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Ecological and Evolutionary Processes on Real and Habitat Islands

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Beyond the concept of oceanic islands as climatic refugia: A high resolution climate dataset for the Canary Islands, CanaryClim

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Understanding how grain size affects our ability to characterize species responses to ongoing climate change is of crucial importance in the context of an increasing awareness for the substantial difference that exists between macroclimates and the actual microclimate experienced by a given species. Climate change impacts on biodiversity are expected to peak in mountain areas and montane oceanic islands, wherein the differences between macro and microclimates are precisely the largest. Here, we generated fine-scale climatic data for the Canary Islands, a mountainous oceanic archipelago and a hotspot of endemism, and compared predictions of climate change impacts on species distributions using the newly generated data at 100 m resolution *versus* available data at 1 km resolution. In particular, we compared the accuracy and spatial predictions of ensemble of small models for 14 Macaronesian endemic bryophyte species using these two climate models: CHELSA (~1 km) and the newly generated CanaryClim (100 m). We also generated future climate data from five individual model intercomparison projects for three warming shared socio-economic pathways. Based on species distribution models generated from CanaryClim and CHELSA, we found that models exhibited a similar accuracy, but CanaryClim-based models predicted buffered warming trends in mid-elevation ridges. Although both climate datasets predicted similar, high future range loss, these were lower for a number of species with CanaryClim. Predicted mean range gains were substantially higher with CanaryClim than with CHELSA. Overall, predicted species extinctions were higher with CHELSA than with CanaryClim. Our results highlight the important role that fine resolution climate datasets can play in predicting the potential distribution of both microrefugia and new suitable range under warming climate across topographically complex oceanic archipelagos.

Addressing the effectiveness of trait imputation methods for island floras

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Island researchers are increasingly incorporating functional traits into island research, and a trait-based perspective has been shown important to determine how colonization and evolution took place on islands. Despite their importance, the lack of trait data on islands represents a significant challenge. Further, removing species with missing trait data is not ideal, as this may bias the analyses. To address the issue of missing trait data, several methods for trait imputation have been developed, particularly based on allometric and phylogenetic relationships. Nonetheless, the effectiveness of these techniques might be reduced for native island species, which are prime examples of evolutionary trait shifts in response to insularity and consequently often exhibit distinct trait combinations compared to mainland ancestors, so-called island syndromes. In this study, we aim to improve our understanding of functional traits in islands. Particularly, we evaluated five widely used trait imputation methods: k-nearest neighbors, multivariate imputation by chained equations (mice), missForest, Phylopars, and Bayesian Hierarchical Probabilistic Matrix Factorization (BHPMF). We selected species lists and functional traits (plant height, leaf width and length, seed and fruit sizes) from the GIFT database (gift.uni-goettingen.de), for seven subtropical archipelagos of volcanic origin, and evaluated the performance of each method for each functional trait and for different species subsets: island endemics, island native non-endemics and mainland species. Our findings will enhance our ability to study functional traits in island ecosystems and help to understand which plant traits respond most strongly to insularity and enhance our ability to study functional traits on islands.

Towards a mechanistic understanding of plant invasion on islands: the case of the Compositae family in the Canary Islands

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Invasive species are recognized as one of the most important threats to biodiversity. Oceanic islands harbor a fragile and unique native biota that make them especially vulnerable to biological invasions, among other human-induced disturbances. However, the mechanisms behind the invasive success remain uncertain. Charles Darwin proposed two competing hypotheses to predict the species invasive potential, known as the Darwin's Naturalization Conundrum (DNC). First, the "pre-adaptation hypothesis" proposes that species closely related to the native community will have a higher probability of invasion because they have similar life-history traits that make them pre-adapted to establish and thrive under the same local environmental conditions. Alternatively, the "naturalization hypothesis" predicts that species distantly related to native species can exploit empty niches and avoid competitive exclusion, having a higher invasive potential. These two opposite hypotheses, which rely on environmental and biotic filtering, respectively, can decisively contribute to determine invasive success. In practice, the study of the DNC can be addressed by assessing two different dimensions of relatedness between species: phylogenetic and functional distance. Herein we present the preliminary results of a long-term project that aims to test the DNC in the Compositae family across the oceanic archipelago of the Canary Islands. From a super-phylogeny that includes all the genera and most of the species present in the archipelago, we estimated the phylogenetic relatedness between alien, non-endemic native and endemic species. In addition, functional traits were measured from all the species collected in the field and subsequently functional distances were calculated between the three functional groupings. Integrating both phylogenetic and functional approaches, it allows us to explicitly assess the invasive potential of insular alien species under the framework of the DNC.

