SPECIES RECOVERY PLAN
FOR THE MADEIRAN BRIMSTONE
Gonepteryx maderensis

Butterfly Conservation Europe
Madeira Fauna & Flora

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Contents

INTRODUCTION

This document presents a summary of all the information available for the Madeiran Brimstone *Gonepteryx maderensis* and the results of the field surveys undertaken during the field season of July to October 2021.

Species Recovery Plans (SRPs) are documents which bring together relevant information about a given threatened species, present an analysis of the threats that the species faces, and list actions needed to reverse these threats. If successful these actions will help protect the species from extinction and greatly improve its conservation status. SRPs are vital tools for the conservation of highly threatened animal and plant species. However, in Madeira, recovery plans have never been produced for endemic butterfly species, and therefore one of the aims of this document is to fill this gap and provide for the first time guidance for the conservation of threatened endemic butterflies.

This Species Recovery Plan is one of the outputs of the *Conservation of Madeira's Threatened Endemic Butterflies* partnership project by Butterfly Conservation Europe and Madeira Fauna & Flora, funded by LIFE4BEST.

The production of this SRP involved three steps. First, we gathered all the information available for the species in the form of scientific papers, reports and distribution records. Second, fieldwork was planned to survey a selection of areas within the Madeira Nature Park (Parque Natural da Madeira PNM) recording the distribution and abundance of the adult butterflies using a standardised methodology. Casual observations were also made of the species' ecology (e.g. nectar sources, larval hostplants), as well as any threats to the butterfly at each survey site. Photographs of typical habitat and identified threats were also taken at each survey site regardless of whether the species was present. Finally, we met with local stakeholders and conservation experts to develop appropriate measures and discussed possible conservation actions during 2022.

The document is divided into three main sections. The first section summarizes the available information for the species and shows new data gathered during the project. A second section deals with information that is relevant for the conservation of the species, particularly an analysis of the threats that have been mentioned for the species and those that were detected during fieldwork. The final section explains in detail the specific actions that are proposed for an improvement of the species' conservation status. At the end of the document there is a comprehensive list of references and an acknowledgement section.

IDENTIFICATION

The life-cycle of *G. maderensis* has been studied in detail by Aguiar et al. (2009) and is the main source of the descriptions provided below.

Wing morphology

The male imago has a wingspan of 52-57mm. The male forewing upperside is bright orange, with narrow yellow marginal borders and the hindwing upperside is yellow (Figure 1a). The forewing is scarcely falcate (Leraut 2016). Both fore and hindwings have orange discal spots, which are more distinct on the latter. Both the costa and outer margins are bordered by a fine reddish-brown line which is expanded and slightly darker at the vein extremities. The undersides are greenish-yellow with an orange tint in the forewings (Figure 1b). The small reddish-brown spots at the vein extremities are also evident on the undersides and the light red-brown discal spots with paler centres are present on both fore and hindwings.

Females are slightly larger with a wingspan of 59-61mm and broadly similar to the males but with pale yellow upper and undersides. The female hindwing is more strongly yellow than the forewing (Leraut 2016) (Figure 1c) and both the underside hind and forewing costal areas dull green (Tolman and Lewington 2008) (Figure 1d). On the upperside there is an orange tint near the forewing costa and on the underside a slight orange tint in the discal cell and costa.

In both sexes the thorax and abdomen are covered in long silver hairs and abdomen tips are dusted with yellow scales.

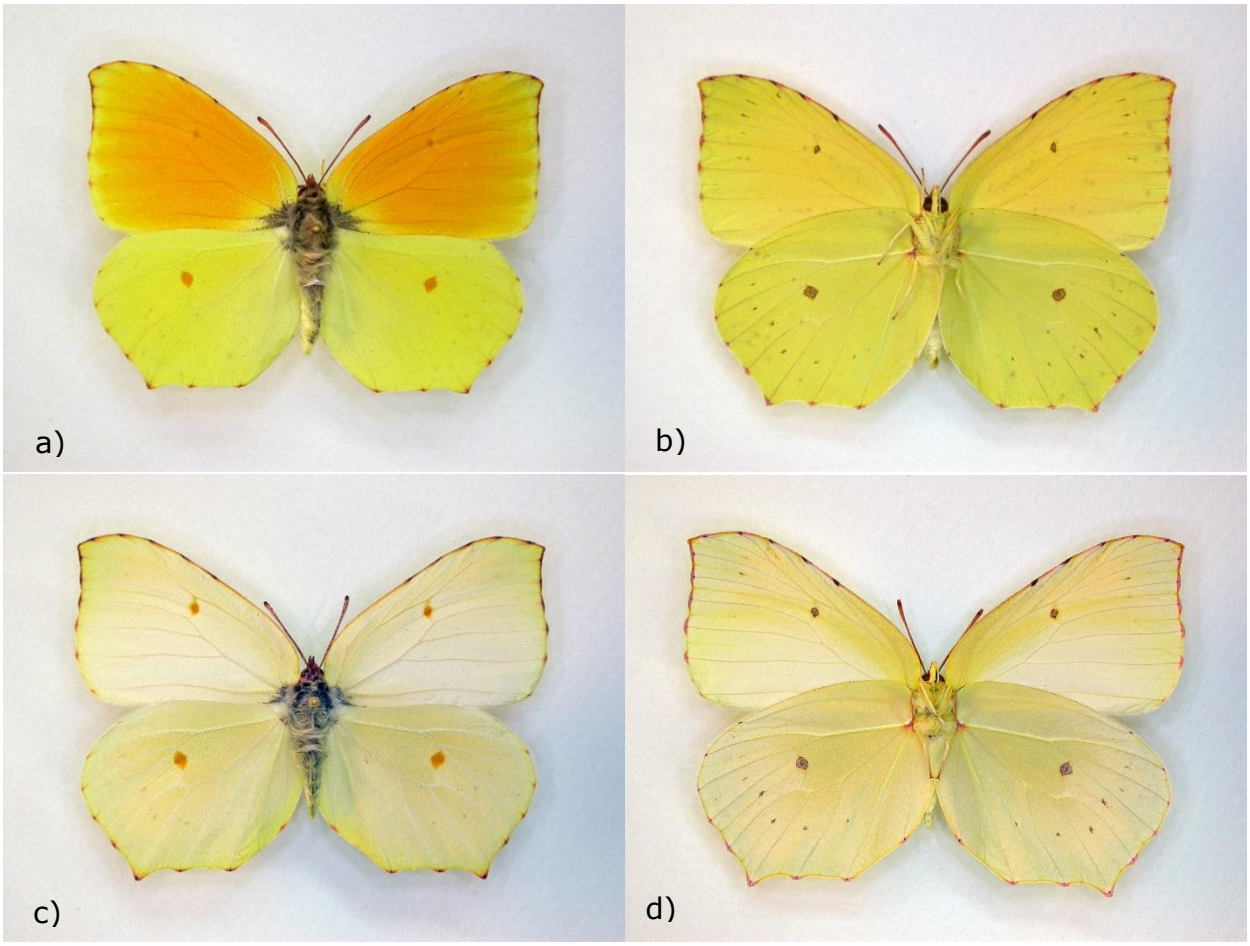

Figure 1: Madeiran Brimstone *Goneteryx maderensis* imagos. Male a) upperside and b) underside and female c) upperside and d) underside. Photo credits: António Aguiar

Immature stages

The cone-shaped egg is 1.45 to 1.50mm in length and is yellowish-white when first laid becoming orange-yellow closer to hatching (Figure 2a). The egg-case has nine vertical keels separated by wider furrows.

The freshly emerged larva is about 2mm in length and yellowish-green in colour. The full-grown larva is green with a narrow spiracular white strip running along the whole length of the body (Figure 2b). A white suffusion occurs above the horizontal line and the larva has a velvety appearance due to the presence of minute black dots, which are in fact setae with tubercles. There are four instars with lengths of 8mm (first), 12mm (second), maximum 18mm (third) and maximum 35mm (fourth instar).

The pupa is 23—26mm in length, pale green in colour longitudinal white stripes visible on the larva disappear (Figure 2c).

Figure 2: Madeiran Brimstone *Goneteryx maderensis* immature stages a) Ovum laid on *Rhamnus glandulosa* twig b) Fourth instar larva c) pupa on *Rhamnus glandulosa* twig. Photo credits: António Aguiar

TAXONOMY

Common name: Madeiran Brimstone (English) or Cleópatra da Madeira (Portuguese)

Latin name: *Gonepteryx maderensis* C. Felder, 1862

Phyllum: Arthropoda

Class: Insecta

Order: Lepidoptera

Family: Pieridae

Five species belonging to the *Gonepteryx* genus occur in Europe. The Brimstone *G. rhamni* is widespread across Europe, the Cleopatra *G. cleopatra* is restricted to southern Europe and the Powdered Brimstone *G. farinosa* to south-eastern Europe. Only two species occur on the Macaronesian islands, with the Canary Brimstone *G. cleobule* restricted to the Canary Islands and the Madeiran Brimstone *G. maderensis* restricted to the island of Madeira.

