DAVIS EXPEDITION FUND

REPORT ON EXPEDITION / PROJECT

Expedition/Project Title:	A Survey of the Lepidoptera of the Azores
Travel Dates:	18 August – 1 October 2023
Location:	Azores archipelago, Portugal
Group Members:	Jamie C. Weir, PhD BSc(Hons) (Project Leader) Daniella Di Pirro, BSc(Hons) BVM&S (Self-funded Research Assistant)
Aims:	1) Collect records, voucher specimens, and genetic material (for COI barcoding) of Lepidoptera across the Azores archipelago. Increase our knowledge of the distribution of the Lepidopteran fauna across the islands in order to inform conservation efforts and provide a basis for future biogeographic studies. 2) Focus fieldwork efforts on collecting and recording specimens of *Noctua* spp. for comparative morphological study and make systematic field and captive observations of these species. Contribute to our understanding of the evolution of this genus (a potentially promising model for biogeographic and biodiversity work), and that of the Lepidopteran fauna of the islands more widely. 3) Make adventitious records and natural history observations of other taxa, particularly invertebrates and other groups hitherto relatively under-studied and/or under-recorded.

Photography consent form attached: (*please refer to your award letter)*

☒ Yes
☐ No

Outcome (a minimum of 500 words):-

See attached report.

A Survey of the Lepidoptera of the Azores

August – October 2023

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Cover Image: View upwards, from the interior of the Algar do Carvão, Terceira, © Jamie C. Weir.

Summary

Located in the centre of the Atlantic, over a thousand kilometres from the coasts of North America and Europe, the Azores are an isolated archipelago of nine volcanic islands. Although the islands have a long history of human settlement and population, much remains unknown about the biology of their flora and fauna—particularly more obscure groups such as the invertebrates. Isolation has led to the evolution of a significant number of unique taxa found nowhere else (9.4% of terrestrial species), presenting an ideal model system for work on island biogeography. Amidst continuing man-made land use change and the growing occurrence of invasive species, a detailed knowledge of the distribution, abundance, and ecology of native species is vital if conservation efforts are to be effectively targeted at endemic species, habitats, and ecosystems. I mounted a seven-week expedition to the Azores (August – October 2023), systematically collecting and recording Lepidoptera across all nine islands in the archipelago. Over 2,500 records of Lepidoptera were collected, many records of other poorly-studied insect groups, notes/observations on ecological associations, and specimens for morphological study and genetic analysis. Among the larger moths collected (so-called 'macro-moths'), some 6% of specimens identified so far are 'new-to-island' records. One economically significant pest species, the Box Tree moth *Cydalima perspectalis*, is reported for only the second time in the Azores, on a new island. Even among the relatively conspicuous and well-known butterfly fauna, I report the occurrence, for the first time, of the American Painted Lady butterfly *Vanessa virginiensis* on the island of Graciosa. This data provides a valuable contribution to our understanding of the Lepidoptera of these islands, and a solid basis for future scientific work.

Introduction

The Azores are a Macaronesian archipelago of Portuguese islands located in the middle Atlantic Ocean, 1400km from the European mainland and 1900km from the coast of North America. Covering a total of 2300km^2, the nine islands vary in size from Corvo (17km^2) to São Miguel (759km^2). The islands are divided into three groups, clustered across 7° of longitude (approx. 600km): the western or occidental group (comprising Flores and Corvo), the central group (Faial, Graciosa, Pico, São Jorge, Terceira), and the eastern group (São Miguel and Santa Maria) (Fig. 1). The islands are volcanic in origin (see Figs. 12-13), ranging in age from 270,000 years (Pico) to 5.5 million years old (Santa Maria), and sit on the Azores Plateau, at the junction of three major tectonic plates (Queiroz, 1997; Carracedo and Troll, 2020). Compared to the other Atlantic islands, the Azores are notably younger—for example, the Canaries are up 21 million years old—which has implications for the native flora and fauna (Schäfer, 2021). Volcanic activity continues to occur on some, though not all, of the islands. As recently as 1957, the eruption of the Capelinhos volcano on Faial added 2.4km^2 of land to the island.

The Azorean climate is temperate, with perhaps the most important ecological factors being the mild temperatures (annual average of 17.5°C), high humidity (often approaching 100%), and high rainfall (1000-1600mm at sea level) (Schäfer, 2021). The islands of the eastern group are subject to the Trade Winds (NE) and in the western and central groups the prevailing wind is from the N, NW, and SW (Schäfer, 2021). The general direction of these winds accounts for decreasing rainfall from NW to SE in the archipelago and, in consequence, increasing insolation. However, the environmental conditions can vary markedly across the altitudinal gradients of the islands, the tallest of which is Montanha do Pico (2351m) (Schäfer, 2021). These factors are significant determinants of local ecological conditions and community composition.

Alongside the other Atlantic islands, the Azores have been colonised successively by immigrant terrestrial species from the neighbouring continental landmass. These isolated populations have in many cases become distinct, and the island groups host a large number of endemic species, sub-species, and/or races. On the Azores, 420 of the 4467 known terrestrial species (9.4%) occur nowhere else—largely invertebrates (Borges *et al*., 2005a). However, the arthropod fauna of the islands remains rather poorly recorded and understood (e.g. Borges *et al*., 2005*a*; Borges *et al*., 2018), and species new to science continue to be discovered (e.g. Borges *et al.*, 2004; Borges and Wunderlich, 2008; Bamber and Costa, 2009). Although the islands are limited to around 150 species of Lepidoptera, 35 (23.3%) of these are endemic to the Azores (Borges *et al*., 2005*b*), making this a significant taxon from a conservation perspective, worthy of increased study.

