Project Number: 101062427

Project Acronym: PALEOSIM

Project Title: PALEOclimate modelling of Small Islands in the Mediterranean and possible impacts on arthropod habitats

TFR2: Technical and Financial Report 2

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Technical Overview

This report is an update on the Technical and Financial Report 1 (TFR1, submitted to UM project supervisor in December 2023), and the information provided below represents updates and new content. As the TFR1, this document is divided into two parts, an overview of the technical aspects of the project, PALEOSIM, and an update of the financial plan.

The main objective of PALEOSIM is ***to determine the impacts of climate change on arthropod habitats in the last 21,000 years, and extending to the current global warming projections***. To achieve this goal, PALEOSIM was sectioned into 6 Work Packages (WPs) with their own associated tasks and goals, of which the first 3 WPs contain research goals, and the latter 3 make up transfer of knowledge, dissemination, and management of the project. An overview of each WP is presented in the following sections. Reference will be made for TFR1 throughout the document, as unchanged content is not repeated in this document.

Updates to WP1 - Climate Impacts on Arthropod Habitats

Refer to TFR1 for T1.1, T1.2, T1.3, & T1.4.

Updates to T1.2 - Arthropod Observations

The collection of arthropod data continued with a field-work trip to the Aeolian islands (*correction from TFR1 Table 4, which was listed as Aegean*). The updated list is presented in Table 1 below. Following the completion of field-work excursions, the citizen-science program was closed and the data evaluation is currently in progress (details in WP5).

Table 1. Date and locations of field-work excursions conducted for PALEOSIM (*update to TFR1 Table 4*).

Date	**Location**	**Island**	**Companions**
07/09/2022	*Il-Ballut ta Marsaxlokk*	Malta	D. Mifsud, A. Lamoliere
07/01/2023	Buskett Gardens	Malta	*Bioblitz*
22/04/2023	*Valle d'Agira*	Sicily	G. Sabella, D. Mifsud, A. Lamoliere
22/04/2023	*Ponte dei Saraceni*	Sicily	G. Sabella, D. Mifsud, A. Lamoliere
23/04/2023	*Bosco di Malabotta*	Sicily	G. Sabella, D. Mifsud, A. Lamoliere
24/04/2023	Eastern Lampedusa	Lampedusa	D. Mifsud, A. Lamoliere
25/04/2023	Western Lampedusa	Lampedusa	D. Mifsud, A. Lamoliere
04/06/2023	Binġemma Valley	Malta	G. Galea, C. Galea
17/06/2023	Għajn Tuffieħa	Malta	S. Mifsud
11/11/2023	Comino	Comino	A. Agius
29/04/2024	Lipari (town)	Aeolian Isles	D. Mifsud
30/04/2024	Vulcano	Aeolian Isles	D. Mifsud, P. Lo Cascio, F. Allegrino
01/05/2024	Panrea & Stromboli	Aeolian Isles	D. Mifsud
02/05/2024	Western Lipari	Aeolian Isles	D. Mifsud

Updates to T1.4 - Climate Impact Assessment

The results of this task were compiled into a publication (the **WP1 deliverable D1.1**). The paper, entitled "A climate suitability index for ecological habitats applied to terrestrial arthropods in the Mediterranean Region" was submitted to Earth System Dynamics on 18th July 2024 (further delays from the proposed submission date in TFR1 were due to conflicting time commitment resulting from issues with WP2). The submission of this paper marks the completion of deliverable D1.1, which is currently available as a pre-print on EGUsphere (https://egusphere.copernicus.org/preprints/2024/egusphere-2024-1954/).

Updates to WP2 - Modern-day Climate Assessment

Refer to TFR1 for T2.1, T2.2, T2.3, & T2.4.

Notable Risk and Mitigation

Following the delays detailed in TFR1, T2.3 suffered additional delays that significantly impacted the progress of all tasks. Following the hot bias issue identified in summer 2023, a systematic wet bias was identified in December 2023 and resolved in January 2024. Furthermore, a bug in the execution of the land surface model prevented the simulations to proceed until July 2024. To salvage the task, a decision was taken in January 2024 to focus only on the priority GCM listed in TFR1 (MPI-ESM1-2-HR and MPI-ESM1-2-LR for WP2 and 3) and omit the remaining simulations from the project objectives. If necessary, an additional mitigation strategy may be implemented where only 10-year time periods would be considered instead of 20-years.

Updates to T2.2 - Model Configuration

Preparations are being made to store the simulation products on the CINECA ESGF nodes. The final access location of the data will be included in the deliverable D2.1 and the project website (https://www.um.edu.mt/projects/paleosim/).