Plant conservation in the Aeolian Islands: bringing species back from the brink of extinction

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The Aeolian Islands harbor high plant diversity, counting about 750 native taxa, of which eight are endemic to the archipelago. The recent age of the islands and their continuous volcanic activity impacted on the number of endemic taxa and contributed to the fragmentation of their populations. These taxa are particularly precious for their biogeographical value but are at high risk of extinction due to their reduced distribution and human activities' impact. The Seed Bank of the University of Catania is involved in two international projects for the conservation of four threatened Aeolian plants. The Interreg Italia-Malta SiMaSeed PLUS deals with the reinforcement of *Anthemis aeolica* Lojac., reduced to a single population on the islet of Lisca Bianca, close to Panarea. The LIFE project SEEDFORCE focuses on the conservation of 29 Annex II species of the 92/43 EU Directive "Habitat" with unfavorable conservation status. Of these, three species grow in Aeolian islands: *Cytisus aeolicus* Guss. and *Silene hicesiae* Brullo & Signor., endemic to the archipelago, and *Eokochia saxicola* (Guss.) Freitag & G.Kadereit, endemic to the South Tyrrhenian Sea. Both projects aim at using the seeds for ex-situ conservation and to produce plants for the reinforcement of extant populations or for their reintroduction in sites where they went extinct. Seed germination and plant establishment are key stages of plant life but few data are available on the four target species. Therefore, germination and cultivation protocols are being developed, genetic analysis of the donor populations will inform on the best provenance of the seeds to be used, and the trophic relationships (pollinators) are being investigated. To ensure that the conditions in the intervention sites are suitable for the maintenance of viable populations threats are analyzed and mitigated. Finally, ex-ante and ex-post monitoring will produce data on the reinforcements' success and on the demography of these species.

A conservation project for the Aeolian wall lizard *Podarcis raffonei*

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Podarcis raffonei is an endemic lizard of the Aeolian Islands that currently occurs with three small micro-insular populations (on Strombolicchio, Scoglio Faraglione and La Canna) and a relict population in a small area of Vulcano, one of the main islands of the archipelago. The species is classified as "Critically Endangered" by the recent IUCN Red List, but paradoxically is not included in the annex of Directive 43/92 and, despite the urgency of conservation measures, an action plan has not yet been defined. In 2022 the association Nesos launched the project STAL (Save The Aeolian Lizard), financially supported by the foundations MAVA, FPA2, Blue Marine and by the NGOs PIM and SMILO. The project will last three years and include a captive breeding phase with small nucleus of individuals from the two larger micro-insular populations (Strombolicchio and Scoglio Faraglione), after verifying the feasibility of the samples through an assessment of their demographic status. Since 2023, the new-born individuals obtained during the captive breeding program will be released on three islets near Lipari and Vulcano which have been selected on the basis of i) absence of competitors (e.g. the Italian wall lizard *Podarcis siculus*) or predators, ii) occurrence of suitable characteristics to support small populations of the species. The status and demoecology of the new populations will be constantly monitored in the next years. The aim of this project is to increase the number of sites occupied by the Aeolian wall lizard within its original range and to minimize the risk of stochastic events that may lead to its extinction. At the same time, many dissemination activities have been planned, especially at the local level, to spread the biogeographical significance and conservation importance of this threatened species.

INVASION project: Towards an integrative approach for the study of plant invasions on the Canary Islands

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One of the main threats to the conservation of biodiversity is human-mediated plant introductions. When alien species invade new territories, they can significantly modify the structure of native communities and ecosystem functioning. The study of alien-specific traits and their relationship with native communities is thought to inform us about the mechanisms that operate during the stages of naturalization and invasion. In this context, the Darwin Naturalization Conundrum (DNC) provides opposing hypotheses about the potential of alien species to invade natural communities. On the one hand, the "naturalization hypothesis" posits that alien species far related to native species should be more likely to invade due to niche partition or niche emptiness (biotic filtering). On the other hand, the "pre-adaptation hypothesis" proposes that close relativeness of alien species with native communities may facilitate establishment due to potential adaptations to similar environmental conditions (environmental filtering). In the present work, we focus on three of the main ecosystems (laurel forest, pine forest, and dry *Euphorbia* scrub) of the Canary Islands across Tenerife and Gran Canaria islands to study invasive processes under the framework of the DNC. Our main objective is to deepen our knowledge of the mechanisms of invasion in oceanic islands. We integrate ecological, functional, and phylogenetic approaches to explicitly test the DNC hypotheses posited by Darwin. Our preliminary results highlight that functional relatedness between exotic species and native communities, together with species richness, plays a role in establishment and invasion success.

Forest edges increase pollinator network robustness to extinction with declining area

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Edge effects often exacerbate the negative effects of habitat loss on biodiversity. In forested ecosystems, however, many pollinators actually prefer open sunny conditions created by edge disturbances. We tested the hypothesis that forest edges have a positive buffering effect on plant-pollinator interaction networks in the face of declining forest area. In a fragmented land-bridge island system, we recorded ~20,000 plant-pollinator interactions on 41 islands over 3 years. We show that plant richness and floral resources decline with decreasing forest area at both interior and edge sites, but edges maintain 10-fold higher pollinator abundance and richness regardless of area loss. Edge networks contain highly specialized species, with higher nestedness and lower modularity than interior networks, maintaining high robustness to extinction following area loss, while forest interior networks collapse. Anthropogenic forest edges benefit community diversity and network robustness to extinction in the absence of natural gap-phase dynamics in small degraded forest remnants.