Recent phylogenetic study (Wiemers et al. 2020) suggests that *G. maderensis* is most closely related to *G. cleopatra* and then *G. farinosa*, whereas *G. cleobule* is more closely related to *G. rhamni*. The p-distance in COI barcodes between *G. maderensis* and *G. cleopatra* is only 0.5%, which is below the usual threshold of about 2% between most distinct species. In fact, *G. maderensis* was previously considered a subspecies of the Cleopatra and named *G. cleopatra maderensis*.

DISTRIBUTION

Historical distribution

G. maderensis is a European endemic restricted to Madeira Island. Its distribution is closely associated with the distribution of primary laurel forest on the island. Wakeham-Dawson et al. (2002) collated the locations of specimens in museum and private collection, as well as records in published and unpublished papers for the period 1850 and 2000 (Figure 3). Records were plotted on a UTM 1 km^2 grid. *G. maderensis* was recorded from 28 km^2 between 1950 and 2000 but at only 2 km^2 between 1900 and 1950, one of which was not subsequently re-recorded in the most recent period.

In a later study by Aguiar et al. (2009), records on the same UTM scale were presented for the period 1932 (the earliest known record) to 2009 (Figure 4). *G. maderensis* was recorded from 47 km^2, with 19 new km^2 added since 2000. Note

that one square for Quinta Grande (28SCB1115) was erroneously mapped in the earlier paper and subsequently remapped in Aguiar et al. (2009).

Current distribution

Surveys were undertaken in August and September 2021 by walking 49 pre-defined transect routes of approximately 5km length, focussing primarily on *laurissilva* forest but also including other forest types, some open habitats and some close to urban areas. Recording was undertaken on both outward and return walks, so approximately 10 km was surveyed per transect route. Both butterfly distribution and abundance of all species were recorded using the 15-minute Count function in the ButterflyCount app (see *https://butterfly-monitoring.net/bms-methods* for method details); this app is especially useful for gathering butterfly data even in remote areas. The app records the routes sampled and the exact location of each butterfly through the phone's GPS. This can also be done manually by drawing the recorded area but was not necessary in our study. A total of 648 timed counts were made and the data were then analysed using R software to model the distribution of the 14 species of butterfly recorded.

We also used drones to try and survey butterflies and their larval hostplants in more remote and inaccessible areas. However, the image resolution was too low to accurately identify either butterflies or plants, so no drone data is included in the analysis reported below.

In total 117 adult *G. maderensis* were recorded from 16 transect routes (33% of the total surveyed) on 18 survey days. These data were plotted on a ETRS 1 km^2 grid and the density of butterflies recorded as number per 1000m (Figure 5). In total *G. maderensis* was recorded from 29 km^2. The density of adult butterflies varied from 0.1 to 6.8 per 1000m.

Nearly all adult *G. maderensis* butterflies recorded were males. Of the historical records collated by Aguiar et al. (2009) where the sex of the imago is noted, 73% were males (n = 80) and 27% females (n =29). Whilst most butterfly surveys record a higher proportion of males than females, the extent to which the sex ratio was skewed in this species was far greater than is typical for butterflies. Differences in sex ratios in the field do not normally reflect actual differences in numbers of each sex, but are more usually the consequence of behavioural differences. Although we cannot say with certainty, our observations suggest *G. maderensis* females appear to be much less active than the more mobile males (see also Phenology and behaviour, page 24).

Our data confirm the findings of earlier studies that *G. maderensis* has a restricted distribution on Madeira, and one which is closely associated with the distribution of primary laurel forest, although the butterfly was occasionally recorded outside this habitat. Our data also shows this species occurs only at very low densities on the

island and is far from abundant even in the best sites. The butterfly's phenology is discussed in more detail later (page 24), but it is worth noting here that our study was undertaken during the peak flight period (July to September) when the adult butterfly is actually most abundant (Aguiar et al. 2009).

Whilst a direct comparison with the two earlier studies is not possible because we used a different map projection, the distributions from all three are broadly similar. However, in our study the butterfly was only recorded from the north of the island, whereas the two earlier studies indicate a wider distribution including parts of southern Madeira. Since our study sampled across the island, it suggests that *G. maderensis* has indeed contracted in range and that our results are not a sampling artefact.

An advantage of the density map is that it is possible to identify key areas for *G. maderensis* where conservation actions can be mainly focussed. Geographically separate localities where the density of *G. maderensis* was at least 0.3-0.8 per 1,000m were considered key areas.

Altogether we identified eight key areas for the butterfly which are shown in Figure 2:

1. Chão da Ribeira
2. Caramujo
3. Encumeada
4. Ponta Delgada
5. Boaventura
6. Caldeirao Verde
7. Ribeiro Frio
8. Portela

In six of the eight key areas, *G. maderensis* density was at least 0.8-1.3 per 1,000m. All eight key areas fall within the boundaries of the Madeira Nature Park.

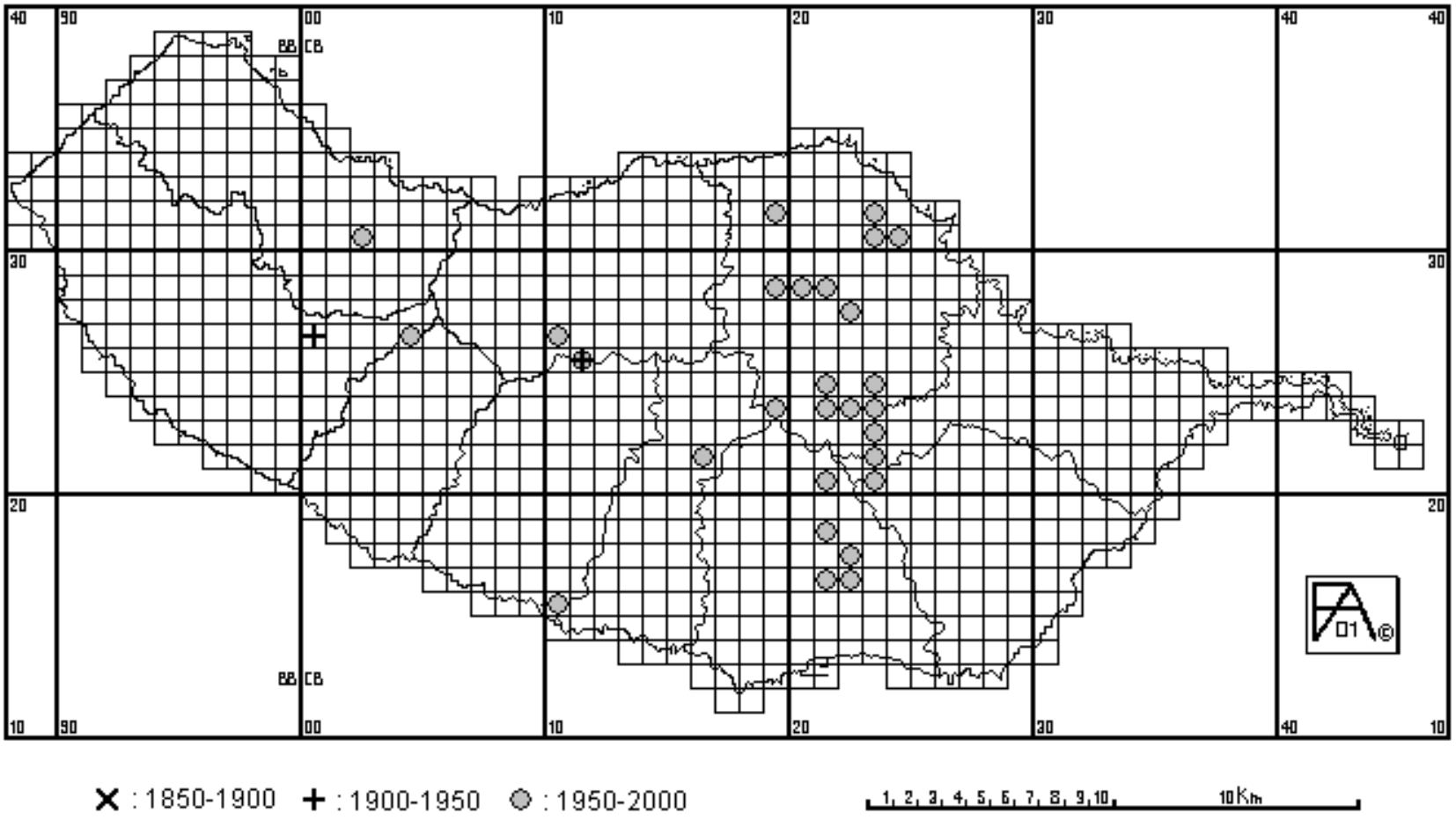

Figure 3: Distribution of adult *G. maderensis* on Madeira Island between 1850 and 2000. Source: Wakeham-Dawson et al. (2002) Reproduced with the kind permission of the authors and the publisher