Updates to T2.3 - Historical and Future Simulations

As mentioned above, the progress on these simulations has been impacted by a series of bugs and thus ERA5 and MPI are the only simulations that have been/will be run for the project. Thus, the current state of the simulations is severely delayed, and Table 2 below shows the update from TFR2 Table 9.

Once all the ERA5 and MPI CP-simulations reach the target date, the milestone **M2.2 (Completion of CP Simulations)** would be achieved.

Table 2. Current state of planned simulations as of 26/08/2024 (*update to TFR1 Table 9*).

Driver	**Start**	**Current**	**Target**	**ECT**
EUR-11 simulation (running rate: 1.963 hr/sim.mon)				
ERA5	1970/01	2019/12	2019/12	Complete

MPI	1970/01	2003/11	2099/12	Nov 2024
WMD-03 simulation (running rate: 6.695 hr/sim.mon)				
ERA5	1995/01	2005/12	2014/12	Sep 2024
MPI: historical	1995/01	1996/01	2014/12	Oct 2024
MPI: GWL1.5	2001/01	(historical)	2020/12	Nov 2024
MPI: GWL2	2041/01	(01/10/24)	2060/12	66 days from start
MPI: GWL3	2072/01	(31/10/24)	2091/12	66 days from start

Update to T2.4 - CP-Simulation Evaluation and Impact Assessment

Given the delays encountered with the simulations in WP2, the milestone M2.2 is expected to be completed very close to the end of the project, and hence **Deliverable D2.1** will be submitted to 'Journal of Advances in Modelling Earth Systems' within the final 2 months of the project.

Updates to WP3 - Paleoclimatic Changes to the Central Mediterranean

Refer to TFR1 for T3.1, T3.2, T3.3, T3.3 & T3.5.

Update to T3.1 - Paleoclimate and Palaeontology review

When considering the climate suitability index developed in WP1, it was concluded that the method was most useful for species with limited geographical range and abundant observations. This is exceptionally challenging for fossilized arthropods. Furthermore, when looking at publications and fossil databases (such as PBDB Navigator: https://paleobiodb.org/navigator/), no specimens could be found of extant arthropod species or genera in the Mediterranean and Europe. For this reason, no paleontological observation can be linked to the climate suitability results obtained within this project.

Update to T3.2 - Simulation Setup: Paleoclimate Adjustments

The land-use maps generated from the Köppen-Geiger (KG) climate classification (Peel, Finlayson and McMahon, 2007) masks, were updated as shown in Table 3.

Table 3. The KG classifications assigned to the BATS categories (Cat.) for the paleoclimate simulations. Urban and Sub-Urban are only assigned for the historical experiment. *mask* – represents the ICE7G glacier mask; *r.u.c.* – remaining unassigned cells (*update to TFR1 Table 12*).

Cat.	Description	Assigned Category
1	Crop/mixed farming	-
2	Short grass	Dsa, Cfa, Cwc, Dfa, Dsb, Dwc
3	Evergreen needleleaf tree	Dsd, Dwd, Dfd
4	Deciduous needleleaf tree	Dfc
5	Deciduous broadleaf tree	Cfb
6	Evergreen broadleaf tree	Am, Af
7	Tall grass	BSh, Aw
8	Desert	Cwa, BWh

9	Tundra	ET, Csc, Dsc
10	Irrigated Crop	-
11	Semi-desert	Bwk
12	Ice cap/glacier	EF, *mask*
13	Bog or marsh	-
14	Inland water (rivers and lakes)	-
15	Ocean	-
16	Evergreen shrub	Dwa, BSk, Csa, Csb, Cwb, Dwb
17	Deciduous shrub	Cfc
18	Mixed Woodland	Dfb, *r.u.c.*
19	Forest/Field mosaic	-
20	Water and Land moisture	-
21	Urban	PFT15<0.4
22	Sub-Urban	0.1<PFT15<0.4

The selection of these categories was done following a quantitative assessment of the EUNIS vegetation database. With the assistance of Arthur Lamoliere (a member of the Institute of Earth Systems at the UM, with considerable experience using GIS systems) the different vegetation types were assigned a BATS category (where possible). Using historical climate data to construct a reference KG data-set, a matrix was constructed that linked the EUNIS data (expressed in BATS types) to the KG data-set. A value for the number of corresponding points was obtained, and a series of transformations were then performed. These are detailed below:

- The sum of values corresponding to each KG classification expressed as a percentage relative to the total number of points in the matrix;
- Each value was expressed as a percentage of the BATS category total;
- Each percentage value was normalized to the percentage sum of each KG classification.

