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Vegetation science and global changes: scenarios, challenges and innovation

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1st session: High-altitude vegetation in global change scenarios

Functional phytosociology: the challenge of traits up-scaling in vegetation science

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Long-term monitoring of vegetation dynamics and carbon dioxide exchange in alpine peatlands

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Peatlands are among the most threatened ecosystems in the world because they host a variety of microhabitats, plants and animals very sensitive to global change. In ombrotrophic mires, *Sphagnum* mosses are the main producers of organic matter that accumulate as peat. The competitive balance between *Sphagnum* mosses and vascular plants plays a major role in determing the capability of mires to act as carbon stores. For this reason, vegetation dynamic in peatlands has received great attention in the last decades. In 2002, we chose a mire in the Italian Dolomites (Passo S. Pellegrino, province of Trento, 1800 m), with the objective of evaluating the long-term dynamics of plant species and plant functional types. In 2003, the mire experienced an exceptional heatwave event. After 8 years we recorded an increase of vascular plants, especially graminoids and ericaceous dwarf-shrubs, at the expense of *Sphagnum* mosses. In order to detect the influence of changes in vegetation composition on carbon storage in the peat, we started another long term experiment to analyze the emission of carbon dioxide gas exchange from the peat. We use the elevation gradient as a proxy for temperature increase comparing two mires at different elevation (1300 m and 1800 m, respectively), mimicking an increase in mean annual temperature of about 3 °C. We determined ecosystem respiration and heterotrophic respiration in the growing seasons 2010-2017 with the closed chamber techinque using an infrared gas analyzer. Carbon dioxide emissions were always higher in the mire at low altitude with a higher input from vegetation than peat. Our results demonstrate that increased cover of vascular plants at the expense of *Sphagnum* mosses, triggered by climate warming, enhance carbon dioxide emission thus decreasing the capability of mires to store carbon in the peat.

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Climate sensitivity of bilberry (*Vaccinium myrtillus* L.) dwarf shrub communities in Alps: interactions between plant growth, temperature and precipitation.

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Shrub expansion is a prominent effect of climate change in the alpine and arctic ecosystems. One of the major drivers of the enhanced shrub growth is the increase in temperatures and many studies have investigated on this. Instead, the effects of the interplay between temperature and other climate variables (*e.g.* rainfall regime) on the shrub growth has been often neglected. This study aims at parsing the relationships between annual growth of *Vaccinium myrtillus* L., key species in the alpine tundra, temperature, precipitation and their interaction in the north-eastern Alps. We considered a 500 meters elevation gradient analyzing xylem rings of 100 cross sections of underground ramets of *V. myrtillus* referring to the period 1995-2015. We found altitude to affected both ramet age (*i.e.* number of rings) and the mean ring width. The mean temperature and annual precipitation showed significant interaction effects on mean ring width and xylem mean lumen area. At low temperatures an increase of precipitations led to a reduction in the mean ring width, while high temperatures and precipitation increased annual ring width. Mean lumen area was affected by precipitation only in cold years. Our results suggest that future scenarios should not overlook for rainfall regime effect by virtue of its possible role in snowpack permanence and summer drought.

Substratum type drives species richness and functional traits of alpine terricolous lichen in the Alps

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The alpine soils above the treeline are among the best-known environments in which terricolous lichens play several ecological functions. Despite their importance, the role of substrate type as a driver of community assembly remains poorly explored. This study aims to explore the relationships between the species richness and the functional composition of terricolous lichen communities growing on two types of substrates (carbonatic and siliceous soils) along different elevation gradients in the Eastern Alps. The sampling design includes 98 belts surveyed within 12 independent transects, ranging from 2100 to 3000 m of altitude. Six transects were established on siliceous soils and six on carbonatic ones. Besides the two soil types, we also considered the cover of bryophytes and vascular plants and the climatic features. Our results revealed that soil type is the main driver of both species richness and functional traits composition. Results also confirmed that a "trade-off" occurs between stress tolerance and the competitive response of communities of terricolous lichens that grow above siliceous and carbonate soils. Our findings contribute to clarify the response of lichen diversity to a climate change scenario, where rapid changes of temperature and rainfall may interplay with an increase of soil instability and erosion.

Plot sizes affect patterns of plant diversity along an elevational gradient

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Factors that should be considered when investigating plant diversity patterns are the spatial arrangement of sampling units (i.e. plots) and their size. At different plot sizes, species diversity is shaped by different environmental variables. As the plot sizes become finer, the environment becomes more unique, causing the filtering of the species that occur in such small areas. Based on plant co-occurrences collected along an altitudinal gradient about 2km wide-ranging from 1100 to 2486 a.s.l in Central Italian Appennines (Velino massif, Abruzzo), we studied the relationship between different plot sizes and plant diversity patterns. The transect was divided into 100 m elevational bands following the contours for a total of 13 bands. Following a standardized protocol, at each sampling site nested plots ranging from 0.0156 m x 0.0156 m to 16 m x16 m were sampled. In this way, co-occurrences were gathered in a total of 84 nested plots over the years 2006 and 2007. Alpha diversity (species richness) was calculated for each plot size while gamma was measured as the total number of species occurring in each plot size belonging to each elevational band. Beta diversity was calculated among all plots (pairwise beta diversity) and inside elevational belts (multiple-site beta diversity). All these patterns were modeled with polynomial linear regression using generalized linear models (GLM). For each plot size, the best model among linear, quadratic, and cubic regression was assessed, based on Akaike Information Criterion (AIC) and parsimony criterion. Alpha and gamma diversity varied widely across plot sizes with a decreasing trend along the elevational gradient. According to the GLMs the influence of elevation on alpha and gamma diversity increase when increasing the plot size. The multiple-site beta diversity didn't show any significant pattern due to the great environmental heterogeneity within elevational belts. Beta diversity among plots, instead, showed a clear pattern driven by the elevational and spatial distances among plots, in the plot sizes bigger than 4 m2. To conclude, this study has demonstrated that sampling sizes strongly affect elevational patterns of plant diversity and that the nested approach used appears to be a promising tool to test diversity patterns along an elevational gradient.