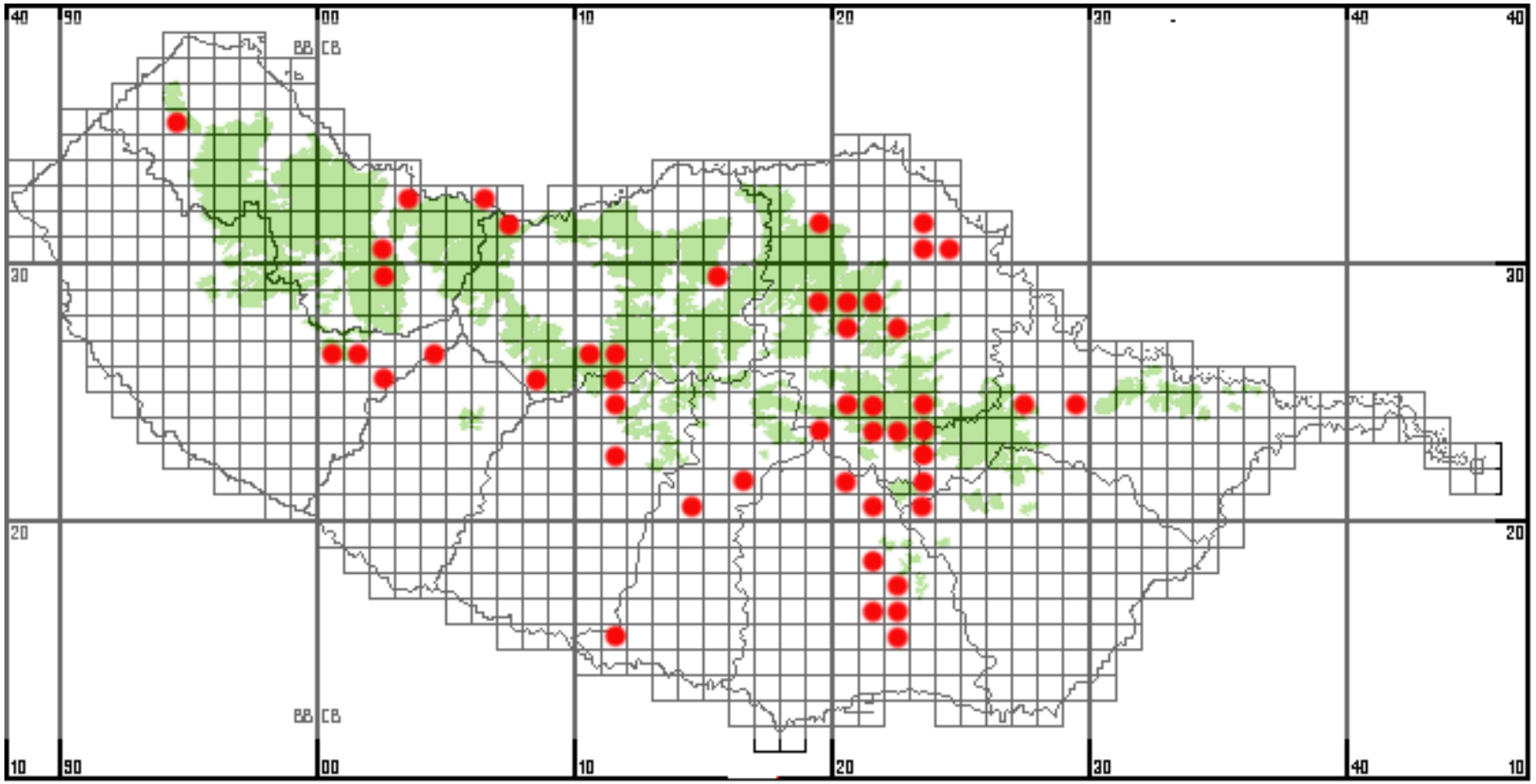

Figure 4: Distribution of adult *G. maderensis* (red dots) on Madeira Island between 1932 and 2009. The extent of humid laurel forest is shown in green. Source: Aguiar et al. (2009) Reproduced with the kind permission of the authors and the publisher

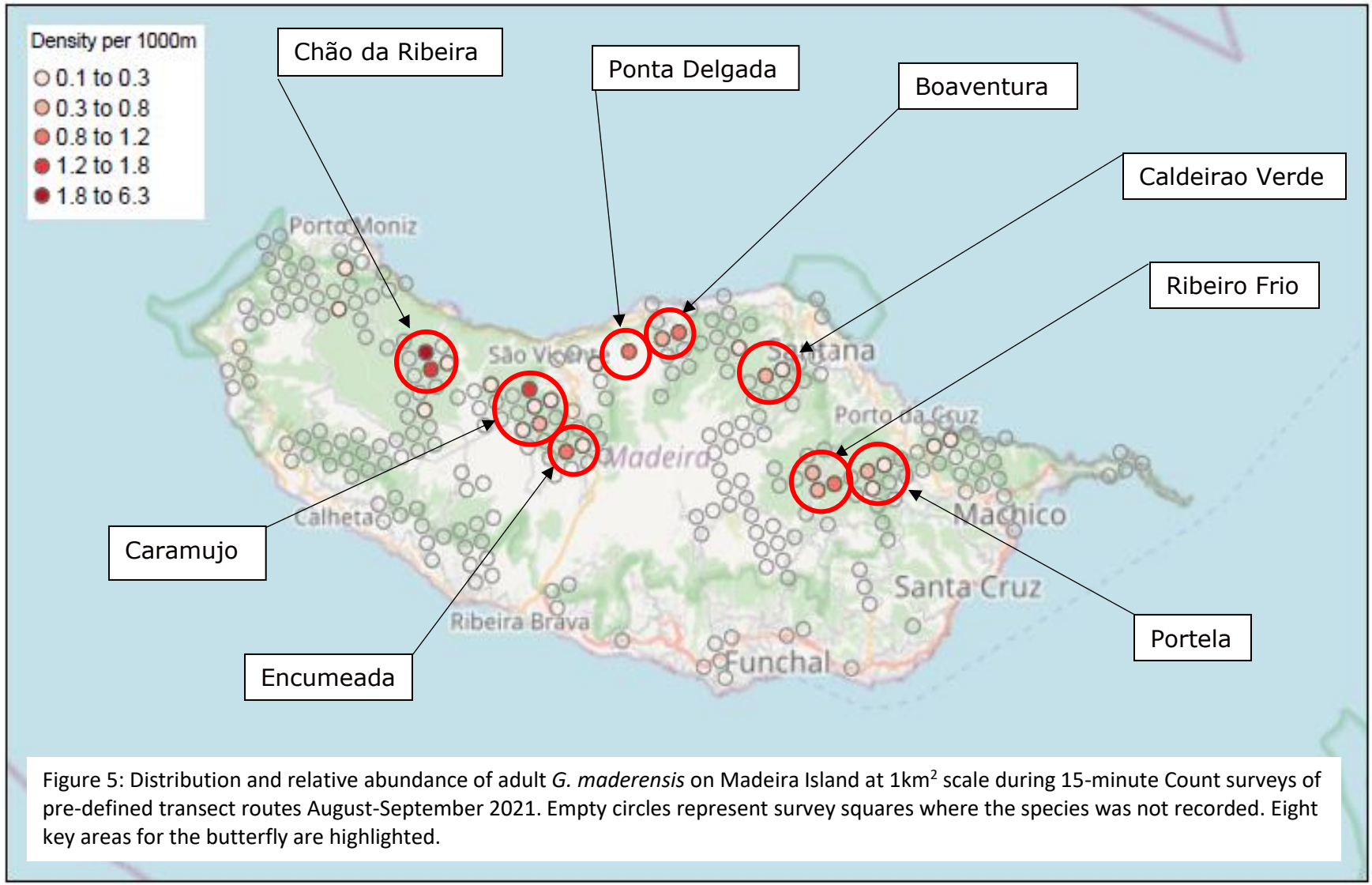

Figure 5: Distribution and relative abundance of adult *G. maderensis* on Madeira Island at 1km^2 scale during 15-minute Count surveys of pre-defined transect routes August-September 2021. Empty circles represent survey squares where the species was not recorded. Eight key areas for the butterfly are highlighted.