Following this, a series of sequential rules were devised to assign each KG classification (KGc) to a single BATS vegetation category (VGc; each VGc can have multiple KGc). The sequence was done as follows (assignments in square brackets):

0. First 4 KGc were assigned manually, as they did not have corresponding EUNIS types within the European data-set used, and their corresponding VGc is logical [VGc 3=Dfd, Dsd, Dwd; 6=Af];
1. The highest KGc was identified from each VGc [6=+Am; 7=BSh; 9=ET; 12=EF; 16=Dwa];
2. If top three at step 1 are similar, the KGc that was the highest amongst all VGc was selected [2=Dsa; 8=Cwa+BWh; 11=BWk];
3. For remaining KGc the highest VGc was selected from one KGc [2=+ Cfa, Cwc, Dfa, Dsb, Dwc; 4= ~~Cfc~~, Dfc; 5= Cfb, ~~Dfb~~; 7= Aw; 9= Csc, Dsc; 16= BSk, Csa, Csb, Cwb, Dwb; *KGc with a strikethrough were reassigned in the upcoming steps*].
4. For the remaining unassigned VGc:
    a. 17 was assigned the one highest KGc from the highest VGc of steps 1-2 [Cfc];
    b. 18 was assigned the highest KGc shared with “tree-type” VGc (except where tree VGc assigned only one KGc) [Dfb];
    c. 13 was not assigned any KGc and was thus not included.

This method is currently being compiled in the publication that will serve as the deliverable for WP3.

Update to T3.3 - Paleoclimate Simulations

Although no computational challenges occurred within WP3, considerable human and computational time were allocated to resolving the problems that occurred within WP2. For this reason, and for consistency within the project, only the MPI-ESM1-2-LR downscaling was done for WP3.

All the MPI CP-simulations were completed on the 2nd June 2024, marking the achievement of milestone **M3.2 (Completion of Paleoclimate Simulations)**.

Updates to T3.4 - Climate Proxy Data Preparation

Following TFR1, the PAGES2k proxy data was found to be limited for the purposes of evaluating gridded simulations. Although PAGES2k contains abundant points of reference, this would still provide very limited coverage for the evaluation. Furthermore, the different proxies, reporting methods, and data formats make the use of this data very cumbersome.

For these reasons, paleoclimate reanalysis data-sets were accessed to be used as reference data-sets. The reference data-sets are described in Table 4.

Table 4. Reference data-sets for WP3 simulations, together with the period where they were applied.

Data-set	**Variable**	**Period**	**Reference**
lgmDA	tas, pr	LGM, mid-Holocene	(Tierney et al., 2020)
MCruns	tas, pr	1000	(Tardif et al., 2019)
ModE-RA	tas, pr	1850	(Valler et al., 2024)
EOBS	tas	Historical	(Haylock *et al.*, 2008; Cornes *et al.*, 2018)
MSWEP	pr	Historical	(Schneider *et al.*, 2013)

Updates to T3.5 - Paleo-Simulation Evaluation and Impacts

The evaluation of the simulations is currently being prepared for publication which will be submitted to ‘npj Climate and Atmospheric Science’ in a few months, serving as **Deliverable D3.1**. A brief overview of the performance of these simulations is displayed in Figure 1.