Human settlement of the Azores has dramatically altered their ecology. Since classical antiquity there have been legends of islands in the Atlantic Ocean (e.g. Plato's *Atlantis*). The Azores began to appear on maps in the fourteenth century, but it was not until the fifteenth century that any serious attempts were made by the Portuguese to colonise the hitherto unpopulated archipelago. The islands were of strategic importance, providing a safe base along the hostile coast of Africa, and were independent of the Castillian-controlled Canary Islands (Crowley, 2016). The islands were initially completely forested, but intensive harvesting of wood let to them becoming, for a time, the principal source of timber for the Portuguese Empire (Schäfer, 2021). Deforestation, increasing human settlement, and waves of agricultural monocultures have led to the destruction of much of the endemic vegetation, and the extinction of many species on some islands (e.g. the Azores cherry *Prunus azorica*) (Schäfer, 2021). Invasive species, associated with human activity, are another major threat to the native flora and fauna (Schäfer, 2021; Gabriel and Borges, 2022) (Figs. 2, 4-6). Due to a combination of these pressures, endemic vegetation (for example, habitats dominated by native laurel *Laurus azorica*, or heather *Erica azorica*) and animal species are now restricted to small and inaccessible localities, such as the interior of caldeiras or coastal cliffs (Schäfer, 2021).

For the purposes of future conservation efforts, understanding the ecological preferences and associations of native and endemic species is crucial, and increased recording and monitoring of the insect fauna of the Azores has been identified as a research priority (Borges *et al.,* 2018). In island biogeography, the combination of ecological and phylogenetic data is proving a powerful tool for analysing differences in community structure, assembly and diversification (Emerson and Gillespie, 2008)—in such work, the Lepidoptera present a very tractable insect

study system. However, as well as lacking ecological data, many endemic Azorean Lepidoptera have few or no publicly available COI barcode sequences which are important tools in identification work and for generating phylogenies.

Among the endemic Azorean Lepidoptera, the two species belonging to the genus *Noctua* were identified as of particular interest prior to the expedition. The yellow underwing moths *Noctua* are large, abundant and widespread noctuid moths (Skinner, 2009). Almost all of these species possess deep yellow, black bordered hindwings (exposed when moving) which perform a defensive function as startle colouration, while the forewings (exposed when at rest) are cryptic and often highly polymorphic. Of the sixteen known species of *Noctua*, six are island endemics, with *N. atlantica* and *N. carvalhoi* occurring variously across the Azores archipelago (Fibiger, 1993).

Hitherto, little work has been directed at unravelling the diversification, ecological specialisation, and phenotypic divergence of the genus *Noctua* (Fibiger, 1993), despite it presenting a potentially interesting and tractable model system for island biogeography. Molecular phylogenetic studies suggest that *N. pronuba* (a continental species) and *N. atlantica* are minimally diverged in their COI sequences (1.4%) but that that separation occurred some 4.7 – 5.9mya—consistent with the formation of some of the older islands in the Azores (Montiel *et al*., 2008). However, little is known about the natural history, and even distribution, of the two Azorean *Noctua* endemics. Indeed, *N. pronuba* occurs alongside both species throughout the archipelago and hybridisation is thought to occur with *N. atlantica* (Lepidoptera and their Ecology, 2022*a*). The extent of any possible hybridisation with *N. carvalhoi* is unknown and addressing this requires extensive sampling of individuals across islands, followed by molecular analyses. Across its range, then, the genus *Noctua* offers a promising potential study system illustrating the processes of colonisation, adaptation, divergence, and speciation.

Expedition Objectives

1) Collect records, voucher specimens, ecological observations, and genetic material (for COI barcoding) of Lepidoptera across the Azores. Increasing our distributional knowledge of the Lepidopteran fauna of the islands, aiding future conservation efforts, and providing a basis for future biogeographic studies.

2) Focus fieldwork efforts on collecting and recording specimens of *Noctua* spp. for comparative morphological study, and make systematic field and captive observations of these species. Contribute to our understanding of the evolution of this genus (a potentially promising model for biogeographic and biodiversity work), and that of the Lepidopteran fauna of the islands more widely.

3) Make adventitious records and natural history observations of other taxa, particularly invertebrates and other groups hitherto relatively under-studied and/or under-recorded.

For more details, see Weir (2023).

Methods

Itinerary—In the initial itinerary for this expedition (Weir, 2023), I proposed to spend four weeks collecting in the islands, with approximately one week on one island of each of the three island groups (western, central and eastern). Specifically, these islands were to be São Miguel, Pico, and Flores. However, following discussions with local collaborators I decided to reallocate time across the schedule. Despite the islands having well-established settlements and a local university, knowledge of the distribution of Lepidoptera throughout the islands is still in a relatively poor state. I decided to prioritise Objective 1, and that spending less time on each island (but covering more islands) would maximise the productivity of the expedition. After making an additional personal contribution to the expedition funds, I was able to visit all nine islands in the archipelago (each for a minimum of three nights, but up to ten nights), extending the total duration of the trip to seven weeks (Fig. 1).

Collecting and Recording Methods—Lepidoptera were collected and recorded across all islands through a combination of light trapping (using MV and actinic light; see Figs. 7-8) at accommodation sites and manual sampling during daytime hikes (treated as 'transects') through various habitat types (Fig. 10). Meta-data (e.g. locality, GPS co-ordinates, habitat associations, general natural history observations; see, e.g. Fig. 9) associated with each specimen was recorded. Specimens were retained where necessary—larger Lepidoptera were stored dried in envelopes and smaller species were micro-pinned in the field and stored in foam-lined cassette boxes. All specimen collection was conducted in compliance with the Code of Conduct for Collecting Insects and other Invertebrates (Second edition, 1987) produced by the Joint Committee for the Conservation of British Invertebrates.