Preliminary quantification of the carbon stock of lowland and midland scrublands of Tenerife, Canary Islands

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The consideration of terrestrial ecosystems as carbon sinks is usually linked to forests and arboreal species. However, insular mature ecosystems dominated by native shrub species could be acting as sinks and contributing to the carbon stock on islands. In the Canary Islands, scrublands occupy around 25% of the archipelago land area. Here we present preliminary data about the total amount of carbon stored in the aboveground vegetation of mature coastal scrubland, and the lowland and midland secondary scrubs of the island of Tenerife. Five plant communities were characterized by measuring, in 40 plots of 400 m^2, the plant cover and the amount of aboveground biomass per unit area, to calculate the carbon stored in each community. We measured all the individuals of scrub and tree species in the plot, including height, two diameters, and basal steam diameters when possible. For the most frequent and abundant scrub species of Tenerife (native, endemic, and invasive), we built preliminary allometric equations using their volumetric data to estimate the biomass of individuals. The average carbon stored in each community was calculated and extrapolated to the total area occupied in Tenerife. Although the carbon accumulated in scrubs is lower than in forests, the importance of their contribution lies in their wide distribution. Information provided by this work is intended to guide management measures to maximize the compensation of the carbon footprint of the Canaries. Additionally, allometric equations will provide a non-destructive method to calculate biomass content in shrubs in the future. The need for protection and conservation of the Canarian ecosystems with the aim of preserving the natural heritage is more than accepted. However, the ecosystem service of carbon sequestration done by native species, not only trees but also shrubs, could be another reason for the conservation and restoration of natural and degraded areas.

Red listing of the ecosystems of the Seychelles granitic islands

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The Seychelles granitic islands represent an archipelago of about 40 islands that form together the smallest oceanic fragments of Gondwana. Their natural history is therefore fascinating, having evolved as remote oceanic islands with a relatively unchanged topography over tens of millions of years, and cyclical fragmentation due to sea-level variations prompted by glaciations. Although the Seychelles is a leader in terms of its coverage by protected areas (48% of the country's land area), the most inhabited islands have a much lower coverage of protected areas: 20% for Mahé and 8.6% for Praslin. It is therefore critical to improve the network of protected areas on these two islands, and we suggest that using only species distribution data is insufficient as it does not provide enough details to fine-tune the exact delineation on the lower slopes. To develop a checklist of the ecosystems of these islands, we have compiled information from the literature and we have collected new field observation data over the last fifteen years. In 2021, we developed in detail our approach to conceptualizing and naming ecosystem-types. Then we discussed the typology (or systematics) of our ecosystem-types in relation to the recently published IUCN function-based typology. We produced ecosystem distribution maps using Sentinel-2 imagery with an Object-Based Image Analysis, done in an Earth Engine script. Finally, we evaluated the risk of collapse for the most important ecosystem-types using the criteria A and B of the Red List of Ecosystem. We found 69 types of terrestrial, freshwater and subterranean ecosystems, distributed among 23 Ecosystem Functional Groups (level 3 of the new IUCN typology). Among those, we found 6 endangered (EN) and 10 critically endangered (CR) ecosystem types. Their distribution has provided keystone data that have allowed the initiation of discussions with stakeholders and landowners for the nomination of new protected areas.

The vulnerability of soil carbon stocks as particulate and mineral-associated organic carbon in shrubland ecosystems of Tenerife

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Soils represent the highest terrestrial organic carbon pool globally, storing three times more carbon than the vegetation. However, this carbon pool is vulnerable, as warming due to climate change enhances CO_2 fluxes from the soil to the atmosphere. In this context, it is relevant not only to quantify soil organic carbon (SOC) but to determine its vulnerability by assessing in which form is stored: as mineral-associated organic matter (MAOM) (more persistent due to its organo-mineral associations), or particulate organic matter (POM) (more vulnerable). This information is especially important for shrub ecosystems with semi-arid climate, where drier and warmer conditions are expected, affecting the vast carbon pool in the soils. In the case of the Canary Islands, this kind of ecosystems occupy large extensions, having a key role in their carbon storage capacity. To determine the magnitude and vulnerability of SOC stocks in shrublands of the island of Tenerife, we sampled five shrub ecosystems representing three shrubland types (coastal, secondary, and summit). We used cores down to 30 cm depth, divided in two samples (0-10 and 10-30 cm) and estimated SOC, MAOM and POM per area and in the entire surface of each ecosystem type. We assessed differences between ecosystems, depths and determine the drivers of soil organic carbon stocks by relating them to the plant community, soil type, temperature, precipitation, elevation and (macro)orientation. The obtained results are highly valuable to understand ecosystem functioning, as well as for the climate change mitigation plans of the Canary Islands, as they contribute with data about the existing carbon pools, and thus to the development of strategies to maintain or increase these important carbon stocks.

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