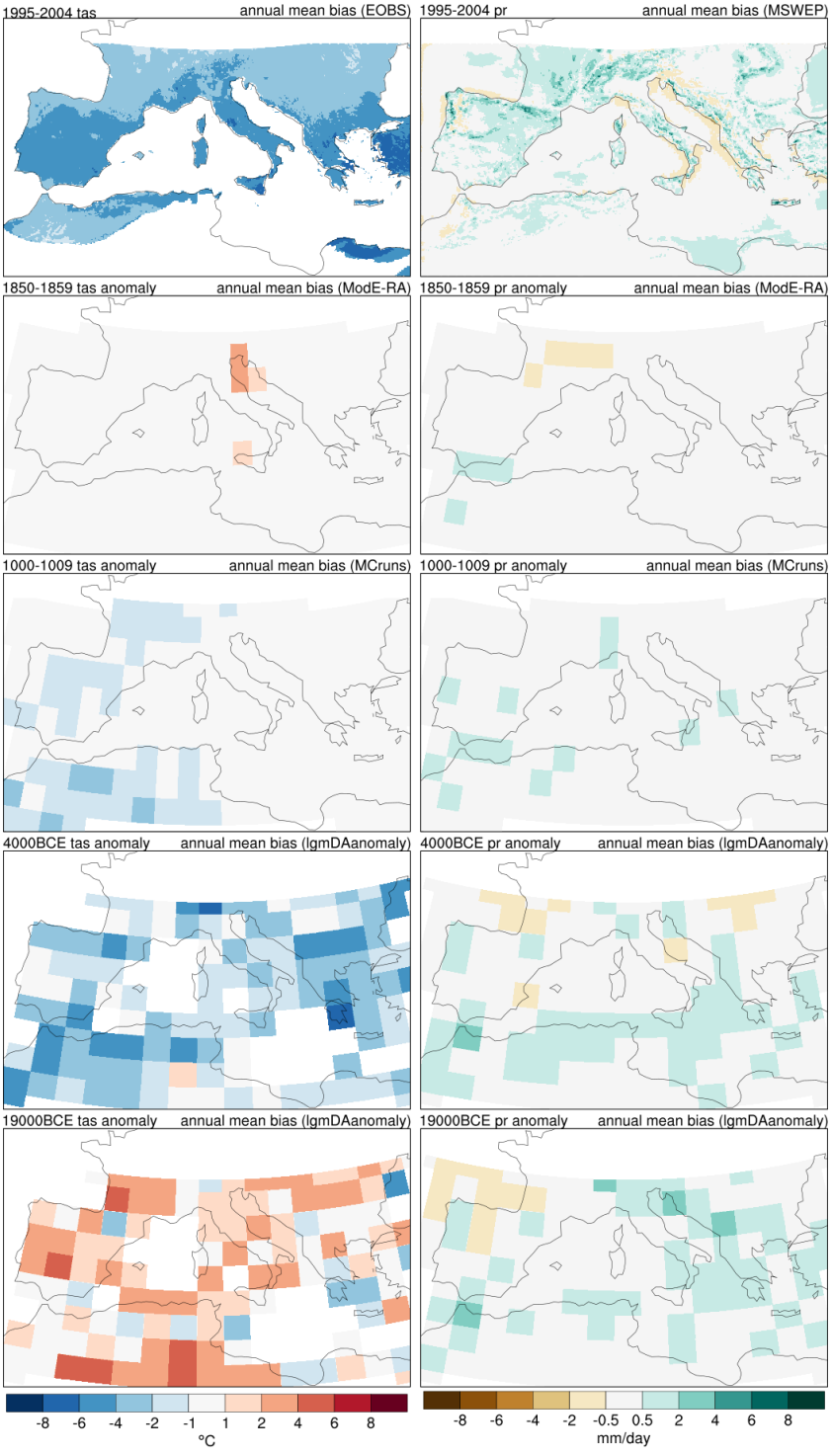

Figure 1. Annual mean biases for temperature and precipitation means of the historical simulation, and the temperature and precipitation anomalies of the remaining WP3 simulations.

Following discussion with the supervisors, a paper covering both the evaluation of the paleoclimate simulations, and the impacts of climate change on arthropods ranging from paleoclimate periods to the future, was deemed too broad. Furthermore, given the delays with WP2, it would not be possible to produce an adequate analysis of the climate impacts. For this reason, the deliverable of WP3 is being focused on the evaluation of these simulations.

An assessment of climate impacts on arthropods however, is still underway. Species such as *Brachytrupes megacephalus* and *Cerambics cerdo*, are examples of arthropods being considered for this analysis. Data is being gathered from sources beyond iNaturalist to enhance the number of observations of the species and obtain more reliable results. Such results may be used within the placement at Esplora, but will be published in a separate publication once a proper analysis can be made. An example of the analysis can be seen in Figure 2.