Not only plants: multi-taxa approach to plant community studies in harsh environments

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Plant community investigation represents a powerful tool for the analysis of environmental factors driving ecosystem functions. Plant communities provide the trophic base and the physical structure of ecosystems and determinate their environmental characteristics.
In harsh environmental conditions, such as those of ice-related landforms in high altitude landscapes, plant cover is often scattered and composed by few, highly specialized species. In some cases, peculiar environmental conditions are marked by the absence rather than by the occurrence of characteristic species. In such cases, to outline the ecological profile of the investigated communities, other organisms may be taken into account together with vascular plants, providing high resolution data about the specific environmental profile. Such organisms include non-vascular plants, which substantially contribute to the primary production, and some arthropod taxa with an important role in the food chain and with a high bioindicator role.
Here we present some case studies about Alpine and Apennine ice-related landforms (debris-covered glaciers and rock glaciers): Calderone Glacier (Gran Sasso, Central Apennines), Amola Glacier (Presanella, Eastern Alps) and Lazaun Rock Glacier (Val Senales, Eastern Alps). Here, the integrated study of vascular plants, bryophytes, springtails (Hexapoda Collembola), ground beetles (Coleoptera Carabidae) and spiders (Arachnida Aranea) allowed to outline the peculiar environmental profile of such landform and their possible role of refugia for cold-adapted species in the present warming cycle.

Elevation patterns of species richness on the Mediterranean island using a published flora

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Understanding abiotic factors shaping the patterns of biodiversity on Earth is a key task for conservation scientists. At the regional scales, meso-climate factors mainly linked to elevation gradients play a crucial role, but their disentanglement is often confused by the effect of different geological substrata. Studies on the impact of elevation gradients in homogeneous geological areas are rare, particularly in the Mediterranean biodiversity hotspot. Mount Limbara, consisting exclusively of granite rocks, is the third highest peak of Sardinia Island (Italy) located in its north-eastern side. This massif covers an area of 262.5 km², reaching an elevation of almost 1360 m a.s.l. It, therefore, represents an ideal model for studying altitudinal patterns based on published flora which includes 1,147 taxa grouped in 46 orders, 120 families, and 486 genera. The endemic and sub-endemic taxa are 86, while the alien flora consists of 137 taxa. We investigated the distribution of plant species richness along the whole elevational gradient of this chain, considering: all species, functional groups of species based on Raunkiær life forms (RLF), and chorological groups of species. Generalized Linear Models (GLMs) were used to analyse richness patterns. Elevational richness models versus the area of the elevational belts were fitted to test the effect of surface area. Our results showed a hump-shaped model of species richness along an elevational gradient. Species life forms were not equally distributed along the elevation gradient: chamaephytes and hemicryptophytes were the richest groups at high elevations, while therophytes showed the highest species richness at low elevations. Endemic species richness increased along the elevational gradient; while, alien species were mainly distributed at low elevations. Our findings suggest that in Mount Limbara there is a major elevational gradient in species composition that could reflect a distinct plant evolutionary history. Furthermore, we highlight the key role of published floras as a relevant source of biodiversity data.

A relict of the alpine community dominated by *Geranium argenteum* at its southern limit of distribution in the Apennines

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Geranium argenteum is a rare subendemic species of alpine origin, which migrated southwards during the glaciation phases of the Quaternary to the Apennines. In the Apennines ridge, *G. argenteum* is found in several mountain groups in the alpine and subalpine belts of the Northern Apennines where the species is rare, at risk of extinction, and listed as a protected species at regional level. Only recently has the species been found in the Sibillini mountains (Central Apennines), which therefore represents its current southern limit of distribution in the Apennines. The aim of the present study was the analysis of the floristic-vegetational features of *G. argenteum* in the Sibillini mountains at the southern limit of the distribution range of the species. The results of the phytosociological analysis allowed us to propose the new association *Festuco italicae-Geranietum argentei* referred to the *Leontopodio nivalis-Elynion myosuroidis* alliance (*Carici rupestris-Kobresietea bellardii* class). The comparison between the plant community in the study area and the coenoses characterized by *G. argenteum* described in the literature, allowed us to identify the floristic, biogeographical and syntaxonomic context of each plant community considered and consequently of *G. argenteum* within its Alpine-Apennine range.