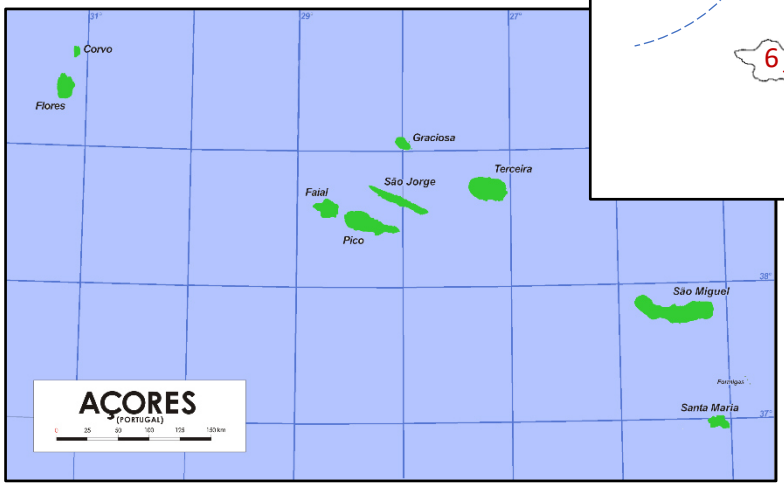
Natural history and evolution of the genus Noctua—Where applicable, special consideration was given to individuals of the genus *Noctua*. Specimens were retained for COI barcoding (sequences of which are limited or non-existent in some species), morphological comparison, and genitalia dissection. Habitat and larval host-plant associations were recorded in the field. The flight times of adults, indications of predation, and behavioural distinctions among species (particularly between endemic insular versus continental taxa) were observed and recorded.

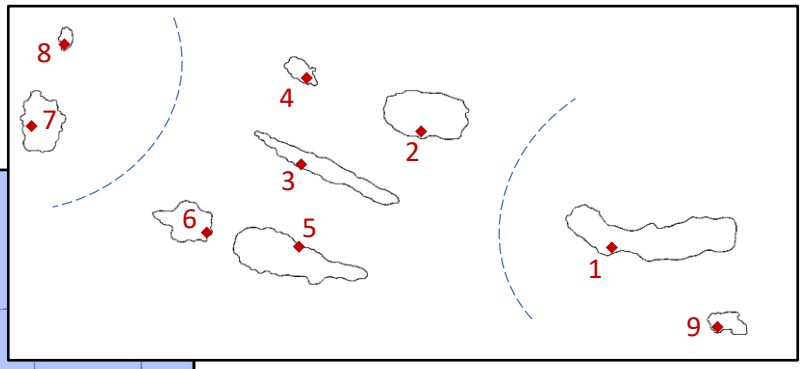
Preliminary Results

Objective 1

In total, over the course of the expedition, I gathered 2,503 records of Lepidoptera. Of these, 1,610 specimens were retained and 893 observational records made of individuals in the field (Fig. 11). There were approximately 937 records made of butterflies (of seven species; Table 1), 522 of macro-moths (the larger Lepidopteran families, such as Noctuidae, Geometridae, Sphingidae), and 1044 of micro-moths (the remaining families of smaller-sized Lepidoptera).

(a) Azores Archipelago





(b) Study sites

(c)

Locality No.	Dates	Island	Locality
1	18 – 24 August	São Miguel	Ponta Delgada
2	25 – 29	Terceira	Angra do Heroísmo
3	30 – 3 September	São Jorge	Velas
4	4 – 7	Graciosa	Luz
5	8 – 11	Pico	São Roque do Pico
6	12 – 15	Faial	Horta
7	16 – 24	Flores	Fajã Grande
8	25 – 28	Corvo	Vila do Corvo
9	29 – 1 October	Santa Maria	Vila do Porto

Figure 1. (a) Geographical situation of the Azores archipelago, (b) location of field sites on each island, and (c) the duration spent based at each locality.

At the time of writing, all observational records of butterflies and moths (*n* = 893), all butterfly specimens (*n* = 937), and 187 (43%) of the macro-moth specimens collected have been identified to species level (Fig. 3). Of the macro-moths identified to date, 31 different species have been recorded. Of the identified specimens and records, 1 butterfly and 11 moths are 'new-to-island' records (species which have not previously been recorded as occurring on that island) (Table 2). Among the moths, this is a new-to-island record per specimen rate of 6%. Since there are 1297 specimens remaining to be sorted, this would project to a potential further 77 new-to-island records. This is likely a conservative estimate, since the remaining specimens include all the smaller or micro-moth families—these are far less studied, and their distributions are likely even less well understood than the larger species, upon which the estimate is based. Distributions of the micro-moths tend to appear patchier across islands, likely due to lower recording effort (Borges *et al.*, 2010).

Objective 2

Despite the regular nightly trapping regime, and trapping and collecting in a variety of habitat types, very few *Noctua* specimens were collected—many fewer than anticipated. In the UK in late summer (Sep-Aug) one might easily collect hundreds of *N. pronuba* in a sub-urban garden environment. From notes made in the field, I estimate the total *Noctua* individuals (of all species) collected during this trip to be at most 25. These specimens have yet to be sorted, but include all three species of the genus present in the archipelago, *N. atlantica*, *N. carvalhoi*, and *N. pronuba*. Why this occurred is unclear, particularly as this expedition took place during the peak season for these species (e.g. Lepidoptera and their Ecology, 2023*a*; 2023*b*). One possibility is that the species may not be as abundant in the Azores as *N. pronuba* is in the UK. This unexpected result limited my ability to address Objective 2, but the findings may provide a basis for a more thorough exploration of the evolution of this genus in future (for example, through subsequent grant applications). If these species do consistently occur at lower density in these islands, a more protracted expedition with an even more intensive trapping effort targeted at specific localities would be required to accumulate sufficient material to address this Objective.