HABITAT

Habitat description

G. maderensis is restricted to dense, humid primary laurel forests (*laurissilva* forests) at middle altitudes (800-1,450 m asl on the south side and 300-1,400 m asl on the north side of the island) (Figure 6), which support the sole known larval hostplant the Macaronesian Buckthorn *Rhamnus glandulosa* (Rhamnaceae) (Figure 7), which occurs also at middle altitudes (600-1,100m a.s.l.) on Madeira and is usually found in riparian vegetation. It is estimated there are fewer than 5,000 individual plants on the island but the population is believed stable.

Figure 6: Primary laurel forest (*laurissilva* forest) at Seixal on the north side of Madeira Island, the habitat of *G. maderensis*. Photo credit: Sam Ellis

Figure 7: Macaronesian Buckthorn *Rhamnus glanduolsa* illustrating the characteristic glands in the axils of the leaves. Photo credit: Cristina Sevilleja

This plant occurs infrequently in *laurissilva* forest and is therefore likely to be the key factor determining the butterfly's distribution and abundance. For this reason, the location of every *R. glandulosa* sapling, shrub or tree encountered was recorded during the 2021 adult surveys (Figure 8), although this was not undertaken in any systematic way.

The distribution of *G. maderensis* mirrors that of *R. glandulosa* although the hostplant was recorded in one locality where the butterfly was seemingly absent but this was at Jardim Botânico da Madeira in Funchal, well outside the butterfly's natural distribution. Only at Portela was *R. glandulosa* found in some abundance.

However, it is very likely our study underestimated both *R. glandulosa* distribution and abundance, partly because identifying in the field is not easy but mainly because the terrain is often very difficult to access for close inspection of possible specimens. In contrast, *G. maderensis* is very visible and identification confirmed even at distance.

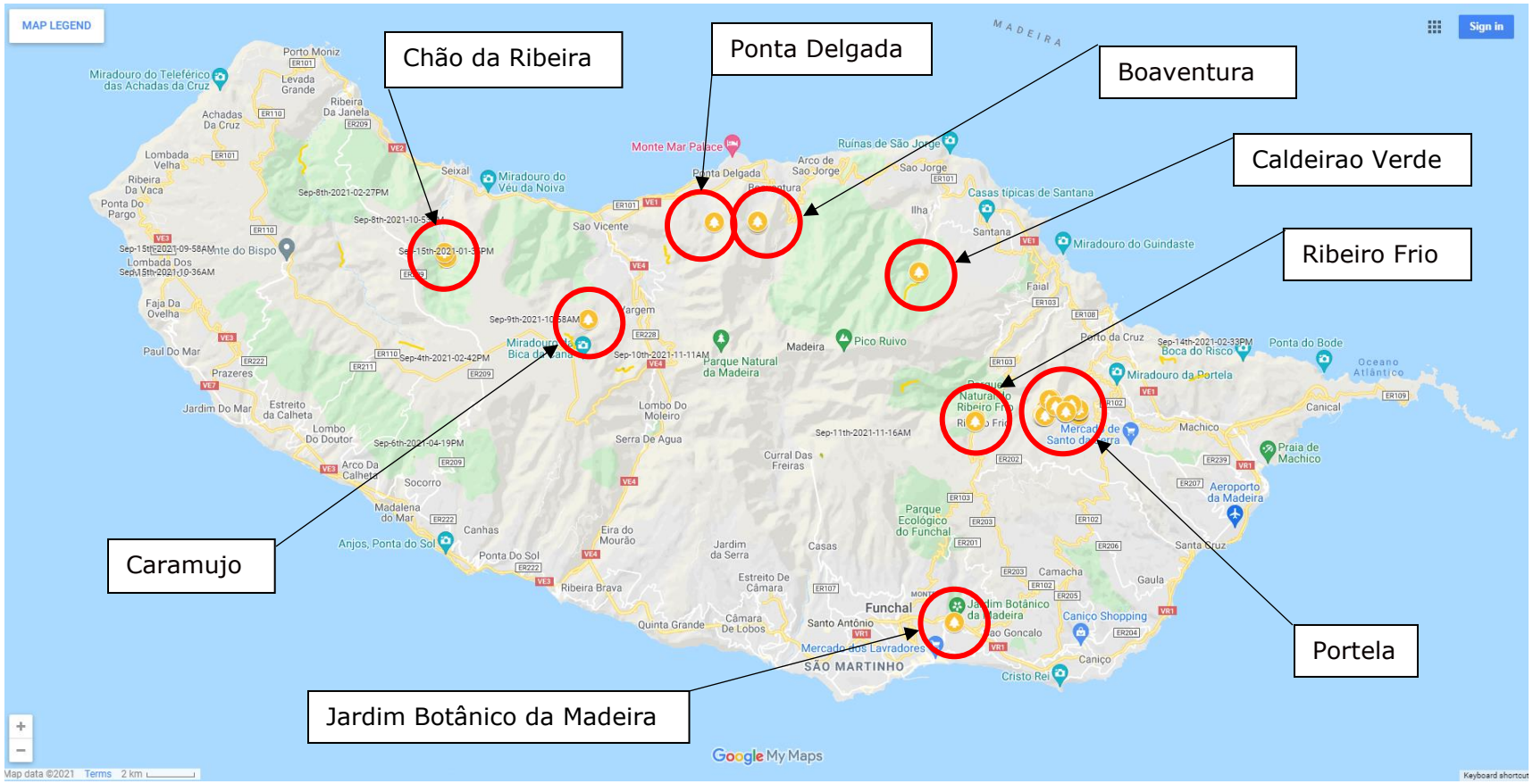

Figure 8: Location of *R. glandulosa* saplings, shrubs or trees (yellow symbols) on Madeira Island recorded during adult *G. maderensis* surveys of pre-defined transect routes August-September 2021.

Species distribution model

In order to identify other potentially suitable locations for each butterfly species on Madeira, species distribution models (SDMs) were built using three environmental variables considered crucial in determining distribution: elevation, distance from rivers and landcover.

To create the landcover map, we used high-resolution images (10m) from the Sentinel-2 satellite accessed it through Google Earth Engine (GEE). Specifically, we used images from the surface reflectance collection for the period 01.08.2021 to 30.10.2021 and obtained the average surface reflection during our sampling period. Then, we used a machine learning algorithm (i.e., smile classification and regression trees algorithm or smileCART) to reclassify the average reflectance of each pixel into one of the following land covers: bare ground, water bodies, agricultural areas, urban areas, *laurissilva* forest, eucalyptus forests, grassland, *Erica maderensis,* and unclassified. To that end, we calculated the percentage of each land cover type in a 100m grid cell and used it as input for the SDMs. Elevation was derived for each 100m square by the R-package elevatr (cran.r-project.org/web/packages/elevatr/vignettes/introduction_to_elevatr.html).

The elevation and distance from rivers are expressed in meters, while the land cover is expressed as percentage of each land cover type in a 100m grid cell. To produce the SDMs we used Random Forest models to account for possible non-linear relationships and low sample size of observations.

All the analyses were carried out in R, using the randomForest package (Breiman 2001). 70% of the set of records of each species was used to train the model, while the other 30% to test it. Besides predicting the probability of occurrence (POO) of the species, a threshold was applied to display presence/absence maps, based on the prediction of the model.

For abundant species, a threshold of 0.3 was applied, that is with a probability higher than 30% the species was considered present in a certain area. For rare species, the threshold was lowered at 0.10 or 0.15. Moreover, the variable importance was calculated as the percentage contribution of each variable to the model. This enabled evaluation of which variables were more important in determining the species distribution, and how this distribution changes with the change in variable values.

Figures 9 and 10 show the predicted distribution of *G. maderensis* based on the results of the species distribution models. In Figure 7 the model shows the POO across the island, whereas Figure 8 displays the data as a presence/absence map. Whichever way the results are displayed, the model predicts the distribution of *G. maderensis* to be more or less restricted the northern part of Madeira.

Figures 9 and 10 are insufficiently detailed for use by recorders in the field wishing to search for new *G. maderensis* localities. For this reason, we have produced dynamic maps (html file) which can be download and opened in a browser. Geographical base layers can be added and the zoom function enables users to focus in on potential search areas (Figure 11).