Dynamics of dwarf shrubs in Mediterranean high mountain ecosystems

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Vegetation around the alpine-treeline ecotone faces changes from both climate and land use (i.e. grazing abandonment) [1]. Broad-scale shrub encroachment is considered an effect of these changes, but it is still unclear how this process is mediated by local-scale environmental heterogeneity [2]. The objective of our study was to identify which local-scale environmental factors influenced the spatial distribution and temporal trends of dwarf alpine shrub vegetation dominated by *Juniperus communis*. Our contribution focused on three sites in central Apennines (Italy): Mt. Terminillo, Mt. Duchessa, and Mt. Ernici, where we combined a series of environmental variables derived from multi-year remote sensing imagery and vegetation data collected in the field. The presence and cover of dwarf shrublands dominated by *Juniperus communis*, as well as the change in cover over time, was modeled using generalized linear and mixed-effects models, which took into account local climate, topography, snowmelt patterns, biomass, and land use.
We found an increase in shrub cover of 10% and occurrence of 12% over a 60-year period (1954-2012). There appears to be a strong relationship between the current distribution and patterns of change in prostrate shrubs in relation to fine-scale topography, aboveground biomass, land use and microclimate. In particular, shrubs were locally favored in areas with more severe alpine environmental constraints and greater resource limitations.
Our study shows that dwarf shrubland of *J. communis* behaves as a stress-tolerant pioneer vegetation found in otherwise sparsely vegetated areas. Contrary to our expectations, at the fine scale, warmer temperatures and regional decreases in grazing did not favor shrub encroachment. Despite the overall increase, *J. communis* shrubs have little competitive ability to successfully invade grasslands and remain restricted to less productive areas. Our contribution provides evidence that fine-scale environmental heterogeneity can strongly influence shrub distribution and dynamics, thus modulating future responses in evolving alpine ecosystems.

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The high-altitude landscape of the Laga mountains. A vegetation mosaics of circumboreal relics and Apennine endemics at the turning point of global warming

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The Laga mountains are the northern sub-unit of the Gran Sasso-Monti della Laga National Park. They act as important refuge site for many plant species and communities which currently exhibit a circumboreal or arctic-alpine distribution due to their moving in the Italian peninsula during the cold periods of the Quaternary age. Some of these species (Agrostis rupestris, Alchemilla sp.pl., Astragalus penduliflorus, Carex demissa, C. hostiana, Huperzia selago, Pseudathyrium alpestre, Pyrola rotundifolia, Salix pentandra, S. breviserrata, S. foetida, S. hastata, etc...) have in the Laga mountains their only C-S Apennines stations so that in many cases this massif represents the southernmost limit of their whole distribution area. It is known that among the species that are majorly considered at risk of extinction in the Apennines in relation to the harmful effects of climate change there are those occurring within the alpine and subalpine belts. This suggests a direct correlation between global warming, threatened micro-thermic rare species and increasing altitude. Although this assumption is to be considered in most cases true, it is nonetheless only partially applicable to the Laga mountains. In fact, the role of refugee site for the relic boreal vegetation carried out by Laga Mountains is mainly expressed in regards to species and communities of humid or sub-humid environments which more than others benefit from the high degree of water retention that characterizes the pelithic-arenaceous substrates. The Laga mountains rich-in-clay soils probably played a main role in hosting micro-thermic and meso-hygrophilous species at the end of the glacial episodes allowing them to withdraw the subsequent periods of intense dryness that marked the Quaternary age. The soil features are in fact the physical factor that radically distinguishes the Laga mountains (the largest and highest siliceous massif in peninsular Italy) from the adjacent Gran Sasso massif (the largest and highest limestone massif in peninsular Italy). In this latter the arctic-alpine species to be here considered as "exclusive" for the Apennines (e.g. Carex firma, C. rupestris , C. ornithopodioides, Potentilla nitida, etc.) are normally found in dry environments, such as rocky slopes, screes and vertical cliffs.

From a coenological point of view, the Laga mountains exhibit the best Apennine expressions of several vegetation types which are not exclusive of this massif, such as Vaccinium myrtyllus heathlands, gravelly stream banks and snow-bed dwarf willows scrubs, windy ridges Carex myosuroides swards, acidophilous beechwoods. Unfortunately, all these vegetation types are all showing the worrying signs of the aggression of a climate that tends to overheat more and more.

2nd session: Application of remote sensing and other technologies in vegetation science

Using remote sensing in vegetation science: disentangling the spectral variability jungle