Objective 3

In addition to collecting records and specimens, I gathered extensive notes on behaviour, ecology, and habitat associations for a range of the Lepidopteran and other insects encountered, as well as general natural history observations. I recorded and collected approximately 350 specimens of insect taxa other than Lepidoptera (Fig. 11). Many of these remain to be identified. I collected 34 specimens of Orthoptera during the expedition, of which five are new-to-island records (Table 3). In addition, the known range of the introduced Indian Stick Insect *Carausius morosus,* which has hitherto only been recorded on the islands of Faial and Terceira, was extended to include Graciosa, and Pico. In the latter case, in a first or second instar was encountered, demonstrating that a breeding population is likely established on that island.

Table 1. Butterflies recorded from the islands of the Azores, including one new-to-island record (*).

Species	**Island**	**No. Records**	
American Painted Lady *Vanessa virginiensis* (Drury, 1773)	Graciosa	1	*
	Faial	1	
Clouded Yellow *Colias croceus* (Fourcroy, 1785)	Terceira	152	
	Sao Jorge	106	
	Graciosa	226	
	Pico	7	
	Faial	33	
	Flores	41	
	Corvo	97	
	Santa Maria	21	
Large White *Pieris brassicae azorensis* Rebel, 1917	Terceira	1	
	Pico	3	
	Faial	1	
	Flores	8	
	Corvo	15	
Long-tailed Blue *Lampides boeticus* (Linnaeus, 1767)	Terceira	63	
	Sao Jorge	4	
	Graciosa	83	
	Pico	5	
	Faial	8	
Monarch *Danaus plexippus* (Linnaeus, 1758)	Sao Miguel	4	
	Sao Jorge	2	
	Graciosa	6	
	Pico	3	
	Flores	18	
Painted Lady *Vanessa cardui* (Linnaeus, 1758)	Terceira	4	
	Graciosa	1	
	Faial	3	
	Corvo	1	
Red Admiral *Vanessa atalanta* (Linnaeus, 1758)	Sao Miguel	1	
	Terceira	2	
	Graciosa	3	
	Faial	4	
	Flores	1	

Table 2. Distribution of macro-moths recorded from the Azores, indicating new-to-island records. As yet 43% of all macro-moth voucher specimens collected have been identified.

Species	**Islands (New to Island)**
Beet armyworm *Spodoptera exigua* (Hübner, 1808)	**Santa Maria**
Bloxworth Snout *Hypena obsitalis* (Hübner, 1813)	**São Jorge** – Santa Maria
Box Tree moth *Cydalima perspectalis* (Walker, 1859)	**Terceira**
Chevron Snout *Hypena lividalis* (Hübner, 1796)	**Pico**
Cosmopolitan *Leucania loreyi* (Duponchel, 1827)	**São Jorge**
Cotton Bollworm *Helicoverpa armigera* (Hübner, 1808)	Faial – São Jorge – Graciosa – **Santa Maria**
Egyptian Cotton Leafworm *Spodoptera littoralis* (Boisduval, 1833)	**Terceira** – Faial – **São Jorge** – São Miguel – Santa Maria
Grass Webworm *Herpetogramma licarsisalis* (Walker, 1859)	**São Jorge** – **Santa Maria**
Hummingbird Hawk-moth *Macroglossum stellatarum* (Linnaeus, 1758)	Terceira – **São Jorge** – Graciosa – Corvo

Table 3. Records of Orthoptera from the Azores, indicating new-to-island records.

Species	**Islands (New to Island)**	**Total Records (all islands)**
Gryllus bimaculatus	Flores	1
Migratory Locust *Locusta migratoria*	Graciosa – **Sao Jorge** – Faial – Corvo	12
Oedipoda caerulescens	Faial	2
Phaneroptera nana	**Graciosa** – **Pico** – **Flores** – Corvo	7
Platycleis falx	**Graciosa**	7
Ruspolia nitidula	Sao Miguel – Graciosa – Sao Jorge – Faial	5

Among the butterflies—where more extensive research and collection has already been conducted—there is the potential to consider phenotypic differences among islands. On the island of Terceira, I collected dwarf specimens of the Clouded Yellow butterfly *Colias croceus* and recorded their abundance within the local population. Similar dwarf forms are known from other localities (Eeles, 2024) and it may represent a local genetic form, rather than a developmental aberration caused by poor nutrition or suboptimal conditions.

Work Remaining

I anticipate that all the remaining lab- and analysis-based work outlined in the expedition proposal document (Weir, 2023), along with the preparation and submission of a paper based on these results, will be completed by the end of 2024. See Table 4 for an approximate timeline. Tasks that remain to be completed are:

(a) *Identification of the remaining specimens*—Of the 1,610 voucher specimens collected in this expedition most remain to be identified (253 macro-moths, 1044 micro-moths). The macro-moths remaining will be identified across a period of several weeks. The micro-moths are however more challenging to identify and often require dissection/genitalia examination—as such, identification will likely be more protracted. However, among these smaller species there are likely a greater proportion of new-to-island records, and possibly new records for the archipelago or previously undescribed species. New species of Lepidoptera continue to be described from the Azores, even among the larger, more conspicuous families (see Introduction and Weir, 2023).

(b) *Analysis and examination of* Noctua *specimens*—Far fewer specimens of this genus were collected in the course of the expedition than anticipated. Based on cursory examination of specimens in the field, approx. 25 individuals of *N. pronuba, N. atlantica,* and *N.*

Table 4. Schedule for completion of the remaining work on voucher specimens from the Azores.

	Task		J	F	M	A	M	J	J	A	S	O	N	D
(a)	Identification of remaining specimens	'Macro-moths'												
		'Micro-moths'												
(b)	Examination and analysis of *Noctua* specimens													
(c)	Preparation of material for COI barcoding													
(d)	Examination and analysis of *Colias* specimens													
(e)	Publication of results	Preparation												
		Submission												
(f)	Deposition of records													

carvalhoi were collected from several islands. These specimens will be pin mounted for morphological comparison with specimens of *Noctua* from the European mainland, and to determine the status of any potential hybrid individuals. Notes made on the behaviour and ecological associations of the specimens collected will be collated.