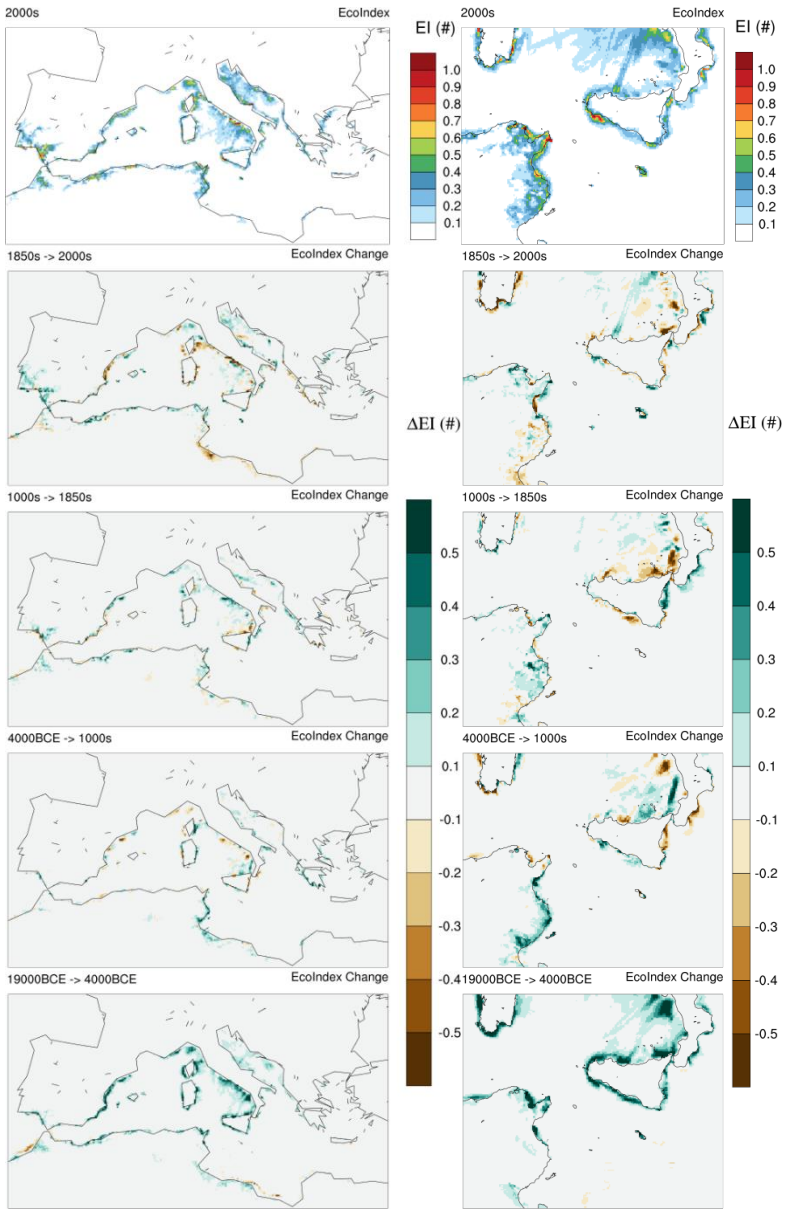

Figure 2. Change in climate suitability for *Brachytrupes megacephalus* using 98 observations (obtained from iNaturalist, GBIF, EUNIS, and publications of Prof. Louis Cassar) across the WP3 time periods (the change is presented on a relative scale, where positive values describe a favourable change of climate, and negative values describe a degradation of climate conditions). The left panel shows the results for the entire CP simulation, and the right panel shows a focus on the Circum-Sicilian Islands.

Updates to WP4 – Training and Transfer of Knowledge

Following TFR1, the **deliverable D4.1** (Training and Secondment Report - TSR) was completed and submitted to UM project supervisor in May 2024. An agreement was signed between the University of Malta and Esplora where the objectives of the **Placement (P; Display preparation)** was detailed. The placement started on the 1st August 2024, and the objective is to prepare physical displays (in the form of posters and photos), a show, and potentially some workshops, using the material of the project. Currently, collaboration with the team of Esplora promises to have more detailed concepts of each of these outputs by September 2024 which will mark the achievement of milestone **M4.2 (Design plan of display for Esplora)**. The idea of an interactive data atlas, included in the project proposal, could not be to set up, as it would require purchasing of substantial hardware and specialized software developers that would be too expensive.

One of the discussed outputs of the display was the use of professional or semi-professional photos of insects to help visitors at Esplora gain a more favourable perspective of arthropods, given the public's negative perspective view of these animals. For this reason, Dr Ciarlo` signed up for a UM course on Nature Photography to improve his photography skills and obtain semi-professional photos of charismatic subjects, during the last months of his field-work, to be used in outreach campaigns. Figure 3 shows a sample of 6 photos taken for the Nature Photography course and being used as outreach (during the seminar, on social media, and for the upcoming display at Esplora) to help the public see insects in a new light.

