* for his rearing attempt (see introduction), his method would have led to the conclusion that the larva would live on *Urtica:* This plant was used by H. Beck (pers. comm.), and he brought larvae up to approximately the same instar as Pinker.

The main hostplant of *P. furnasi* is *Calluna vulgaris*. More than 90% of the recorded larvae lived on that species. *Erica azorica* from the same plant family is also used, but much less, though preferred in rearing. It is interesting that larvae could also been found on *Rubus*. In rearing, most larvae accepted *Rubus*. Even if many larvae may have switched from interspersed *Calluna* in the field, two records refer to *Rubus* at places where *Calluna* did not grow within a 10-m-radius. But it must be studied in the field if *Rubus* is regulary also used for oviposition.

P. interrupta is mainly restricted to ferns of various genera. It seems to be less polyphagous than *P. wollastoni* from Madeira (which seems to prefer ferns and possibly also *Rubus* in nature). Pinker (1971) used *Pteridium aquilinum* for breeding. But I also recorded this species on *Rubus,* in some cases feeding at night when searching with a torch. In most of these cases ferns grew together with *Rubus* and larvae may have switched. But oviposition also occurs there at least occasionally as is indicated by a single egg found on *Rubus*.

P. kruegeri has the same focus on ferns. It is unknown whether this species sometimes also uses *Rubus*.

P. meticulosa is a truely polyphagous species which uses a broad variety of ferns, herbs and low-growing woody plants in the field.

It is interesting that except for *P. kruegeri* (possibly only lack of data?) all other Azorean *Phlogophora* larvae can be found on *Rubus*. However, this is the main hostplant only for *P. cabrali*. Thus largely a separation concerning hostplants can be observed: not two species show the same main hostplant in the same island.

Herbal spermatophyts are not among the hostplants of the endemic species. Rearing on such substitute plant species (e.g. *Urtica*) did not succeed in obtaining mature larvae in *P. cabrali* and *P. furnasi,* but may work in some *P. interrupta*. Though a certain polyphagous strategy is intrinsic in *Phlogophora* in general, the Azorean endemics show clear restrictions and specializations in hostplants in the field.

Life cycles

All species are found as adults and presumably also as larva throughout the year (e.g., Fibiger & Hacker 2007). But rearing and field results indicate that the situation is a bit more complicated. *P. cabrali* and *P. meticulosa* have a continuous flow of development and obviously no dormancy stage. However, in *P. cabrali* reared numbers of larvae might be too low for final conclusions. *P. interrupta* showed a retarded pupation only in a small percentage of individuals. Thus it is found year-round, but some larvae might aestivate as a prepupa, contributing to an adult peak in autumn. *P. kruegeri* probably shows a similar behaviour.

In rearing, *P. furnasi* nearly always had a dormancy of mature larvae prior to pupation. This dormancy was very variable in duration. Adults of this species can be also found year-round, but with peak in autumn. In December, a very high peak of young larvae appeared at a minimum of older larvae and in March almost only older larvae could be detected. This may be explained as follows. The majority of larvae developing in winter are mature in March and April and create a cocoon where they undergo dormancy. Some of them pupate after some weeks and deliver summer or early autumn adults. The others (presumably the majority) will pupate not before early autumn and deliver adults between November and January. Conditions triggering this effect are not exactly known, but humidity, day length and temperature may be decisive.

This year-round life-cycle (with above-mentioned restrictions) is possible because even young larvae can cope with old and quite hard leaves of their hostplants. Even if *P. interrupta* prefers young fern leaves for oviposition, eggs and young larvae have also been found on older ones. In *P. furnasi* and *P. cabrali* almost no young leaves or shoots are available in *Calluna* or *Rubus* in winter. Especially *Calluna* shows only quite hard, mature plant parts at this time. The decisive factor for young larvae to cope with this situation probably is high humidity.

Habitats and threats

Phlogophora cabrali is quite widespread in medium and upper zones in and around woodlands and also in sheltered open landscapes with wind-protection. The species benefits from the spread of *Rubus* as a result of fertilization. But on the other hand, it can live in cattle pasture zones only if there are broad hedges and thickets with *Rubus* interspersed. In general, possible expansion of intense cattle pastures is the most important threat for this species, too. It restricts its habitats, but thanks to the species' flexibility it is not severely endangered at the moment.

