

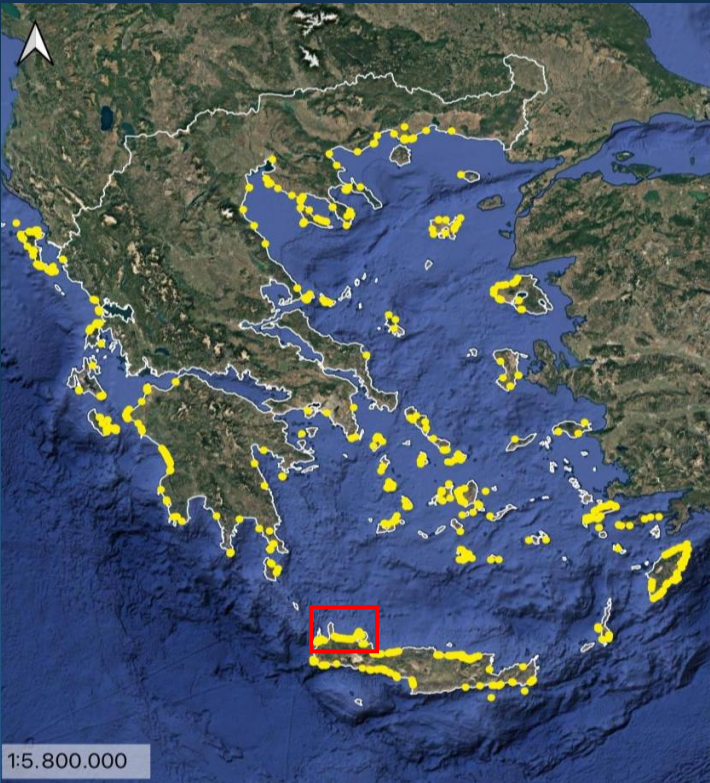


Between Sand and Concrete: Mapping the Fate of a Dune Lily

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Introduction

The sand lily *Pancratium maritimum* is a flagship species of Mediterranean dunes, yet is under increasing threat from tourism, land use intensification, and ineffective coastal protection. This study investigates the spatial distribution of *P. maritimum* populations along a 22 km coastline west of Chania, Crete—an area characterized by high tourism activity and partial Natura 2000 designation.



To identify key pressure gradients on *Pancratium maritimum*, we applied Principal Component Analysis (PCA), followed by heatmap visualization of PC1 (human impact) and PC2 (environmental conditions). K-means clustering grouped the coastline into three pressure zones. Wilcoxon and Kruskal-Wallis tests explored group differences, and a quasi-Poisson GLM evaluated how combined factors affect plant abundance. This multi-method design allowed us to distinguish overlapping drivers of pressure and isolate the specific effects of temperature, human intervention, and regulatory protection on population dynamics.

Parameter	Source	Type
Irrigation, Fencing, Pollution, Umbrellas	Field observation	Qualitative
Temperature, Soil pH	Field measurement	Quantitative
Soil moisture	Field measurement	Qualitative
Beach width	Google Earth	Quantitative
Natura 2000 designation	Geodata.gov.gr	Qualitative
<i>P. maritimum</i> meadow	Field + GIS (Google Earth)	Qualitative

Methodology

In-situ sampling was conducted across 253 randomly selected 1m² plots along ~22 km of the western Chania coastline, including both tourist-heavy and Natura 2000 protected sites. Ten ecological and anthropogenic variables were recorded.



Results

Across the coastal transect, **anthropogenic pressures were widespread**, with **56%** of sites showing pollution, **34%** hosting umbrellas, and **22%** exhibiting irrigation activity. Despite part of the area falling within **Natura 2000**, protected zones were **not less pressured**, indicating limited enforcement of management measures.

Multivariate analysis revealed two clear gradients: **PC1**, driven by human-induced pressures (umbrellas, watering, fencing), and **PC2**, associated with environmental factors such as temperature and pH. These components highlighted contrasting zones of disturbance and natural variability. Subsequent **k-means clustering** separated the coastline into **three pressure categories**—low, moderate, and high—capturing spatial patterns of combined impact.

Finally, the **GLM** showed that **higher soil temperature** and **overconcentration within dense meadows** exerted significant negative effects on plant abundance, underscoring the sensitivity of *Pancratium maritimum* to both environmental stress and local habitat saturation.



Conclusions

Our results demonstrate that *Pancratium maritimum* distribution in western Chania is driven by the combined impact of environmental conditions and anthropogenic pressures—most notably umbrellas, irrigation, and pollution. Although much of the area lies within Natura 2000 zones, human disturbance remained widespread, exposing major enforcement and awareness gaps.

GLM showed that soil temperature and meadow overconcentration reduce populations, while PCA and clustering revealed distinct pressure zones—underscoring the need for active monitoring beyond institutional protection. Adaptive management and stronger local action are vital for the long-term survival of this coastal species.