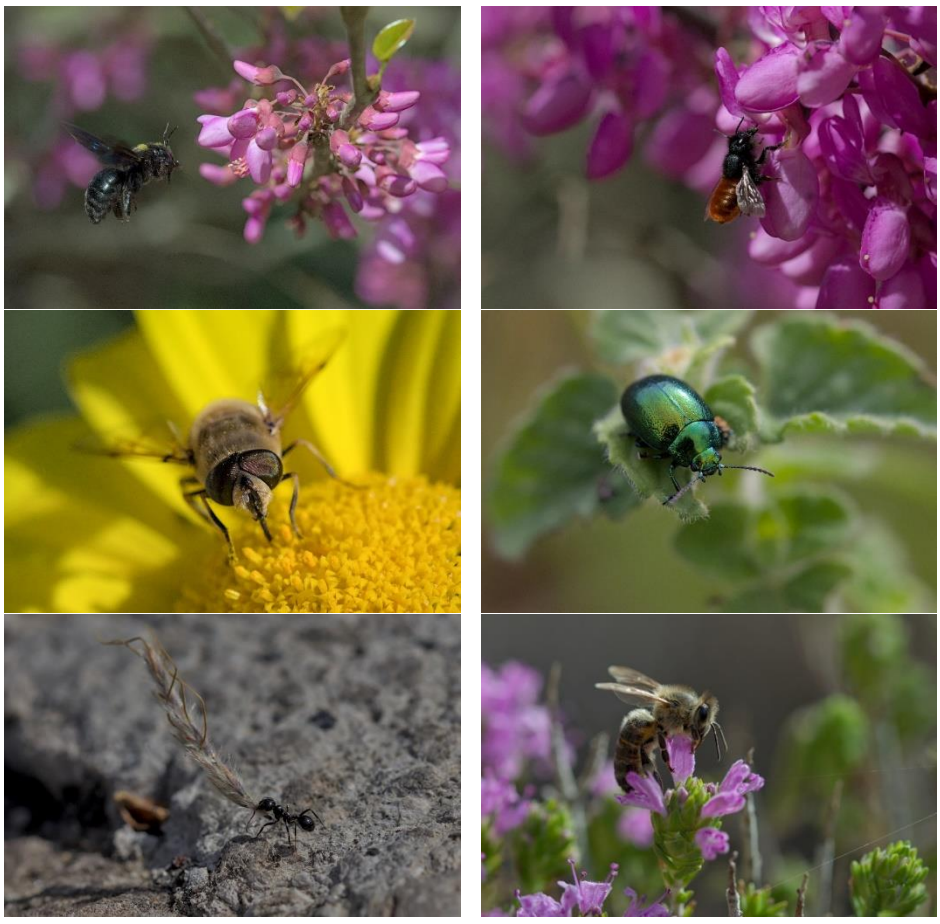

Figure 3. A panel of insect photos taken by Dr James Ciarlo` for the Nature Photography course and currently being used in the PALEOSIM outreach campaign.

The material prepared with the Esplora team will be displayed in a special even at the end of January 2025 (precise date to be determined), marking the completion of **deliverable D4.2**, and it will also be combined with the final seminar S5 (detailed in WP5).

WP5 – Communication, Dissemination, and Exploitation

As mentioned in the TFR1, seminars S3 and S4 were combined in one seminar:

- Seminar S3/4 at UM entitled '*Ecological Impacts of Climate Change on Small Islands: Unveiling Insect Responses through PALEOSIM*' took place on 28 June 2024. The seminar also included a guest speaker Prof. Simone Fattorini.

Seminar S3/4 was recorded and uploaded on the project social media page, and a local news team (TVM news) came to the seminar for an interview which was aired on national television (acting as a News report item, N – as suggested in the project proposal).

A final seminar (S5) is envisaged for the end of January 2025, which may will likely take place at Esplora.

Figure 4. Dr James Ciarlo` presenting the Seminar S3/4 at UM (left) and being interviewed by TVM news (right).

On 29 May 2024, PALEOSIM was also featured with a poster at the UM Research Expo, that detailed the progress in paleoclimate simulations, and their application to climate suitability modelling for arthropods.

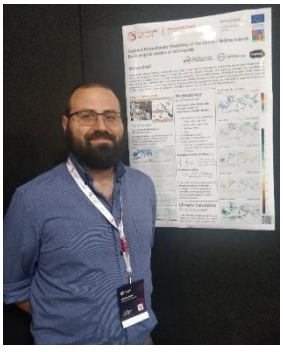

Figure 5. Dr James Ciarlo` presenting at the UM Research Expo 2024.

Following workshop W0 and conferences C0 & C1, mentioned in TFR1, presentations focusing on the new climate simulations and their application to ENM were given at the American Geophysical Union (AGU) Fall Meeting 2023 (C2) in San Francisco [11-15 December], and the European Geosciences Union (EGU) General Assembly 2024 (C3) in Vienna [14-19 April 2024]. The presentations were entitled '*Convection Permitting simulations of the Mediterranean driven by CMIP6 data for the application of an ecological niche model for arthropods*' (C2), and '*Climate-induced variations in arthropod habitats of the Circum-Sicilian islands according to convection permitting simulations of the Mediterranean driven by CMIP6 and PMIP4 data*' (C3). Furthermore, an opportunity to network at the Med-CORDEX workshop (W0b) was taken, which proved to be essential in establishing contacts and learn about new datasets relevant to the project.

Figure 6. Dr James Ciarlo` at (left to right) C1, C2, and C3 in Heraklion, San Francisco, and Vienna respectively.

The website [https://www.um.edu.mt/projects/paleosim/] and social media page [https://www.facebook.com/paleosim.msca] (WS), are still in use to share project updates and promote the progress and objectives of the project. In recent weeks, photos taken from the Nature Photography course are being uploaded as a small campaign to show arthropods in a different light to the public.

Plans are currently underway to participate in the European Researcher's Night (ERN) in September 2024 (Science in the City). This will likely be a stand with posters and props for the audience to approach and interact with the researcher at the stand.