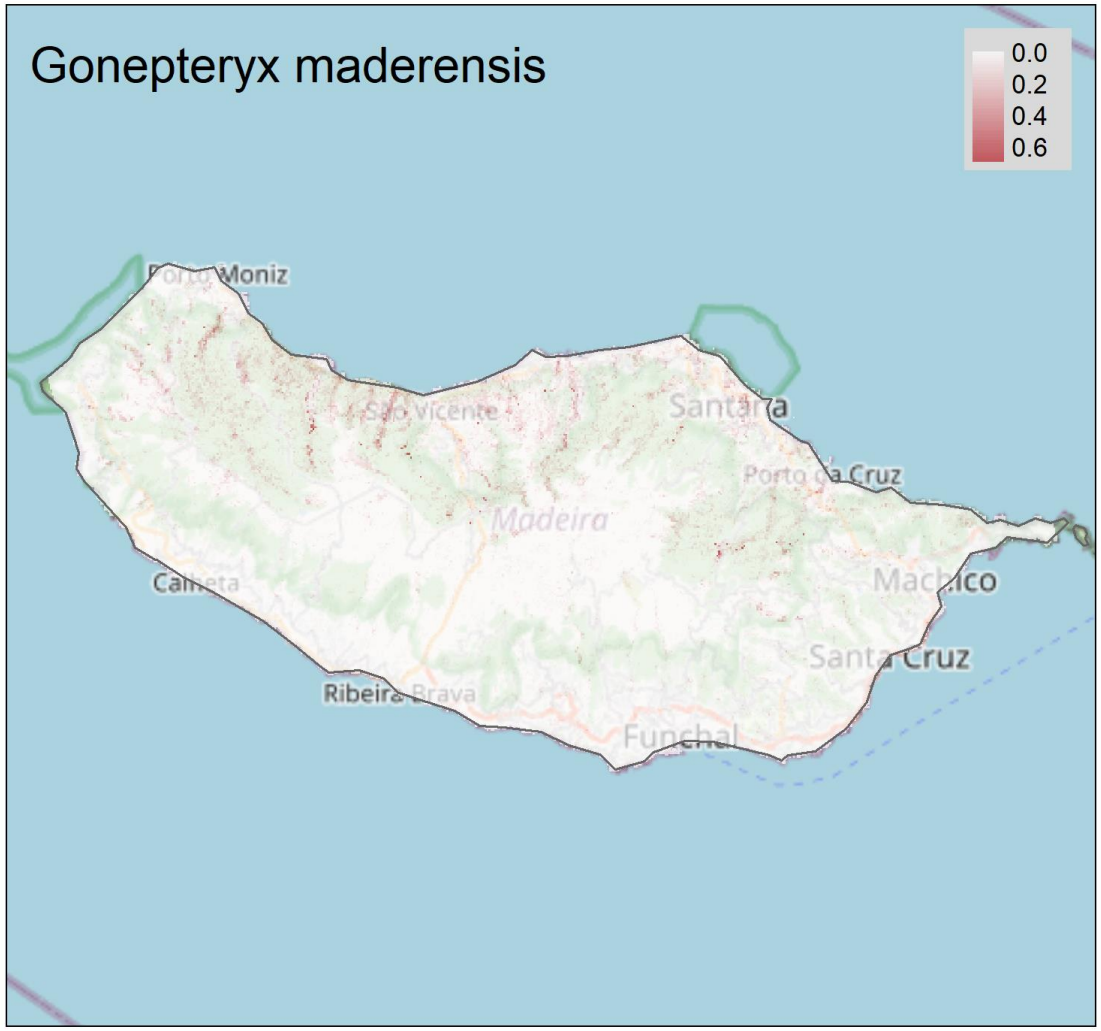

Figure 9: Probability of occurrence of *G. maderensis* on Madeira Island as a result of the Species Distribution Model.

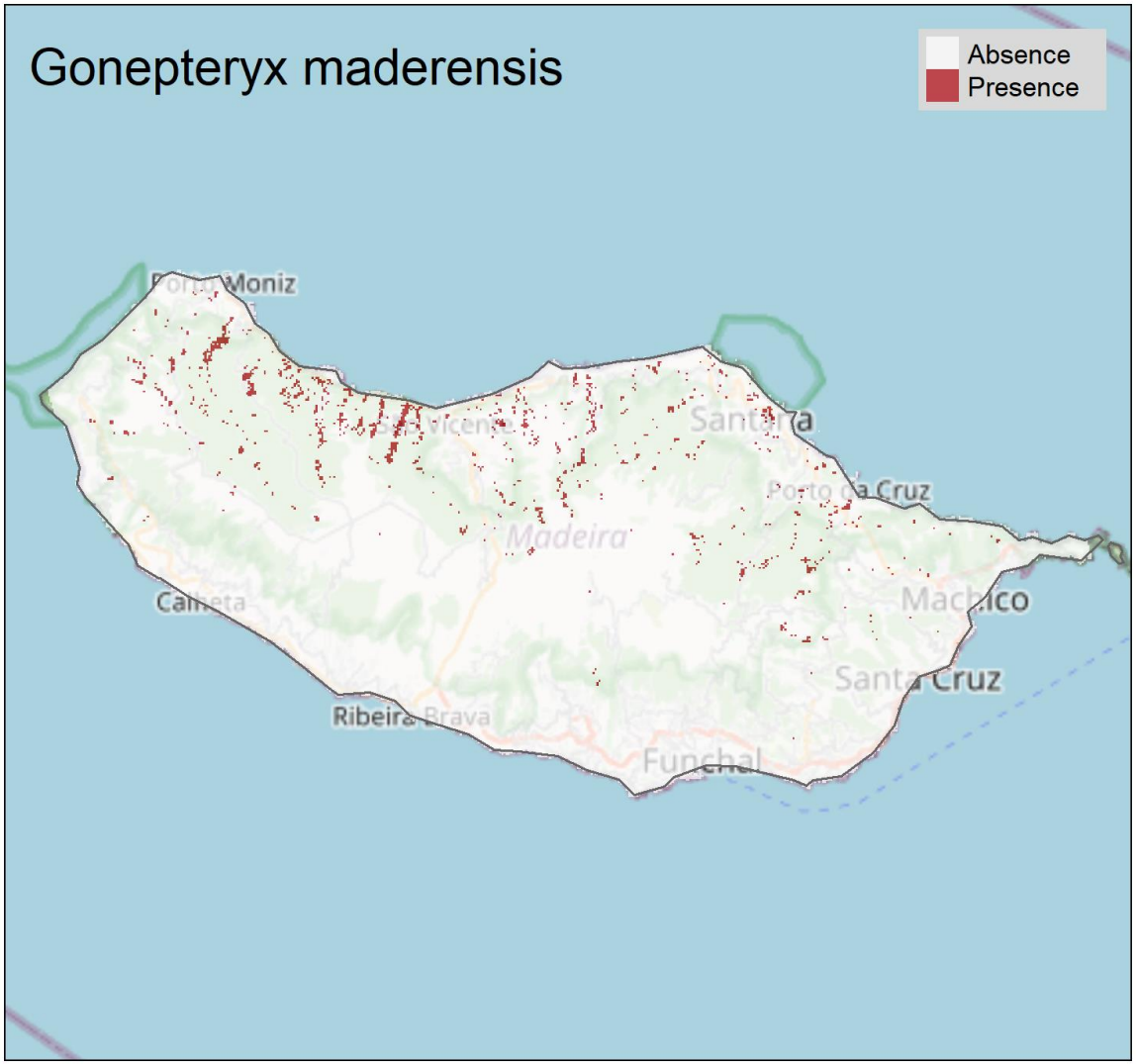

Figure 10: Binary distribution map for *G. maderensis* on Madeira Island as a result of the Species Distribution Model.