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Given the present rate in global change, biodiversity assessments at different scales and on a real-time basis are of prime importance. In the last 50 years ecology has witnessed and has been an actor of major technological revolutions, which include the rapid advances in the field of remote environmental sensing. New remote-sensing platforms have increased the availability of spectral data with high spatio-temporal resolution at both local and global scales, giving us the opportunity to bridge the monitoring gap. When surveying vegetation, spectral data represents an aggregated signal of how light interacts with the chemical and structural composition of the canopy, which in turn is underpinned by a plant's biochemical and morphological traits. This means that the spectral diversity of a certain area, defined as the variation of the spectral signal over space, should reflect the ground diversity, its functional diversity, and therefore its ecosystem functions. However, this link (generally identified as the spectral variation hypothesis) is highly context-dependent because it will be influenced by scale effects, the chosen metrics, plant phenology, and interspecific variation, among other factors. Nevertheless, there is a growing body of studies assessing under which circumstances and to which facets spectral variability can be related to plant diversity. It is emerging that a community scale, spectral variability is more strongly linked to the functional diversity compared to the taxonomical diversity of the communities sampled. More importantly, functional characteristics such as vertical structure could even mediate the link between spectral variability and species diversity. Contrarily, at landscape scale, the link between spectral diversity and taxonomic diversity is maintained, albeit depending on the land cover category analyzed as well as on the metric used to describe spectral diversity. The need for a more systematic testing of the links between spectral variations and biodiversity applies also with respect to other RS- based approaches to map and monitor biodiversity. Apart from disentangling and defining a protocol for using remote sensing data to quantify biodiversity, future studies could focus more on efficiently capturing changes in landscapes over time (and hence a potential change of biodiversity) rather than solely on the direct mapping of biodiversity patterns across space.

A transdisciplinary application of vegetation maps: back to the Nuragic Sardinia

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Biodiversity maps are commonly used both to investigate those phenomena pertaining to the natural world and address conservation issues, yet their application to other research fields remains mostly uncharted. In this context, we implemented a transdisciplinary application of biodiversity maps, precisely the Map of Vegetation Series (VS) of Sardinia (Italy). A VS is represented by the dynamically connected set of plant communities present within an environmental unit, characterized by homogeneous abiotic factors, sharing the same potential natural vegetation. With due caution, we here build on the assumption that in Sardinia these units have remained approximately the same during the last 4000 years.

Our specific aim was to enrich the knowledge about the land occupation strategies of Nuragic civilization, flourishing in Sardinia between the 18th and 8th century BCE. About 5000 remains of nuraghe, megalithic edifice distinctive of the Nuragic civilization, are still present on the island and were accurately mapped through a citizen science project coordinated by Nurnet Foundation (https://www.nurnet.net/).

Under a 'complete spatial randomness' scenario, we tested whether nuraghe remains were randomly located across the VS or more (or less) clustered in some units than expected by 'chance.' To further support and integrate the discussion about the occupation strategies of Nuragic people, we also derived the geomorphological and past climatic profiles (3200 BP) of the nuraghe distribution at a regional scale.

According to our results, the occurrence of nuraghes is mostly connected to specific VS, rather than being randomly distributed. In particular, they appear to be related to those located in the thermo-mesomediterranean bioclimatic belt, at low-to-medium altitudes, in flat areas on intrusive magmatic rocks in environmental units characterized by the presence of rivers and ponds.

In light of these findings, we have related the possible use by Nuragic people of the ecosystem services supported by the different VS.

Helical graphs to track ecological trends

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Global change caused by human activity has several effects on the biomes of Earth, such as land fragmentation, deforestation, pollution, anthropization of natural landscapes and alterations in the functioning of ecological systems. In this context, remote sensing represents an important tool to assess ecosystem changes, as it allows to collect a huge amount of data at different time and spatial resolutions concern- ing different components of Earth system (land, ocean, atmosphere, and cryosphere), from which different measurements such as precipi-tation patterns, global temperatures, snow cover and aerosol can be determined. The aim of this work is to exploit this wide availability of data to display the ecosystem changes using a new visualization method: the helical graphs. The helical graphs represent the change of a variable over time, reporting on the y-axis its moving averages and on the x-axis its rates of change. These new charts were tested on vegetation indexes and climate data retrieved from Google Earth Engine (https://earthengine.google.com/) to visualize trends on selected biomes of Earth. The results show that the helical graphs are a useful tool to highlight trends that might not be easy detected in a time series. In conclusion, the helical graphs can have a lot of applications in ecology, especially exploiting the wide amount of data available thanks to remote sensing.

Mapping of Yucca gloriosa invasion along Mediterranean coastal dunes using unmanned aerial vehicles (UAVs)

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Invasive Alien Plants (IAPs) are defined as those species whose introduction and/or spread outside their natural distribution can threaten the biological diversity of an ecosystem. They represent a severe threat to biodiversity and can severely alter the performance of crucial ecosystems such as coastal dunes. Coastal dunes are composed of specialized fauna and flora, converting them into strategic ecosystems due to their unique ecological functions.

Coastal dunes are one of the most invaded European environments, with a total flora composed of up to 7% of IAPs. One of these IAPs is *Yucca gloriosa* L. (Asparagaceae), a homoploid hybrid native plant from the United States of America introduced to Europe for ornamental purposes. For Italy, *Y. gloriosa* is a typical invasive species related to fixed dunes dominated by *Juniperus* sp. pl. (with which it competes).

Concerning biological invasions, maybe the most effective management strategy is early detection and mapping. In that sense, this work explores and tests the potential of unmanned aerial vehicles (UAVs) for detecting, mapping, and managing the *Y. gloriosa* invasion along the Mediterranean coastal dunes of a protected area located in Tuscany (Italy).

In detail, this work focuses on four aspects: i) determine the suitability of RGB images to map *Y. gloriosa*, ii) identify the best time of data acquisition, iii) detect changes affecting the occurrence and cover of *Y. gloriosa*, and iv) propose a set of management actions to preserve a coastal dune ecosystem subjected to plant invasion.