The Citizen-science Observation Program (COP) wrapped up data collection, and the Epicollect5 app was closed on the 13th June 2024. As experts have been contacted and are currently identifying the entries, the total is currently at 616 observations (with 344, 55.84% identified entries as of 26/08/2024). Figure 7 and Figure 8 show the geographical distribution and variety of observations uploaded through the COP. When all the entries are identified, a short report will be compiled, and the dataset will be uploaded on the Zenodo platform, marking the achievement of the **milestone M5.2 (online publication of field-work/COP results)**.

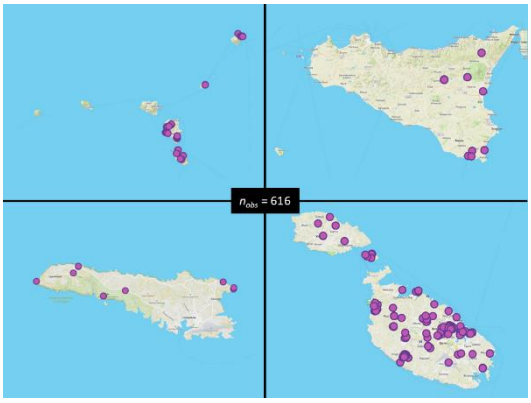

Figure 7. Input locations taken in the Aeolian islands, Lampedusa, Sicily the Maltese islands through the COP.

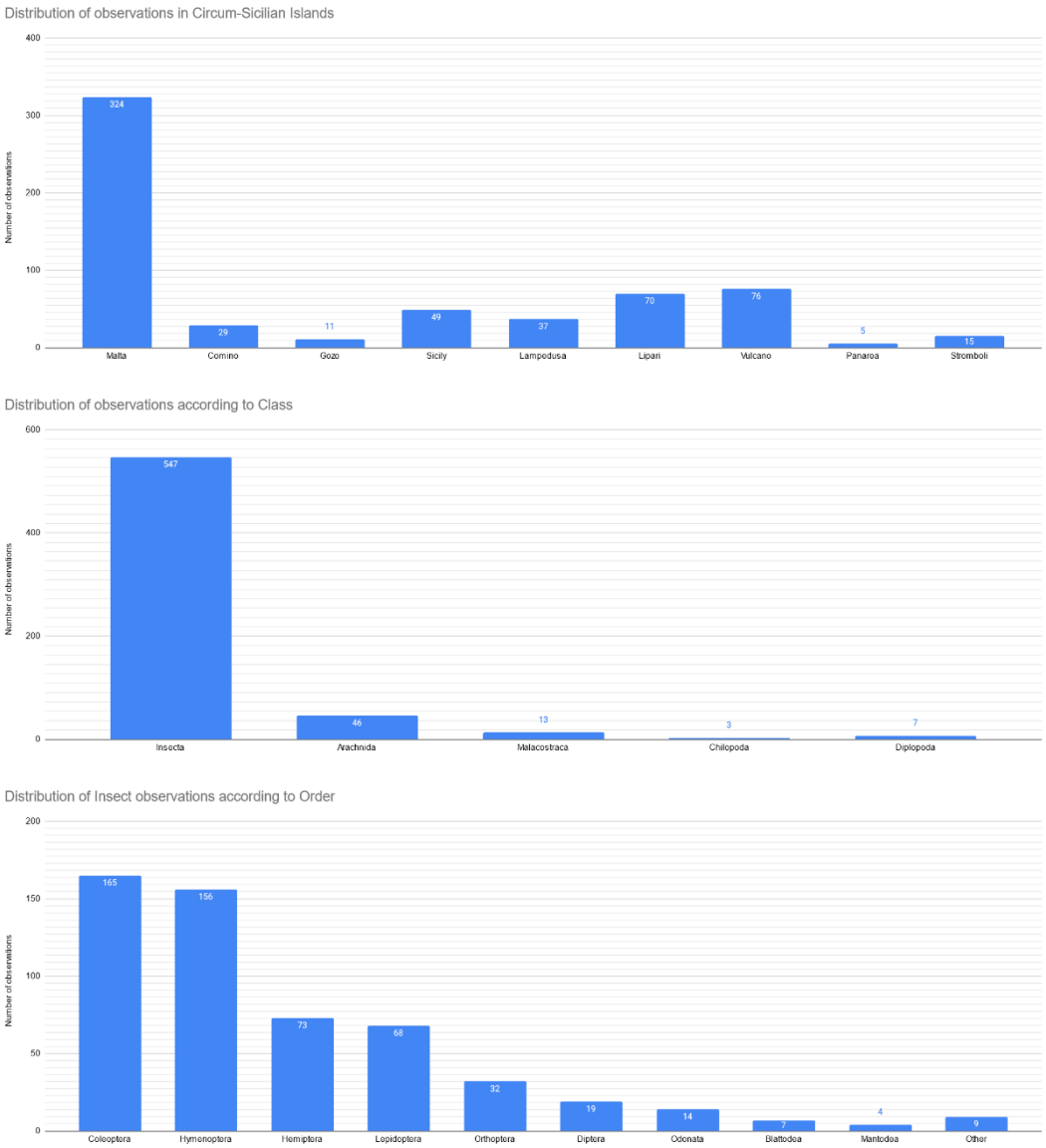

Figure 8. Bar charts of COP observations divided by islands (top), arthropod classes (middle), and insect orders (bottom).