(c) *Preparation of material for barcoding*—When all specimens have been identified, individuals will be assessed against two criteria to determine if material ought to be submitted for COI barcoding: if a COI sequence is currently not available for that species; if a specimen is a putative hybrid (e.g. *N. pronuba* x *carvalhoi*). Selected material will be submitted for barcode sequencing to the Canadian Centre for DNA Barcoding, which will subsequently be made publicly available.

(d) *Analysis of Clouded Yellow material*—Specimens of the Clouded Yellow butterfly were collected from eight islands in the archipelago. On the island of Terceira, a number of dwarf specimens were collected, potentially representing a local size polymorphism. These specimens will be pin mounted and set for quantitative comparison among islands, and with specimens collected on the European mainland. This analysis will aim to determine: if there is consistent evidence of geographical phenotypic variants local to the Azores, particular island groups, or particular islands; and, if the dwarf forms found on Terceira represent a discrete morphology, or the extreme end of continuous variation in adult size.

(e) *Publication output*—The main publication outcome from this expedition will be a paper focused on the advances made in our understanding of the distribution of the Lepidoptera across the whole archipelago (in addition to other key groups, such as the Orthoptera and Phasmatodea). As well as reporting and describing the records made in the expedition, this paper will document and synthesise field observations made, such as novel habitat and host-plant associations. I anticipate initial submission to *Frontiers of Biogeography.* Further publications may arise from the work remaining to be done on the data/specimens, as outlined above. For example, examination and barcoding of *Noctua* specimens (though few in number) may demonstrate the existence of hybrids and, in combination with pre-existing data, may facilitate a phylogenetic study of this genus.

(f) *Deposition of records*—A comprehensive data-base of records made during the expedition will be made available alongside the distribution paper. This data will be shared with my local collaborators at the University of the Azores. The records will also be formatted and uploaded to GBIF, making them widely accessible to researchers.

Future Research

Even at this early stage in the analysis of the results of this expedition, its success in extending our knowledge of the distribution of species among islands highlights the importance of continued, systematic biological recording in the Azores. In the course of this relatively short survey, I was able to add a new-to-island record for a butterfly species—certainly the most conspicuous and well-known group of Lepidoptera. There are several notable areas where future research would likely be very productive:

Firstly, focussing recording effort on both obscure/under-studied taxonomic groups and on more remote, less studied islands. The careful study of insect groups less charismatic than the butterflies and moths, for example, would almost certainly yield new species and a range of hitherto unrecorded taxa. A matter of pressing concern for the protection of the island's biodiversity is to engage researchers with niche taxonomic expertise in studies of the islands by making suitable funding available. Furthermore, many individual islands have received disproportionately less research attention, from the perspective of biological recording. One example is Graciosa, which is less well developed and often more difficult to reach than other islands in the archipelago, and an outlier in the central group.

Secondly, among the Lepidoptera, much remains to be understood about the host-plant associations and life history of many of the smaller species. Understanding the ecological requirements of taxa is a vital step in effective and sustainable conservation. Although I made a deliberate effort to collect host-plant information and collect specimens of larvae in the field, these records were necessarily limited because of the schedule of this expedition. To collect this data on a larger scale and in a more comprehensive way would require a less mobile approach to recording, and a more fixed and long-term base of study. This would allow captive breeding of species, an extended period for observations (both field and captive), and enable careful, systematic experiments on host breadth and preference.

Thirdly, the long-term ecological impact of invasive species and introductions is poorly understood. This is particularly important in a location such as the Azores, which are isolated with many endemics but which also have a long legacy of human settlement and development. New species continue to arrive on the islands and to spread rapidly (Fig. 2). For example, on the 27th August I recorded a Box Tree Moth *Cydalima perspectalis* in Angra do Heroísmo, on the island of Terceira—this is only the second record of this species in the Azores, and the first on this island (Vieira, 2020). In many parts of Europe this species is considered a serious pest, and can cause significant damage to ornamental and native plants (e.g. Plant *et al*., 2019). The ongoing impacts of invasive and introduced species on the native communities of the Azores would certainly repay future study.

The collaborative links I have established in carrying out this project—as well as the experience organising, co-ordinating, and planning extensive fieldwork abroad—have laid the ground-work for future research on the Lepidoptera of these islands, collaborative work on island biogeography with the University of the Azores (Azorean Biodiversity Group), and for securing more funding in future for a continuation of these recording/collecting efforts. Contingent on the remaining work still to be done on this material (see above), I anticipate potentially submitting a further proposal to the Davis Expedition Fund for the 2025 field season to continue work in the archipelago. In particular, I would seek to focus on recording in the more obscure, little-studied islands of the archipelago and spending more time based at a given island location. The quicker turn around adopted in this expedition was most productive as an initial survey—in future, a more protracted and in-depth approach would enable me specifically to tackle some of the outstanding areas for research outlined above. To aid recording work in the islands, I would be keen to develop (subject to the availability of suitable funding) a short identification guide to the Lepidoptera of the Azores. The relatively small fauna makes this feasible, and the availability of a compact and comprehensive 'field

guide' has the potential to vastly increase recording both by local scientists and particularly tourists.

Expenditure

My total project expenditure was £8383.21, with £6380 contributed from the Davis Expedition Fund and personal contributions of £2003.21. *COI barcoding work has not yet been conducted, and the £750 contribution from the Davis Fund will be used to finance this once specimen sorting and identification has been completed.