The UAV images allowed the generation of ultra-high spatial resolution maps to assess the *Y. gloriosa* invasion and distribution along the surveyed sandy dunes. The morphological characteristics of this plant – especially at the foliar level – make the invasion of *Y. gloriosa* particularly suitable for being evaluated and managed using UAV mapping, especially in coastal dunes vegetation that can be a mosaic of different plant communities hard to identify when airborne or satellite images are used.

According to the obtained results, the spring season is the perfect time to collect data because light conditions are ideal, with minimal shading effects. Also, due to the peculiar morphology of *Y. gloriosa* leaves, the timing of data collection seems not crucial for mapping this IAP on coastal dune habitats.

Despite the massive eradication action funded by a LIFE project during the period 2005-2009, *Y. gloriosa* is still present in the protected area and affects the priority habitat of juniper. This might be linked to the fact that *Y. gloriosa* is a perennial rhizomatous shrub capable of switching its photosynthesis from the C3 to CAM pathway and, therefore, withstand the harsh environmental conditions of dune ecosystems.

The early detection using UAVs is the first line of defense against IAPs colonization over any ecosystem. From a conservation and management point of view, this work suggests the development of annual biomonitoring of *Y. gloriosa* to check its distribution over time and control its spread where it becomes particularly invasive. In this case, one possible strategy will be to keep the IAP in isolated nuclei of plants that are easier to remove with mechanical methods. In a broader view, the study area and the Mediterranean coast must include the ban on introducing non-native species as a strategy, adopting a short-term non-native Management Plan as urgent action.

Remote sensing tools to parse the acclimation response of saltmarshes to flooding stress: upscaling perspectives in lagoon systems

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Sea level rise is considered a prominent aftermath of the ongoing global warming, which is expected to seriously treat the worldwide coasts. Among coastal environments, saltmarshes harbor plant communities particularly sensitive to the increase of flooding. Although saltmarshes might contrast sea level rise by accretion and niche shifting, sea rise rates and the coastal squeeze phenomenon undermine the acclimation capacity of such plant communities. For these reasons, parsing the underlying mechanisms of the response of saltmarshes to flooding is of outmost importance to foresee the future scenarios for these important ecosystems. In this light, linking different ecological scales using an upscaling approach might provide new insight into the ecological processes involved. We analyzed main traits of plant community and the growth of the key species *Salicornia fruticosa* (L.) L. in 9 saltmarshes along the flooding gradient (Marano and Grado lagoon, northern Adriatic Sea). In particular, we considered community (*i.e.* species richness, dry biomass, dry matter content) and individual growth (*i.e.* shoot annual growth, dry biomass, dry matter content, plant height) and physiological traits (i.e. pigments and secondary metabolite content) in response to flooding gradient. Concurrently we carried out a UAV (Unnamed Aerial Vehicle) multispectral survey, in order to obtain remote sensing-derived vegetation indices (*i.e.* NDVI - Normalized Difference Vegetation Index, LCI - Leaf Chlorophyll Index, ARI - Anthocyanin Reflectance Index) for the upscaling of plant responses. We found that the flooding gradient produced a significant decrease of plant biomass and growth, affecting both plant traits and plant community features. We also found remote sensing-derived indices to be related to the analyzed plant traits, showing promising perspectives for the upscaling plant flooding stress response. In particular, NDVI was mainly linked to individual annual plant shoot elongation while the other indices were also related to stem pigments and secondary metabolites content. Our findings shed new light on the potential use of the remote sensing tool for the understanding of the response of saltmarshes vegetation to the future increase of the sea level, proving to be a promising method for long-term monitoring of these plant communities.

From Remote Sensing to Species Distribution Modelling: an integrated workflow to monitor spreading species in key grassland habitats

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Remote sensing has been widely adopted as a tool to investigate several biotic and abiotic factors, directly and indirectly, related to biodiversity conservation. European grasslands are one of the most biodiverse habitats in Europe. Most of these habitats are subject to priority conservation measures, and several human-induced processes threaten them. The broad expansions of a few dominant species are usually reported as drivers of biodiversity loss. In this context, using Sentinel-2 images, we investigate the distribution of one of the most spreading species in the Central Apennine: *Brachypodium genuense*. We performed a binary Random Forest classification of *B. genuense* using remotely sensed images and field-sampled presence/absence data. Then, we integrate the occurrences obtained from image classification into species distribution models to identify the topographic drivers of *B. genuense* distribution in the study area. Lastly, the impact of *B. genuense* distribution in the Natura 2000 habitats (Annex I of the European Habitat Directive) was assessed by overlay analysis. The Random Forest classification process detected cover of *B. genuense* with an overall accuracy of 94.79%. The topographic species distribution model shows that the most relevant topographic variables that influence the distribution of *B. genuense* are slope, elevation, solar radiation, and topographic wet index (TWI) in order of importance. The overlay analysis shows that 74.04% of the target species identified in the study area fall on the semi-natural dry grasslands. The study highlights the remotely sensed classification and the topographic species distribution model's importance as an integrated workflow for mapping a broad-expansion species such as *B. genuense*. The coupled techniques presented in this work should apply to other plant communities with remotely recognizable characteristics for more effective management of Natura 2000 habitats.