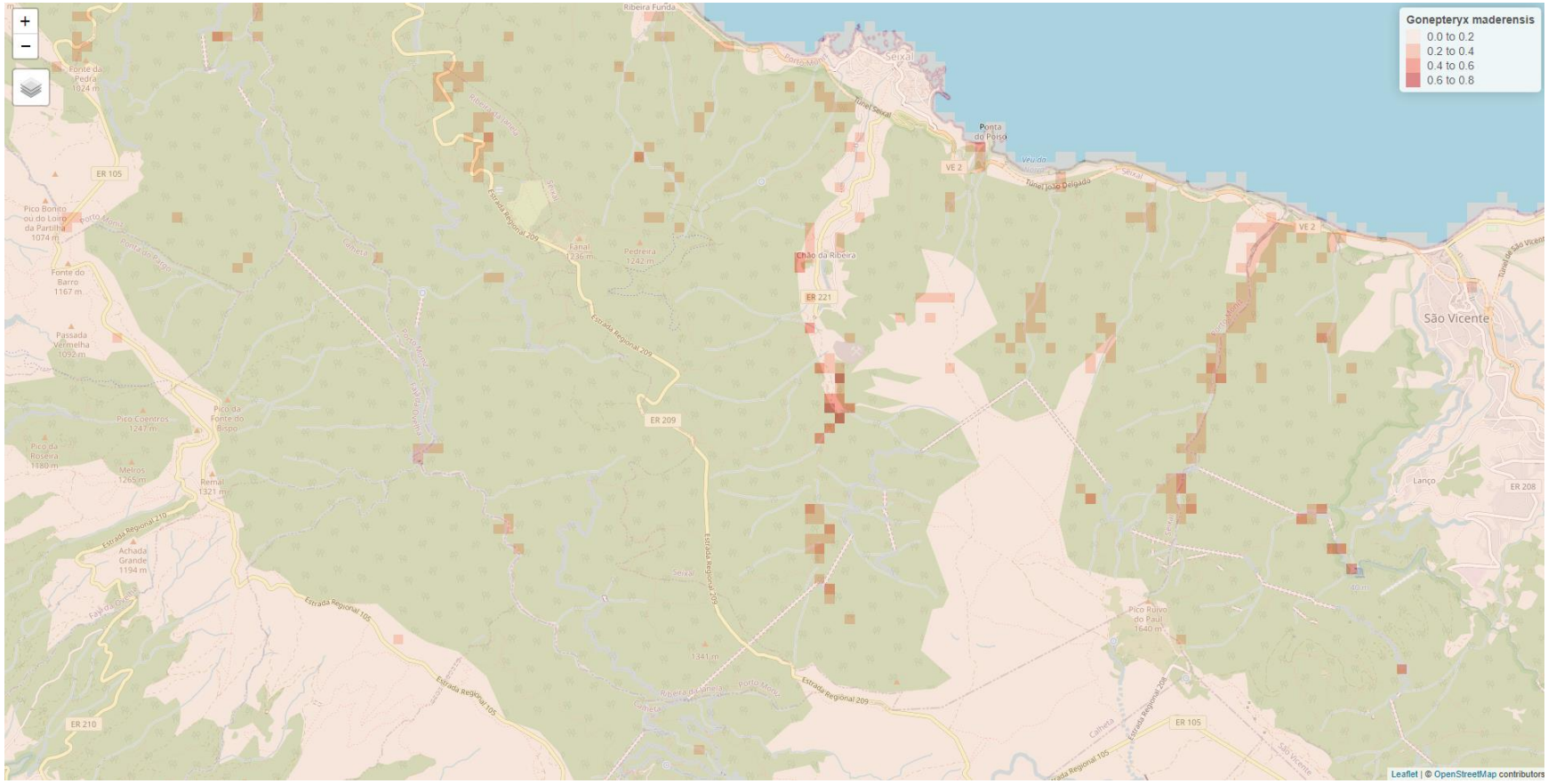

Figure 11: Probability of occurrence of *G. maderensis* on Madeira Island. Data displayed as a dynamic map (html file) showing Probability of Occurrence within a small geographical area suitable for recorders to undertake surveys.

BIOLOGY

Phenology and behaviour

G. maderensis has been recorded more or less year round leading to much speculation regarding adult longevity, voltinism and diapause. Aguiar et al. (2009) analysed the phenology from all adult records from 1932 to 2009 and showed the butterfly was on the wing from February and November but most abundant between April and September. However, there were fewer records in June. The early stages have only been found between the end of April and August. Aguiar et al. (2009) suggest the butterfly is therefore univoltine with egg-laying, egg, larval and pupal development all taking place in June and July with no diapause between stages. Our own observations indicate that egg-laying and larval development can extend into August, but no early stages could be found in September or October. The next generation of adults emerge from June to September with a peak in July and fly until a winter diapause between December and January. Adult activity increases from February onwards, but there are fewer records in this post-diapause phase presumably as a consequence of over-wintering mortality and/or cooler weather.

Aguiar et al.'s (2009) study was based on a small sample size of eggs and larvae, nevertheless these data suggest *G. maderensis* has a similar univoltine life-cycle to *G. rhamni*. The closely related *G. cleopatra* also has a univoltine life-cycle in much of Europe, but voltinism in *G. cleobule* is uncertain with adults recorded in all months and egg-laying observed in April, August and December.

Adult butterflies generally remain high in the *laurissilva* canopy (Wakeham-Dawson et al. 2001). Females nearly always remain high in the canopy but males only when dispersing or patrolling for females. Adults have been recorded flying between 50 and 1800 m a.s.l., but 80% of observations have been made between 500 and 1,000 m a.s.l, which corresponds to the altitudinal limit of the larval hostplant. However, adults are occasionally seen in atypical habitat (mountain heathland and mesophilous grassland) on the plateau 1,500 m a.s.l., presumably dispersing to other areas of laurel forest (Sérgio Teixeira, pers. obs.). Males patrol over relatively large distances between areas of *laurissilva* forest but females are more localised in their movements (Aguiar et al. 2009). Given that much of the primary laurel forest where the less active females reside is inaccessible to surveyors explains the skewed sex ratio in both the historical records and in our observations (see Current distribution, page 11).

Larval hostplants

The sole larval hostplant is *Rhamnus glandulosa*. The tree is usually a component of the upper canopy making observation of egg-laying and larval behaviour difficult,

but eggs have been found on a low-growing wild *R. glandulosa* plant (Aguiar et al. 2009).

The Azorean Buckthorn *Frangula azorica* has been suggested as a possible alternative larval hostplant. Although this plant is extinct in the wild on Madeira, several specimens have been planted in areas of humid laurel forest utilised *G. maderensis*. Whilst feeding damage was observed, no larvae were found but it would be worthwhile to undertake further searches (Sérgio Teixeira, pers. obs.).

Eggs

Data on the early stages is limited to Aguiar et al.'s (2009) study in captivity of six eggs and four first instar larvae collected from the wild. Eggs were laid on both surfaces and the margins of young leaves and sometimes on twigs.

Larva

Larvae sometimes partially eat the egg case after hatching. They are very sluggish during the day but more active at night when they feed. The only defence mechanism observed was falling from the hostplant when disturbed and hanging by a silk thread (Aguiar et al. 2009).

Pupation

Prior to pupation the larva suspends itself head down from a leaf by the cremaster and a silk thread around its body (Aguiar et al. 2009).

Under laboratory conditions, the mean duration of the larval stage was 17.5 days and the pupal stage 11 days. The average duration of the pre-adult stages was 29.3 days (range: 27-32 days) (Aguiar et al. 2009).

Nectar sources

Adults, especially males, seek nectar from flowering plants closer to the ground (Wakeham-Dawson et al. 2000).

Natural enemies

The butterfly appears to have no know natural enemies. Unlike other *Gonepteryx* species, neither sex of *G. maderensis* reflects ultra-violet (UV) light from the wing undersides (Brunton et al. 1996) which may give them a cryptic advantage against

insectivorous predators, when the butterflies roost amongst, rest and possibly diapause amongst similarly non-UV reflective laurel leaves (Aguiar et al. 2009).

It is not known what role, if any, parasitism plays in *G. maderensis* population dynamics. Given both *G. rhamni* and *G. cleopatra* have specialist parasitoids (various *Cotesia* species and *Hyposoter rhodocerae*) it is possible they could be important factors in the *G. maderensis* life cycle (Constanti Stefanescu, pers. comm.).

POPULATION

G. maderensis has low population densities. It appears to be declining in abundance on Madeira, but without an established butterfly monitoring scheme, this is based on subjective rather than quantitative assessment.

As far as we know Mark, Release and Recapture (MRR) has not been undertaken for this butterfly we cannot provide a population estimate for this species. However, the low number of observations, even allowing for the fact that many inaccessible areas remain unsurveyed, suggests that the total global population size of *G. maderensis* is actually very small for an insect. It could be fewer than 1,000 and highly unlikely to be greater than 10,000.

CONSERVATION

Legal protection

G. maderensis and other Madeiran endemic Lepidoptera are not directly or specifically protected by any national or regional laws or other legislative acts by national or regional parliaments. However, about two thirds of the island are included in the Madeira Nature Park, which comprises several types of nature reserves and protected areas, including *G. maderensis* habitat. Some areas of pristine primary laurel forest are strict nature reserves and fully protected. Additionally, the native laurel forest which is the main habitat for *G. maderensis*, is also listed as SAC PTMAD0001 'Laurissilva da Madeira' in Natura 2000 Ecological Network under the Habitats Directive. Therefore, although *G. maderensis* is not specifically addressed by any legal protection, it is indirectly protected by several legislative acts. Their main habitats are protected and under the surveillance of the Regional Authority, Institute of Forests and Nature Conservation (IFCN).

Conservation status

G. maderensis was assessed as Endangered and a Species of Global Conservation Concern by van Swaay and Warren (1999) because it is restricted to Europe and globally threatened, with an extent of occurrence less than 500km^2, fewer than five locations and was undergoing a continuing decline.

It was also listed as Endangered for both pan-Europe and the EU 27 in the European Red List of Butterflies (van Swaay et al., 2010).