Item	Cost (£)
Accommodation	5299
Subsistence	900 (estimate)
Flights (to Portugal, return)	289.32
Flights (interisland)	525.58
Flights (additional due to ferry cancellation)	87.72
Ferry	52
Literature	71.23
Within island transfers (e.g. bus and taxi)	230
Equipment and Materials	158.56
LED moth trap	169.80
DNA barcoding*	750
Post-trip stipend	750
Total	**£8383.21**

Acknowledgements

I would like to thank the Davis Expedition Fund for supporting this expedition. I am also extremely grateful to Daniella Di Pirro for her contribution to the project—providing extensive support throughout and valuable assistance in the field. Ally Phillimore provided helpful and constructive comments on an early draft of the project proposal before submission. I greatly appreciate the co-operation of the University of the Azores and the government of the Região Autónoma dos Açores in obtaining permission to conduct fieldwork in the archipelago. In particular, I would like to thank Paulo Borges and Virgílio Vieira for their advice and support.

References

Bamber, R.N. and Costa, A.C. 2009. The tanaidaceans (Arthropoda: Peracardia: *Tanaidacea*) of Sao Miguel, Azores, with description of two new species and a new record from Tenerife. *Acoreana Suplemento* **6**: 183-200.

Borges, P.A.V., Serrano, A.R.M., and Amorim, I.R. 2004. New species of cave-dwelling beetles (Coleoptera: Carabidae: Trechinae) from the Azores. *Journal of Natural History* **38**: 1303-1313.

Borges, P.A.V., Aguiar, C., Amaral, J., *et al.* 2005*a*. Ranking protected areas in the Azores using standardised sampling of soil epigean arthropods. *Biodiversity and Conservation* **14**: 2029-2060.

Borges, P.A.V. et al. 2005*b*. *A list of the terrestrial fauna (Mollusca and Arthropoda) and flora (Bryophyta, Pteridophyta and Spermatophyta) from the Azores*. Direccao Regional de Ambiente and Univ. Azores.

Borges, P.A.V. and Wunderlich, J. 2008. Spider biodiversity patterns and their conservation in the Azorean archipelago, with descriptions of new species. *Systematics and Biodiversity* **6**: 249-282.

Borges, P. A. V., Costa, A. C., Cunha, R., Gabriel, R. 2010. *A List of the Terrestrial and Marine Biota from the Azores*. University of the Azores.

Borges, P.A.V., Santa-Rita, J.V.P., Nunes, R. *et al.* 2018. Species conservation profile of moths (Insecta, Lepidoptera) from Azores, Portugal. *Biodiversity Data Journal* 6: e23311.

Carracedo, J.C. and Troll, V.R. 2020. North-East Atlantic Islands: The Macaronesian Archipelagos. In Alderton, David; Elias, Scott A. (eds.). *Encyclopedia of Geology*. Oxford: Academic Press.

Crowley, R. 2016. *Conquerors: How Portugal Forged the First Global Empire*. Faber & Faber.

Eeles, P. 2024. *Clouded Yellow* Colias croceus. UK Butterflies. URL: https://www.ukbutterflies.co.uk/species.php?species=croceus [11 January 2024]

Emerson, B.C. and Gillespie, R.G. 2008. Phylogenetic analysis of community assembly and structure over space and time. *Trends in Ecology and Evolution* **23**:619-630.

Fibiger, M. 1993. *Noctuidae Europaeae: Noctuinae II.* Entomological Press.

Gabriel, R., and Borges, P. A. V. 2022. *Guia Prático da Fauna Terrestre dos Açores: Field Guide to the Azorean Terrestrial Fauna.* Instituto Açoriano de Cultura.

Lepidoptera and their Ecology. 2023a. URL: http://www.pyrgus.de/Noctua_atlantica_en.html. [Accessed 16 Jan. 2023]

Lepidoptera and their Ecology. 2023b. URL: http://www.pyrgus.de/Noctua_carvalhoi_en.html. [Accessed 16 Jan. 2023]

Montiel, R., Vieira, V., Martins, T., Simões, N. and Oliveira, M.L. 2008. The speciation of *Noctua atlantica* (Lepidoptera, Noctuidae) occurred in the Azores as supported by a

molecular clock based on mitochondrial COI sequences. *Arquipélago: Life and Marine Sciences* **25**: 43-48.

Plant, C. W., Poole, C., Salisbury, A., and Bird, S. 2019. The box-tree moth *Cydalima perspectalis* (Walker, 1859) in Britain: an overview of its spread and current status. *Entomologist's Record and Journal of Variation* **131**: 122-147.

Queiroz, G. 1997. *Vulcão das Sete Cidades (S. Miguel, Açores): história eruptiva e avaliação do hazard*. PhD Thesis, Universidade dos Açores.

Schäfer, H. 2021. *Flora of the Azores: A Field Guide.* Margraf Publishers GmbH.

Vieira, V. 2020. First record of *Cydalima perspectalis* (Walker, 1859) from São Miguel island, Azores (Portugal) (Lepidoptera: Crambidae). SHILAP Journal of Lepidopterology **48**: 141-146.

Weir, J. C. 2023. Davis Expedition Fund Project Proposal. *A Survey of the Lepidoptera of the Azores: and the natural history and evolution of* Noctua atlantica *and* Noctua carvalhoi *(Lep.: Noctuidae), two endemic Azorean moths*.