Functional data analysis of remotely sensed time series for vegetation mapping and monitoring

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Data collection technology has evolved so as to allow observations densely sampled over time, space (i.e. remote sensing data). These data are representable as curves or functions (functional data). A functional datum is not a single observation but rather a set of measurements along a continuum that, taken together, constitute a single entity. The Functional Data Analysis (FDA), that is still rarely used in remote sensing and ecology, can extract information contained in the functions more efficiently than the classical multivariate statistical methods [1].
Here we present a new methodological framework based on the analysis of remotely sensed time series with the FDA approach for the mapping and monitoring of plant associations and habitats. We validated the methodology in two different Special Conservation Areas (SACs) of Central Italy ("Monte Conero" - IT5320007 and "Gola di Frasassi" - IT5320003) [2,3,4].
The methodology allowed accurate mapping of several forest, shrub and grassland plant associations identified on the ground by the phytosociological approach. We obtained an overall accuracy of 85.6% for the "Gola di Frasassi" area and 87.5% for the "Monte Conero" one. The results highlighted that: (i) plant associations, together with their own typical floristic composition, exhibited exclusive phenological dynamics (seasonal spectral profile) that manifest differently with respect to spectral bands and vegetation indexes; (ii) the main seasonal spectral variations (identified by FDA) are effective spatial predictors to obtain accurate plant associations and habitat maps and that are suitable for the ecological interpretation.
FDA approach considered a stack of remote sensed images as a unique entire temporal archive (constituted of pixel-based functions-temporal trajectories) rather than as a series of individual images, providing new ecologically relevant perspectives. The proposed methodology is useful and promising for habitat mapping and monitoring, as it can contribute to produce periodically detailed vegetation-based habitat maps that reflect the "current" status of vegetation and habitats, also supporting the analyses of phytosociologists and decisions of land managers.

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An overview of Baseflow and Baseveg developed by Philippe Julve: A tool designed for phytosociological knowledge and monitoring of European habitats: challenges and opportunities

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Da più di venti anni, Philippe Julve costruisce, con l'aiuto di diversi specialisti, una banca-dati non solo delle specie della flora francese (con sistematica, ecologia, fenologia, ecc.), ma pure delle vegetazioni, della Francia, ma anche dell'Europa e, da poco, del mondo, nella chiave sinusialista. Questi due file sono legati e permettono al naturalista di gestire velocemente uno o più relevés.
La comunicazione presenterà il programma e i due file, con esempi di uso e ipotesi di interpretazione.

A GIS-Based approach to define Bioclimatic Maps for landscape classification and planning

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Bioclimatic maps are an important tool for land-use planning/management and for biodiversity conservation purposes. Such maps show the distribution of some important bioclimatic indicators, obtained through a rigorous classification process. These indicators aim to link climatic elements to the distribution of biological entities at different levels (individuals, populations, ecosystems, biomes).

In this work, the applications of the Rivas-Martinez's Worldwide bioclimatic classification system for the elaborations of a bioclimatic map for the whole Europe at a high spatial resolution (approximately 1 km^2) is presented.

Data analysis was performed in GRASS GIS 7.6 using the CHELSA climatic dataset. GIS analysis was carried out for global land areas and the following datasets were produces: the Macrobioclimatic map, that encompassed five macrobioclimates; the Bioclimatic map (subdivided into 27 Bioclimates); the Thermotypes map (31 Thermotypes); the Ombrotypes map (36 Ombrotypes). The subset of European Bioclimatic data was the first step in defining the correspondence and correlation between plant communities distribution and the bioclimatic units.

The results of the calculations provided high quality-resolution bioclimatic data that will be essential not only to understand the geographical distribution of vegetation, but also to define predictive models for the distribution of habitats, biotopes and ecosystems, and to describe the dynamic relationships between communities. Understanding the relationship between climate and vegetation will be crucial to predict the impact of Climate Change on organisms, to find threatened ecosystems and to implement biodiversity conservation strategies.

3rd session: The role of protected areas in habitat conservation

Protected Areas in Europe: Current Status and Outlook

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The widespread exploitation of ecosystems and species is leading to an unprecedented biodiversity decline, threatening humankind's persistence on Earth. Indeed, biodiversity decline ultimately leads to ecosystem collapse and the loss of associated ecosystem services. Among the drivers of such a crisis, there are global changes, pathogens, biotic invasions, natural resource overexploitation, and land use changes. Notably, the latter is likely the most impactful threat to biodiversity.
Several measures were proposed to halt and reverse such a trend, and Protected Areas (PAs) have the biggest potential. The history of PAs began in 1872, with the establishment of the iconic Yellowstone National Park. Since then more than 250,000 PAs were established worldwide, covering more than 15% and 8% of land and sea area, respectively. In 1994, following Birds and Habitats Directives, began the establishment of Natura 2000. Natura 2000 is the most important conservation tool of the European Union and makes up the largest coordinated network of PAs in the world. Also, Natura 2000 sparked a vast amount of research, however, the vast majority of it focused only on one or few PAs, species, or habitats (Orlikowska et al., 2016). Therefore, large-scale studies are urgently needed to assess the overall status and capacity of Natura 2000. Hoffmann et al. (2018) published one of the very first large-scale study on Natura 2000, by exploiting Europen Union monitoring data, they found that the peripheral portions of the network contribute disproportionally to its functioning. Ricci et al. (in prep.) used the same data to assess the representativeness of protected species within Natura 2000. Chiarucci et al. (in prep.) are currently investigating vascular plant diversity within and outside Natura 2000 at the network level. Cazzolla Gatti et al. (under review) found an uneven distribution of strict PAs in the European Union, calling for data-driven land planning.
To face the current biodiversity crisis, similar research should be carried on soon. This will help plan future PAs and assess the functioning of the whole network.