According to the International Union for Conservation of the Nature, the global conservation status of *G. maderensis* is Endangered B1 ab(i,iii); *The IUCN Red List of Threatened Species* 2010 (downloaded on 24th August 2021).

Conservation actions proposed by van Swaay et al. (2010) were:

1. More research is needed urgently on the distribution and ecology of the species.
2. Suitable habitats should be protected and appropriately managed.
3. The effects of conservation actions should be monitored by a Butterfly Monitoring Scheme.

THREATS

The species is largely restricted to primary vegetation susceptible to human interference. The most direct threats therefore come from primary *laurissilva* forest habitat loss or habitat degradation, particularly where these impact on the larval hostplant and therefore the butterfly. Habitat loss and habitat degradation can lead to fragmentation and isolation of remaining habitat. Whilst some fragments of primary laurel forest in the southern half of the island are quite isolated, the majority seems to have a high degree of connectivity and is unlikely to have an impact on the butterfly's ability to occupy new habitat patches should they become available. However, this has not been tested in the field.

The main threats can be summarised as:

1. Direct loss of primary *laurissilva* forest due to conversion to agriculture or commercial mixed and/or exotic (comprising non-native trees) forests outside protected areas.

2. Degradation of primary *laurissilva* forest leading to changes in woodland structure and/or plant species composition/abundance. This habitat is under pressure from:

    a) Increasing levels of water abstraction as a result of increasing human demands will negatively affect the riparian vegetation where the larval hostplant naturally occurs.

    b) Invasive Alien Species (IASs) such as Wild Tobacco *Solanum mauritianum,* Tree of Heaven *Ailanthus altissima,* Blue Gum *Eucalyptus globulus, Acer pseudoplatanus,* Wandering Trad *Tradescantia fluminensis,* Creeping Croftonweed *Ageratina adenophora,* Creeping Croftonweed *Ageratina riparia,* Montbretia *Crocosmia x crocosmiiflora,* Black Wattle *Acacia mearnsii,* Broom *Cytisus scoparius,* Common Gorse *Ulex europaeus,* Dwarf Gorse *Ulex minor,* Ginger Lily *Hedychium gardnerianum,* Banana Passion Fruit *Passiflora molissima,* Hortensia *Hydrangea macrophylla* and Hardy Fuchsia *Fuschia magellanica*.

    c) Changing fire regimes in the forests and fires of increasing intensity can both degrade habitat directly by affecting the natural vegetation but also by making conditions more suitable for IASs.

3. Climate change is predicted to lead to reduced rainfall and increasing temperatures (European Commission, 2014) which in turn could exacerbate the problems associated with increasing water abstraction and fire risk.

4. Whilst there is very little evidence that disturbance or collecting butterflies from the wild has any significant impact, for a species of limited global distribution and low population density, excessive disturbance or collecting for respectively research purposes or for museum specimens could be a potential threat, even if unlikely to be on the same scale as those listed above. Collection of large numbers of *G. maderensis* specimens has occurred in the past (Sérgio Teixeira, pers. obs.) and given that the butterfly occurs at low densities, this potential threat should not be entirely discounted.

SPECIES ACTION PLAN

This chapter discusses the possible actions, which, if implemented over the five-year period 2023-2027, will significantly improve the conservation status of the species. In each section we discuss the actions that are necessary and where appropriate, describe them for the different parts of the species' geographic range on Madeira. The actions have been discussed and agreed with representatives of the Institute of Forests and Nature Conservation (IFCN), the Directorate for Agriculture and Rural Development (DRADR) and the Directorate for Environment and Climate Change (DRAAC).

It is essential to monitor the populations of the species because the effectiveness of the proposed measures would only be evident if the butterfly population trends are positive. In general, the conservation actions are focussed on habitat management. The main goal is to propose positive interventions, avoiding negative interventions wherever possible. Public awareness actions are also important to inform civic society of the importance of the species and the main goals of conservation measures.

Legal protection

At this stage there is no evidence that disturbance or collecting have a negative impact on *G. maderensis* or other Madeiran endemic butterflies. We therefore do not propose specific legal protection for the butterfly. In our opinion increasing public awareness of the potential harm of disturbance and collecting might be more effective than an onerous permit system. The existing permit system could be more focussed on permissions for conservation research than collecting for other purposes. We advise a watching brief and for the relevant authorities to only introduce legislation if necessary.

Protected areas

G. maderensis was recorded during the surveys only in laurel forests on the northern coast, all of which are within existing protected areas. The Species Distribution Model predicts the butterfly could occur in some southern areas of laurel forest, but these are largely degraded and currently unsuitable for *G. maderensis*. The minor exceptions of good quality habitat in the south are already protected. There is therefore no reason to propose extensions to existing protected areas for *G. maderensis* during the timeframe of this recovery plan. However, this should be kept under review if for example laurel forest restoration outside protected areas provides new habitat for the butterfly.

Conservation measures

The main habitat actions for the conservation of the species can be summarized as follows:

HABITAT MANAGEMENT

As primary vegetation, the humid laurel forests are 'managed' mainly by non-intervention. However, there are management interventions that could be utilised which would improve habitat quality for the larval hostplant in the butterfly's key areas (see Figure 3), without undermining the integrity of the laurel forest itself.

For example, maintaining the minimum flow required by law or restoring natural water flow in river systems would improve the quality of riparian vegetation and therefore the habitat of *R. glandulosa*. This could be achieved by reviewing abstraction rates, particularly in the drier months, with Madeira Water and Waste (Águas E Resíduos Da Madeira ARM).

Water flow is also affected by conditions outside the laurel forests. Efforts to re-vegetate the mountain plateau heathlands with native plants should improve water retention during high rainfall and lead to more natural water flow rates through the forest ecosystem.

Within degraded laurel forests, removal of Invasive Alien Species would also help restore habitat quality, particularly where this is coupled with planting of native trees and shrubs. Removal of IASs is also an important component of the restoration of mountain heathlands.

HABITAT CREATION

Given *G. maderensis* only utilises one hostplant, one simple way to increase the island's carrying capacity for this species, would be to grow *R. glandulosa* saplings which once established could be planted out at suitable locations where the butterfly could use them for breeding (Figure 12). Given the precise habitat requirements of the butterfly are still unknown, it could take many years for this action to yield positive results if only full-grown trees are utilised for breeding by the butterfly. However, if saplings were utilised the positive impact could be in a matter of few years.

This proposed action is already underway as IFCN work with expert horticulturists to propagate native plants, including growing *R. glandulosa* from seed, for planting in suitable locations. However, this may be on an insufficient scale to make a

significant difference to the hostplant's and hence the butterfly's populations. The Ecological Park of Funchal is also involved in native plant propagation and planting with assistance from volunteers.

Discussions should be held with both IFCN and the Ecological Park of Funchal to determine if capacity can be increased and whether civil society could be actively engaged in an enlarged propagation programme. This conservation action lends itself very well to primary age schoolchildren learning about the natural world.

Careful thought would need to be given to site selection for planting and agreed with IFCN if planting in humid primary laurel forests was proposed. However, there should plenty of opportunities to utilise propagated plants where degraded forests are being restored. A pilot project on a site exhibiting the full transition from degraded to primary laurel forest (e.g. Levada da Ribeira) could help establish the most appropriate methodology and test the effectiveness of planting the hostplant.

Figure 12: *Rhamnus glandulosa* shrub planted at Ribeiro Frio. Photo credit: Cristina Sevilleja

Survey and monitoring

The Species Distribution Model shows that *G. maderensis* is likely to be more widespread than the current distribution suggests. Given this species' limited global distribution, it should be a high priority to search those areas highlighted as having the highest Probability of Occurrence. However, many of these new potential search areas are inaccessible, so the focus will need to be narrowed further with only those accessible by footpaths or levadas likely to be surveyed. Although casual observations of the adult butterfly are important, recorders should be encouraged

to use the 15-minute Count method as this provides both data on distribution and abundance.

Since the distribution of the butterfly is closely linked to that of its sole larval hostplant, improved knowledge of the latter would assist in targeting other conservation measures in the recovery plan. Sites where *R. glandulosa* is most often encountered are generally remote and inaccessible, so encouraging IFCN forest rangers and nature guides to record the location of the plant whenever it is encountered should be a priority.

The recent establishment of the Madeiran Butterfly Monitoring Scheme means that for the first time, changes in the abundance of adult *G. maderensis* (and other species) will be assessed. The main source of data for such analyses will be from weekly transect counts along fixed routes but data from 15-minute Counts may also be included. It is therefore a priority that transects falling within the butterfly's distribution continue to be monitored over the long-term. In practice this means ensuring there are sufficient well-trained and well-motivated volunteer recorders willing and able to walk the transects each week of the flight period. In turn this depends on an equally well-trained and well-motivated monitoring scheme co-ordinator being present in Madeira who can provide the necessary support to the recorders and provide regular feedback. The capacity of the Madeira Butterfly Monitoring Scheme would be increased with some external funding to enable training of both professional staff (e.g. IFCN rangers) and volunteers in monitoring methods.