Special acknowledgement is given to all the anonymous numerous volunteers who upload their observations through the Epicollect5 app, as well as the following individuals who made this Citizen Science Program successful:

- **Preparation and support with Epicollect5:** *Simone Cutajar, Arthur Lamoliere*
- **Participation in PALEOSIM field-work:** *Giorgio Sabella, Pietro Lo Cascio, Francesco Allegrino, David Mifsud, Arthur Lamoliere, Adrian Agius, Michelle Ciarlo`, Gareth Galea, Claire Galea, Stephen Vella*
- **Identification of observations:** *Louis Cassar, Aldo Catania, David Dandria, Godwin DeGabriele, Enrico de Lillo, Henrik Enghoff, Albena Gjonova, Pietro Lo Cascio, David Mifsud, Roberto Pantaleoni, Giorgio Sabella, Matthew Calleja, Simone Cutajar*

During the proposal, it was envisaged that at the end of the research-phase, a **Report on Suggested Policies** will be prepared as the final **deliverable (D5.2)** of WP5. Given the delays in WP2, and the limited preparation time, this will be pushed towards the end of the project.

Updates to WP6 – Project Management

As mentioned in TFR1, progress on the project is discussed with supervisors at irregular intervals, depending on the requirements of the project. This **Technical and Financial Report 2 (TFR2)** will serve as **deliverable D6.3**.

Financial Overview

The list presented below is an update from the FMP included in the PCDP (D6.1), on the completed and upcoming expenses associated with the project.

Expense	Cost (€)	WP	T
Book: The Insects (5th Ed) - Gullan & Cranston	78.00	4	TR1
Book: Insect Ecology (5th Ed) - Schowalter	162.75	4	TR1
First Aid course	55.00	1	T1.2
Secondment 1: Domain setup (Trieste)		2, 4	SC1
Flights	157.46		
Accommodation	1100.00		
Islands Visit 1: Catania & Lampedusa		1	T1.2
Flights	162.09		
Subsistence Allowance (6 nights)	1242.00		
Secondment 2: Paleoclimate setup (Trieste)		3, 4	SC2
Flights	90.92		
CORDEX Conference registration	200.00		
Accommodation	950.00		
ECE 2023 Conference		5	C1
Conference registration	575.00		
Flights	490.95	5	
Subsistence Allowance (7 nights)	1160.00	5	
Social Media Adverts	80.67	5	WS
Advertising Specimen	115.00	5	WS
Malta International Airport Data	4535.55	1	T1.3
Education Supplies (insect models + thermometers)	73.50	5	LS
AGU 2023 Conference		5	C2
AGU 2023: Year Membership	51.32		
AGU 2023: Application	63.03		
AGU 2023: Registration	690.87		
Flights	1042.35		
Subsistence Allowance (6 nights)	1854.00		
Nature Photography Course	120.00	4	P
EGU 2024 Conference		5	C3
EGU 2024: Year Membership	20.00		
EGU 2024: Application	50.00		

EGU 2024: Registration	525.00		
Flights	214.31		
Subsistence Allowance (7 nights)	1421.00		
Islands Visit 2: Aeolian Islands		1	T1.2
Flights	71.62		
Subsistence Allowance (4 nights)	828.00		
Med-CORDEX Workshop		5	-
Flights	129.98		
Subsistence Allowance (3 nights)	621.00		
10T Hard Drive	202.21	2, 3	-
UMRE24 poster	20.00	5	-
Seminar venue	63.75	5	S3/4
Total Spent	**19,217.33**		
Open-access: Earth System Dynamics	1953.00	1	D1.1
Open-access: Journal of Advances in Modelling Earth Systems	2120.04	2	D2.1
Open-access: npj Climate and Atmospheric Science	2571.70	3	D3.1
Esplora Placement		4	P
3 Posters (€15/poster; €100 design)	345.00		
Seminar catering (~90 pax)	550.00		
Paleolandscape design (2 sets, 5 colour illustrations/set, est. €1250/set)	2,500.00		
Total Estimated	**10,039.74**		
Total Spent + Estimated	**29,257.07**		
Current Estimated Surplus	***742.93***		

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