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Challenges and pitfalls in assessing protected areas effectiveness

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Protected areas are recognized as the cornerstone of global conservation efforts, yet their effectiveness in safeguarding biodiversity is currently debated. Specifically, in spite of a number of studies focused on measuring representativeness (e.g. how many species do protected areas host as opposed to non-protected areas), evaluations of biodiversity outcomes are mostly lacking. The most important reasons for that include conceptual and terminological confusion surrounding the definition of effectiveness, as well as difficulties in its measurement. In turn, this is due to the lack of fine temporal field data, but also to uncertainties related to defining objectives and choosing the correct indicators. Finally, the absence of experimental designs requires us to undergo a thoughtful pre-processing and analysis of observational data, which often implies borrowing tools from other scientific disciplines. After introducing basic concepts and highlighting potential pitfalls in performing outcome-based evaluations of protected areas effectiveness, we will present a case study on Mediterranean coastal dunes, currently listed among the most threatened ecosystems on Earth. Results did not reveal substantial differences between protected and non-protected areas, highlighting the importance of overcoming mere legal existence and incorporating effective management to achieve the target of maintaining and/or improving the conservation status of these fragile habitats. All in all, our findings call for extending similar analyses to additional habitats, thereby assessing the actual contribution of protected areas to safeguarding biodiversity in the context of an adaptive management strategy.

From phytosociological relevés to the conservation of Habitats of Community Interest in Umbria: a first tool developed by the LIFE IMAGINE Project

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Here we present a conservation tool, developed within the Action A11 of the LIFE Integrated "IMAGINE" Project (LIFE19 IPE/IT/000015), consisting of a comprehensive process for selecting native species with a key role for the *in-situ* and *ex-situ* conservation of some herbaceous Habitats of Community Interest (Annex I to the 92/43/EEC Directive) occurring in Umbria region.
This tool is intended as an essential, first step in response to pressures such as successional processes, frequently triggered by the abandonment of traditional practices, as well as overgrazing and alien species invasions, that negatively affect the conservation of some Annex I Habitat types (in particular: H3130, H3170*, H6110*, H6210(*), H6220*, H6230*, H6510), as resulting from the prioritization conducted by the previous Life Project (SUN LIFE).
Starting from the collection of all the regional vegetation data available for the target Habitats (more than 600 phytosociological relevés from the VegItaly database), different Habitat subtypes based on phytosociological and ecological characteristics have been identified.
First, an ISA (indicator species analysis) has been performed in order to identify the species pools that characterize each habitat subtype. Then, a protocol of species scoring has been developed, taking into account the attributes of suitability, feasibility of field collection, and concrete susceptibility of *ex-situ* conservation of each pre-selected *taxon* for the reference habitat.
Based on this scoring, a list of selected, habitat-specific, native, plant species has been thus individuated, that will be used both in *ex-situ* conservation activities (e.g. stored in the DSA3 Germplasm Bank, or conserved *in vivo* in the Botanical Garden), through the forthcoming development of protocols for germplasm collection, reproduction and storage, and in concrete future *in-situ* regional conservation interventions, such as habitat reinforcements, reconnection and creation of ecological terrestrial corridors.

Conservation status of threatened plant species in the protected areas SIC IT4060002 "Valli di Comacchio" and SIC IT4060003 "Vene di Bellocchio" (Emilia-Romagna): a preliminary overview

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"Valli di Comacchio" and "Vene di Bellocchio" are part of the Po River Delta regional park, one of the most extensive Italian wetlands. For several years, in the past, this area has been subjected to intense anthropogenic pressures, such as salt production, fish farming and urbanization, resulting in the reduction and fragmentation of the original natural habitats. Despite that the coastal wetland preserves areas of high naturalistic and scientific values which comprise a system of lagoons, characterized by brackish or salt water. The natural vegetation is represented mostly by halophytic shrubs and by perennial or annual pioneer grasslands of coastal salt muds. These sites are part of "Rete Natura 2000" and have been designed as SCI (Site of Community Importance, according to the Habitat directive; codes IT4060002 and IT4060003), and as ZPS (Zones of Special Protection).
This study is part of a three-year long project on the conservation of plant biodiversity in this unique environment. In fact, the first step consists in a preliminary survey on the status of plant populations belonging to threatened or rare species reported in these areas of the Po Delta [1, 2].
During the first sampling campaign we verified the presence/absence of the taxa reported in literature in each studied site. We confirmed the presence of small populations of some rare orchids such as *Anacamptis coriophora, A. palustris, A. morio, A. pyramidalis, Cephalanthera longifolia, Ophrys apifera, O. bertolonii, O. sphegodes, Neotinea tridentata* and *Serapias vomeracea*. Populations of *A. laxiflora, C. rubra, O. tenthredinifera*, *Orchis anthropophora* and *O. simia*, instead, seem to be disappeared. The Comacchio Saltworks vegetation consisted in species typical of saltmarshes, like *Limonium bellidifolium, L. densissimum, L. virgatum, Crithmum maritmum, Spartina maritima, Halocnemum cruciatum* and *Salicornia veneta*. In areas characterized by coastal salt muds we reported populations of *Cistus criticus, Centaurea tommasinii* and *Polygonum maritimum.*
This checklist was useful to map the current distribution of natural populations. Each of these populations was plotted for the future investigations and for each plot we will determine the number of reproductive individuals, and we will analyze the principal functional traits to determine the potential growth rate and the capacity to disperse and establish.
Moreover, we used a molecular approach for the identification of taxonomically problematic genera or complexes of taxa. The DNA barcoding method was very useful for groups of plants with high phenotypic plasticity and high hybridization frequency such as the genera *Salicornia*, *Spartina* and *Halocnemum*.