Research

Although some research has been undertaken on the life-cycle of *G. maderensis*, this has been based on small sample sizes in captivity. The key factors driving the population dynamics of this butterfly are largely unknown. The butterfly has only one larval hostplant but it is unclear what, if any, growth forms (e. g. saplings, shrubs or trees) are preferred. Nothing is known either about whether females select hostplants growing under different conditions (e. g. shaded or unshaded). Studies which try to identify if there are habitat preferences by ovipositing females should be a priority, since their results could inform habitat conservation measures. However, given the low density of the butterfly collecting data from female ovipositing in the wild could be very time consuming. Whilst recognising captive behaviour may be somewhat different, a complementary approach might be to experimentally manipulate the hostplant under laboratory conditions and use captive stock to test for habitat preferences.

Although habitat fragmentation and isolation is considered unlikely to be a threat to this species, this does require field testing. Studies of the butterfly's population

structure, by for example Mark, Release and Recapture (MRR), could provide valuable estimates of population size and mobility, giving some indication of the butterfly's dispersal capacity. However, MRR could be particularly challenging given the difficulty of capturing sufficient numbers of butterflies even with long-handled nets. The proportion of recaptures could also be quite low, given the apparent high mobility of the males. On the other hand, even a low number of recaptures could provide evidence for example of the extent to which butterflies move between different valley systems.

At the landscape-scale, studies of habitat patch occupancy in relation to area, isolation and quality, would provide insights into this species' metapopulation structure and confirm whether habitat fragmentation and isolation is a potential threat. MRR studies can also be used to identify the extent to which a butterfly is susceptible to collecting.

Autecological studies of *R. glandulosa* may also be beneficial to determine the most suitable growing conditions for the plant, including for example, researching the minimum water flow in river systems. Such insights would for example, assist site selection for habitat creation schemes.

Given the importance of *G. maderensis* to Madeira's biodiversity, it should be a priority to encourage University of Madeira biologists to establish a research programme on this butterfly.

Whilst some autecological research lends itself undergraduate study, some aspects require longer-term input more suited to masters or doctoral postgraduate study. Unfortunately, the University of Madeira does not currently offer postgraduate courses. However, if Butterfly Conservation Europe were able to propose postgraduate research programmes to universities in Portugal and elsewhere on the continent, the University of Madeira could potentially provide some support for students undertaking field and laboratory work.

The University of Madeira have also indicated they would make available their Entomological Collection for research should this be required.

Public awareness

Several of the actions listed above lend themselves to the involvement of civil society and visitors to the island. This applies particularly to survey and monitoring which are largely dependent upon dedicated and knowledgeable naturalists.

It should therefore be a priority to recruit new volunteers who are able to contribute to these conservation activities. In turn this depends on maintaining public awareness of the importance of this butterfly to Madeira's biodiversity.

Where resources allow, public events should be held to introduce Madeira's butterflies to new audiences, which can be followed up with training for those who wish to become more involved with actions to conserve the butterfly.

Whilst he main target for new audiences is likely remain nature conservation professionals and civil society, tourists are another potential source of participant and often provide a high proportion of observations. Training should encompass both survey and monitoring methods as well as how to use relevant websites and apps.

Establishing a website about Madeira's threatened endemic butterflies would be invaluable in raising public awareness by advertising public events and hosting the resources to help train new volunteers.

An identification guide has already been produced for Madeira's butterflies which can be used to encourage more recording. It should also be a priority to produce a factsheet specific to *G. maderensis.* This could provide details on identification of both the butterfly and hostplant, its life-cycle, habitat preferences (once more is known) and best practice habitat management (when known). The factsheet should also include a distribution map of both known and predicted distribution to encourage further surveys. Whilst hard copies of the factsheets could be produced if resources allow, digital versions may be preferable as these can be updated.

Also a priority would be to produce information panels about the butterfly to be located at key sites which receives good numbers of visitors. This could be species-specific or encompass the other Madeiran endemic butterflies.

Plan implementation

Whilst BCE will be able to offer advice if required, implementation of this recovery plan can only be overseen and delivered by organisations based in Madeira.

MF&F are best placed for the coordinating role, as they are either the lead or the partner in all the actions in the table below. MF&F propose to annually gather together a panel of representatives of stakeholder groups and government agencies for biodiversity conservation, protected area management, forestry and agriculture. The purpose of the group will be to review actions undertaken to conserve Madeira's butterflies, with a specific focus on the maBMS and on the actions highlighted in this and other Recovery Plans for threatened endemics (Madeiran Speckled Wood *Pararge xiphia* and Madeiran Large White *Pieris wollastoni*).

Suggested panel participants are:

NAME	ROLE	ORGANISATION
Sérgio Teixeira	maBMS Regional Coordinator	MFF
Cristina Sevilleja	eBMS representative	BCE
Dora Pombo	Head of Entomology	University of Madeira
Miguel Ângelo Carvalho	Organic Farming Course Director	University of Madeira
Manuel Filipe or representative	President of IFCN	IFCN
Paulo Santos or representative	Regional Director	DRADR
Manuel Ara or representative	Regional Director	DRAAC
Vitor Castro	President	Young Farmer's Association AJAMPS
João Ferreira	President	Association of Farmers AAM
Amilcar Gonçalves or representative	President	Madeira Water and Waste ARM
Martin Wiemers	Butterfly expert: Macaronesia	IUCN MAIISG Group
António Franquinho Aguiar	Butterfly expert: Madeira	IUCN MAIISG Group

Species Action Plan summary

ACTION	PRIORITY (High, Medium. Low)	PARTNERS (Lead partner in bold)	TIMESCALE
Legal protection			
At this stage no legal protection measures are planned but would be considered if evidence suggests they are required. In the meantime, raise public awareness of possible negative impacts of excessive disturbance and collecting, and use the existing permit system to limit permissions to conservation research	Medium	**MF&F**, University of Madeira	2023
Protected areas			
At this stage no further protected area measures are planned but would be considered if evidence suggests they are required (e.g. restored laurel forest provides new *G. maderensis* habitat outside protected areas)	Not applicable		
Conservation measures			
Review water abstraction rates in the catchments of the butterfly's key areas with Madeira Water and Waste to improve water flow through forest ecosystems	High	**ARM**, MF&F	2023-2027
Encourage restoration of natural mountain heathland vegetation in the catchments of the butterfly's key areas to improve water retention and water flow through forest ecosystems	High	**IFCN**, MF&F	2023-2027

Encourage removal of Invasive Alien Species and their replacement with native trees and shrubs in degraded laurel forests	Medium	**IFCN**, MF&F	2023-2027
Expand the *R. glandulosa* propagation programme to produce saplings which can be planted at suitable locations within humid primary and degraded laurel forest	High	**IFCN**, Ecological Park of Funchal, MF&F, horticulturists, volunteers, local primary schools	2023-2027
Survey and monitoring			
Encourage and undertake further *G. maderensis* surveys by 15-minute Counts in areas of highest Probability of Occurrence as predicted by the Species Distribution Model	High	**IFCN**, MF&F, volunteer recorders	2023-2027
Record locations of all *R. glandulosa* plants encountered during forest service activities or during volunteer surveys	High	**MF&F** volunteer recorders	2023-2027
Annually undertake transect counts on fixed routes established through the Madeiran Butterfly Monitoring Scheme	High	**MF&F**, volunteer recorders	2023-2027

Research			
Encourage undergraduate and postgraduate autecological research on *G. maderensis*, particularly to identify habitat preferences, understand population and metapopulation structure	High	**University of Madeira**, BCE, MF&F, volunteer recorders	2023-2027
Encourage undergraduate and postgraduate autecological research of *R. glandulosa*, particularly to identify habitat preferences	High	**University of Madeira**, BCE, MF&F, volunteer recorders	2023-2027
Public awareness			
Develop a programme of public events and training to recruit new volunteers able to contribute to the actions identified in this recovery plan	Medium	**MF&F**, Directorate of Tourism	2023-2027
Establish a website about Madeira's threatened endemic butterflies and the maBMS to raise public awareness and host resources to help train new volunteers	High	**MF&F**	2023
Produce a *G. maderensis* species factsheet to facilitate distribution recording and advise land managers on appropriate habitat management measures	Medium	**MF&F**	2023
Produce a *G. maderensis* information panel and erect at key sites popular with visitors	Medium	**MF&F**, IFCN	2023-2024

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