Phlogophora furnasi is primarily an inhabitant of open and semi-open habitats, especially the Atlantic heath in upper zones and sparse, open laurel woodland. It must not be characterized as a forest species as it is the case, e.g., in Fibiger & Hacker (2007) or Hacker (1996), even if it may occur at forest edges with *Calluna, Rubus* or *Erica* stands. *Calluna,* the most important hostplant, does not grow in the darker understory. This main habitat type of open Atlantic heath has been pushed back heavily already in São Miguel, especially due to great extension of cattle pastures and afforestation with foreign conifers. It is thus threatened. Today, the largest moth population still occurs in the Serra de Água de Pau around Lagoa do Fogo. Medium-sized populations are known from the Serra da Tronqueira in the east and the Serra Devassa in the west. In other regions only small populations still persist. Responsible for this may be the species' ability to develop to some extent on *Rubus*. But São Miguel has the advantage that the three mentioned mountain ranges are largely protected now and more or less separated from cattle grazing. For example, in Pico Island the situation is partially worse even if the human population density is much lower than in São Miguel. In most areas of the eastern highland, cows are able to penetrate the remnants of laurel woodland and *Calluna* heaths. These do not tolerate this and degrade fast. Degradation stages result in more and more clear parts which are dominated by trivial plants (grasses etc.) and where *Juniperus, Erica* and *Calluna* are displaced to rocks or steeper parts. The final stage is open trivial grassland without any *Calluna* and only occasional remnants of *Juniper*. Cows should thus urgently be excluded from nature reserves and much of the most interesting and diverse parts of the highlands. The situation there is not at all comparable to Central Europe where the forest/pasture separation caused severe damage to light-dependent woodland edge species, because the autochthonous Azorean habitats are much more sensible to grazing and the resulting plant communities are of low quality and diversity. The European Union and its misdirected subsidies are unfortunately still one of the largest problems for nature in many parts of Europe. It remains to be seen if the situation will change after the most recent abandonment of EU milk quota.

In literature, *P. furnasi* is said to be much rarer than *P. interrupta*. This should now better be interpreted as "only locally common due to special habitat requirements and hostplant". In optimal open, cool, humid and nevertheless somewhat wind-protected habitats, the species can build up very dense populations, too (e.g. Pico do Barroso north side). But many entomologists including Pinker chose the famous Furnas region as collecting site, where *P. cabrali,* but especially *P. interrupta* are common in the forest and on bushy pastures, but where there are only very limited habitats of *P. furnasi.*

Phlogophora interrupta is a common species because it mostly develops on ferns and these are widespread in several types of habitat. It sometimes descends even into the cattle pasture zones and human settlements with wooded ravines, hedges and other partly forested patches. Its description as a forest species in literature is not false, but far too narrow. The habitat is only deter-

mined by the occurrence of ferns, enough humidity and a certain wind-protection especially in more open sites (higher densities then). Thus it can also settle open *Calluna* or *Erica* dominated heathland with ferns e.g. in depressions. The species is not endangered because of this ability to survive even in allochthonous coniferous timber fields and in hedges between pastures.

Except for ***P. meticulosa*** all species are focused on the fog zone between 400 and 1100 m elevation. None of the species has major reproduction habitats below this zone. Higher altitudes are only available on Pico Island and there on Mount Pico itself. But regions above 1200 m are usually above the fog cloud border and thus somewhat drier. Vegetation of Mount Pico is *Calluna*-dominated up to more than 2000 m above sea line. The zones above 1200 m often get frosts in winter. Thus a permanent occurrence of *Phlogophora furnasi* above 1200 m is quite improbable.