FIGURES

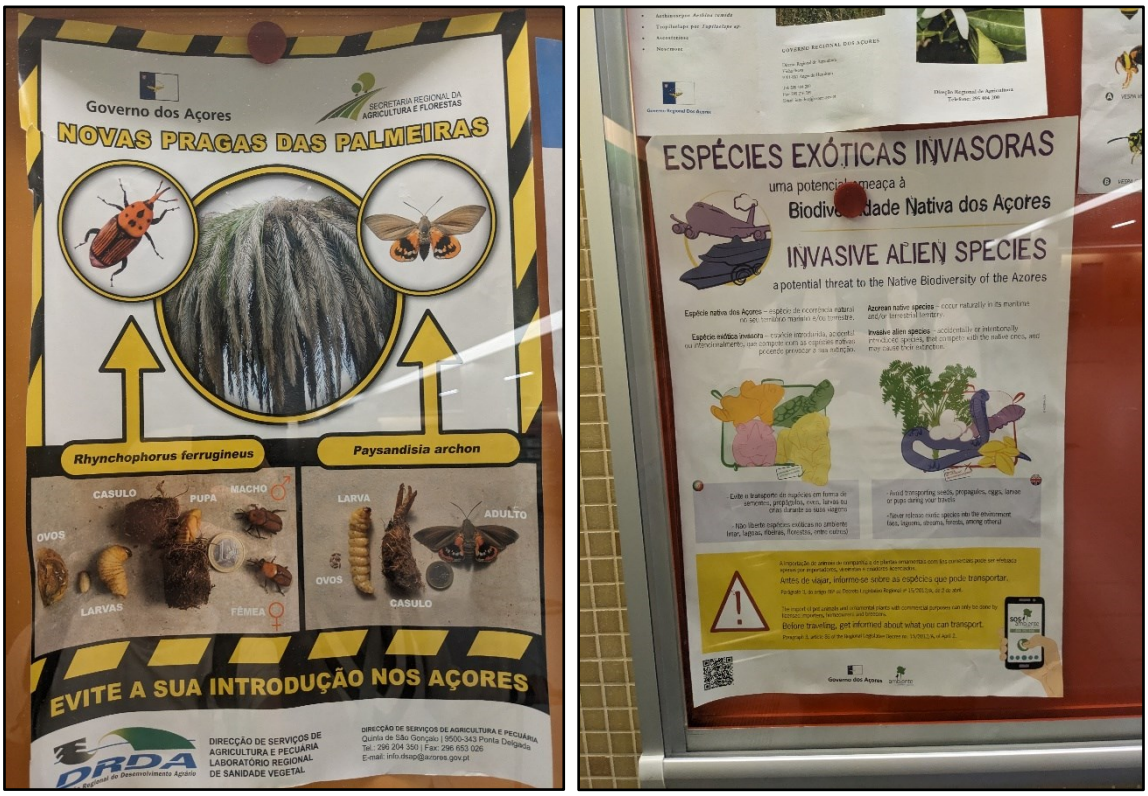


Figure 2. Posters at Terceira airport, warning of the problems associated with invasive species on the islands.

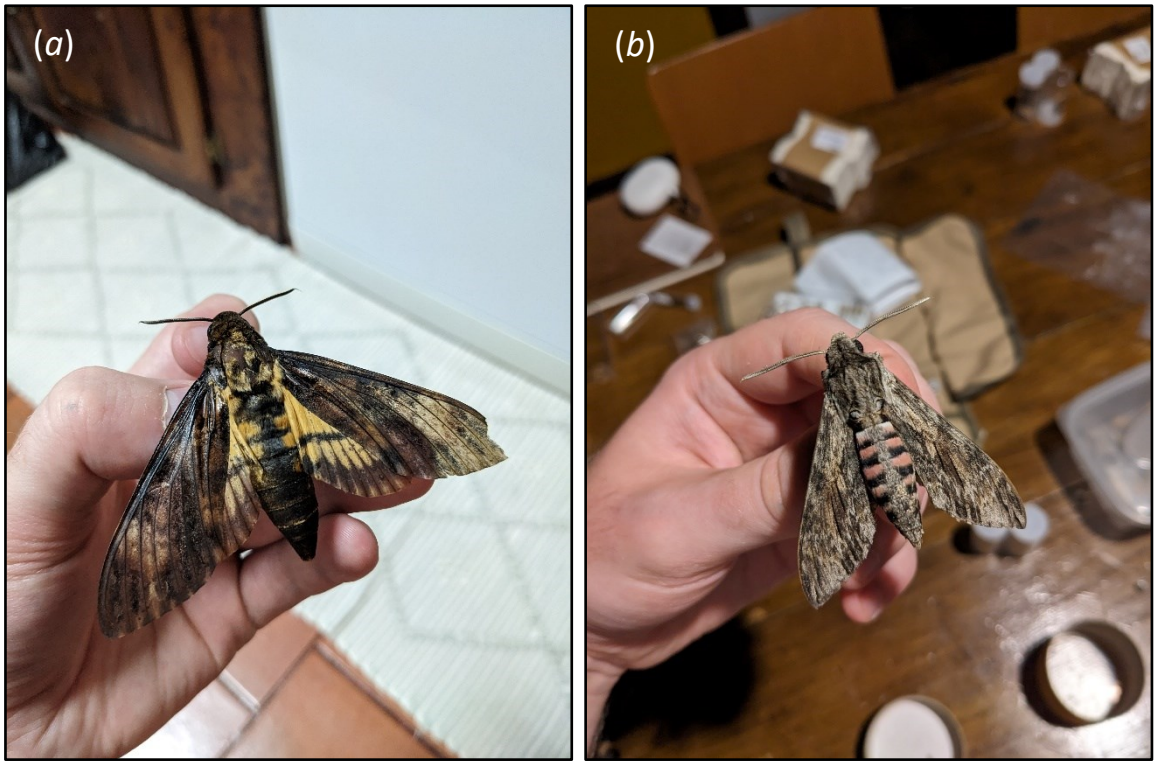


Figure 3. (a) A very worn Death's Head Hawk-moth *Acherontia atropos*, drawn to MV light on Pico; (b) A Convolvulus Hawk-moth *Agrius convolvuli*, drawn to a 20W actinic light on Flores. © Jamie C. Weir.

Figure 4. Invasive Kahili Ginger *Hedychium gardneranum* on the island of Flores. This species was abundant in many locations (e.g. São Miguel, Terceira, Flores), particularly on steep ground adjacent to rock faces and cliffs. © Jamie C. Weir.

Figure 5. Invasive Century Plant *Agave americana* on the southern coast of Santa Maria, thriving in the dry environment of that island. © Jamie C. Weir.

Figure 6. Dense woods of invasive Australian Cheesewood *Pittosporum undulatum*. This species is abundant on all islands, and grows in thick stands, filtering out light. Understory and forest floor rather homogenous with low plant diversity. © Jamie C. Weir.