Taxonomical conclusions for the complex of *Phlogophora interrupta*

According to larvae and ecology, *P. interrupta* and *P. kruegeri* are very close to each other. *P. kruegeri* seems to be the only Azorean-endemic *Phlogophora* in Flores though potential habitat of *P. cabrali* and *P. furnasi* would be available. But it is not clear yet if this is only a lack of data in this island. I did not explicitly search for these species there. But I carefully searched for typical *P. interrupta* without success. Thus *P. kruegeri* is replacing that taxon in Flores – respectively, *P. kruegeri* is the further differentiated form of the otherwise widespread *P. interrupta* in the western group of islands (Flores and possibly Corvo). It obviously has the same ecology with ferns as primary hostplants, very similar larvae and adults. But apart from slight differences in genital structures (see Fibiger & Hacker 2007), larvae and adults of *P. kruegeri* show a certain distance and especially narrowing in phenotype compared to the variability of *P. interrupta:* All 18 larvae recorded in last instar in the field appeared almost identically greyish. This greyish form did not occur in the same intensity in any *P. interrupta*. But the much rarer green form – observed in breeding – should also occur in the field.

Adults show a phenotype that is less variable than in *P. interrupta* and shows some specialities hardly occurring there (e.g. course of brownish shade in central part of forewings, pink elements; for adult phenotype and genitalia see Saldaitis & Ivinskis 2006 and Fibiger & Hacker 2007). Thus *P. kruegeri* represents the most extreme form of the *P. interrupta* complex in the Azores, and species rank is justified.

Flores seems to be predestinated to produce such a deviant form: ever increasing 246 km distance (Flores lies on the American tectonic plate drifting westward some 2 cm per year) to the next island of the central group (Faial) and 511 km distance to São Miguel. Additionally, the western location impedes genetic flow from the more eastern central group because of the predominating westerly winds.

But is *P. interrupta* homogenous in the central and eastern groups of islands? Saldaitis & Ivinskis (2006) described another *Phlogophora* taxon from São Miguel: *P. jarmilae*. Fibiger & Hacker (2007) found no constant differences in genital structures (but genital differences are quite low in all Azorean *Phlogophora* anyway) and thus synonymised it with *P. interrupta*. That is surely correct on species level and is confirmed by most larval characters. But larval morphology reveals that larvae from São Miguel (eastern group of islands) and Pico (central group) differ at least in one character constantly: all larvae from São Miguel showed much larger (about double size) white spots above SD1 on thoracic segments 2 and 3. In all 16 larvae from Pico, these had been much more inconspicuous and thus similar to *P. kruegeri*. Other larval characters (colouration and pattern, also most features of mandibles) did not differ significantly. But apart from the discussed adult differences in morphology, obvious differences in average size of larvae, pupae and moths and different percentages of main forms in wing colouration and pattern variability this constant difference in an otherwise very constant larval character is a hint on genetic distance on subspecies level. While geographic distances are low within the central group (e.g. only 19 km from Pico to Sao Jorge), they are large to the eastern group (170 km distance from Terceira in central group to São Miguel).

P. interrupta was originally described from Sao Jorge. It is very unlikely that relevant differences occur within the islands of the central group. Thus the nominate subspecies *P. interrupta interrupta* (Warren, 1905) occurs in the central group. The *interrupta* specimens which Saldaitis & Ivinskis (2006) used for comparison with their taxon *jarmilae* originated from Faial which is only 9 km from Pico and 39 km from Sao Jorge. The taxon *P. interrupta jarmilae* Saldaitis & Ivinskis 2006 **stat. rev.** must then be applied for the population in São Miguel in the eastern group. The holotype of this subspecies (data: 1.–3. viii. 2005, Lagoa Azul) is, according to Saldaitis & Ivinskis (2006), in coll. University of Vilnius.

Because of similarities of adults, larvae (especially younger larvae) and ecology, the complex of *Phlogophora interrupta* may be considered as sistergroup of the Madeiran *P. wollastoni* (Bethune-Baker, 1891), and most probably both descended from a common ancestor. Though the close relationship of all Azorean *Phlogophora* (e.g., Fibiger & Hacker 2007; mostly stated because of little genital differences) can be confirmed, the other three species seem to stand a bit apart. However, I think that *P. furnasi* may be a bit closer to the *P. interrupta* complex (facultative dormancy, larval pattern, mandibles) than the others. Genetic research should be undertaken in order to reveal the relationships in more detail.

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