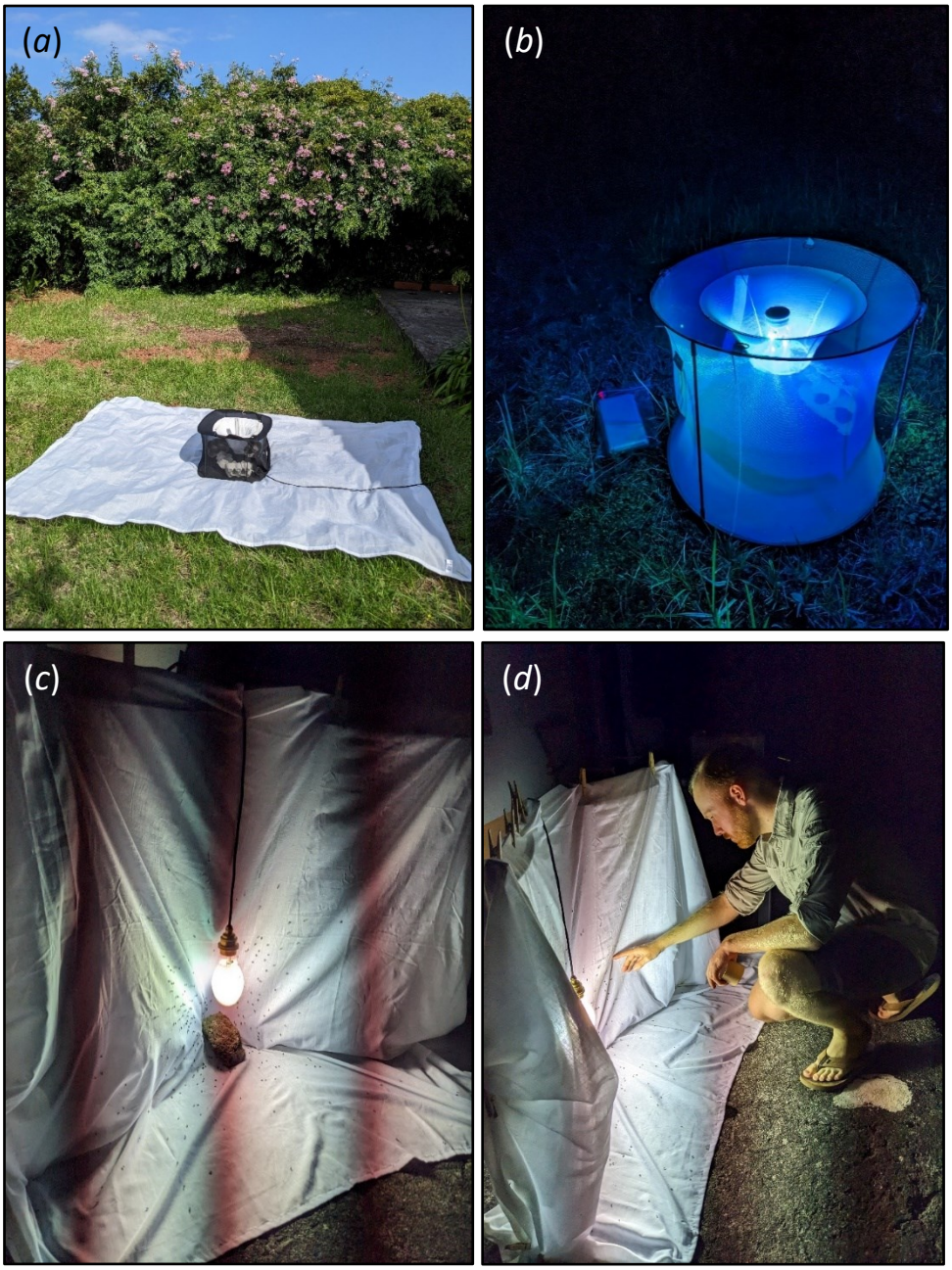


Figure 7. Light trapping techniques for moths employed in the Azores. (*a*) A 'Ranger' moth trap with 20W actinic bulb on Pico. Set up on a white sheet, to collect individuals which approach the light but do not enter the trap. (*b*) A 'Safari XL' light trap set-up using UV LEDs and run from a power bank, on São Miguel. (*c* - *d*) Manually checking a sheet set-up with a 125W MV bulb on Flores. © Jamie C. Weir.

Figure 8. Light trapping using a ‘Ranger’ moth trap with 25W blacklight actinic bulb set up in a suburban garden in Fajã Grande, on Flores. © Jamie C. Weir.

Figure 9. Grass moths *Scoparia* observed feeding/imbibing on/from the surface of leaves (unknown plant sp.), Terceira.

Figure 10. The author examining a Clouded Yellow netted among native heather scrub, near the Capelinhos volcano (Faial).

Figure 11. Some notable insect records from the Azores. (a) Clouded Yellow butterfly *Colias croceus*; (b) house centipede *Scutigera coleoptrata*, very common throughout the islands; (c) wasp spider *Argiope bruennichi*, on Flores; (d) juvenile Indian Stick Insect *Carausius morosus*, recorded on Pico for the first time. © Jamie C. Weir.

Figure 12. Remnants of lava flows preserved in the bedrock on Graciosa, near Luz. © Jamie C. Weir.

Figure 13. Fossil deposits in the Grutas do Figueiral, on the island of Santa Maria. Although almost entirely volcanic, uplift of an ocean shelf on the oldest island (Santa Maria) has led to the formation and exposure of fossiliferous strata. Bivalves were particularly abundant, and exposed both in the walls of the mine and in material scattered outside. © Jamie C. Weir.

Figure 14. Rock samphire *Crithmum maritimum* growing on the western coast of Flores, near Fajã Grande. © Jamie C. Weir.