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New data on the distribution of habitat 3170 in the Lazio Natura 2000 network

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The priority habitat 3170 is highly threatened and is in poor or bad conditions in most of its European range. An interpretative gap emerges from the standard data forms of the SACs on how to calculate the cover of this habitat. The distribution of 3170 habitat is often characterized by communities with dimensions of a few square meters, of which is difficult to make estimates of total cover for the territory of a SAC. Furthermore, the distribution outside the Natura 2000 network is almost unknown at present. New data are presented for Lazio region which demonstrate the presence of habitat 3170 in non-protected sites and in sites of the RN2000 where it was not previously reported. The surveys carried out show the presence of three different communities. The first, typical of deeper temporary pools, in which *Isoëtes velata* is present accompanied by *Juncus articulatus, Agrostis canina, Glyceria notata* and *Callitriche* (*C. stagnalis, C. palustris, C. brutia*). The other two communities see the dominance of two iconic species belonging to the *Isoëto-Nanojuncetea*, *Isoëtes durei, I. histrix* and are typical of two different ecological situations. The first is undoubtedly to be assigned to habitat 3170, and is characterized by small and low depth temporary ponds, drying early, with the presence of *Cicendia filiformis, Isolepis cernua, Juncus bufonius, J. capitatus, J. pygmaeus, J. tenageja, Lythrum hyssopifolia*, which in the spring period tend to be colonized by species of *Stipo-Trachynetea*. The second community is developed on minimum areas of few dm2 characterized by a strong edaphic humidity where the physiognomic dominance of bryophytes occurs and where *I. durei* and *I. histrix* are the only *Isoëto-Nanojuncetea* characteristic species. These reports represent an important step forward in defining the distribution of habitat 3170 in the Lazio region and raise questions concerning the way to interpret it in coenological and distributional terms.

The map of Habitat Types of Community Interest of Abruzzo, Lazio and Molise National Park and surrounding Natura 2000 areas

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We describe the process used to produce the updated (2022) map of the Habitat Types (Annex 1 of the EU Habitats Directive) of Abruzzo Lazio and Molise National Park and the adjoining Natura 2000 SCAs, with a total study area of 86,000 hectares (scale 1:50,000; MMU= 4 hectares).
As a first step, we retrieved and when possible geo-referenced all the pre-existing (in publications or grey literature) vegetation relevés for the area (c. 1,300 sampling units). Then, we produced a draft vegetation map based on Sentinel2 imagery (year 2020, both winter and summer sceneries) integrated with Google Earth autumn 2016 images. The vegetation map was checked and converted into a habitat map using >2,600 ground control points (at each point, at least the dominant species were recorded, but often a more complete floristic list was surveyed), 138 relevés (with a sampling area of 1, 10 or 100 m^2, depending on vegetation physiognomy) and 58 sampling points of submerged aquatic vegetation. Habitat interpretation (i.e, translation of vegetation units into Annex 1 Habitat Types) was based firstly on the EUR-28 Interpretation Manual, integrated with the Italian Manual. The useful mapping criteria proposed by the Federal Interpretation Manual of Germany were also often adopted.
We found a total of 37 Habitat Types of EU Interest, of which 9 are new compared to the Standard Forms of the sites. Eight habitat types mentioned in the Standard Forms were not recorded by us, mostly because of the different or more updated interpretation criteria followed, e.g. we used 91E0* instead of 92A0; in some cases because of wrong identification in the previous studies, e.g. 3170* is clearly erroneous and should be referred in the area to 3130.
The most interesting new finding is habitat type 6240* "Sub-pannonic steppic grasslands", that we report here for the first time in the Apennines following the discovery of large areas characterized by Festuca valesiaca. Habitat 9180* "Tilio-Acerion forests of slopes, screes and ravines" had not been recorded in the Standard Forms, yet we found many interesting examples of plant communities that can be clearly referred to it. Another interesting finding is that the Lake of Barrea, despite being an artificial basin, contains a wide extension of Chara-dominated submerged vegetation with many macrophytes, so we referred the whole lake to code 3140. Habitat type 7230 (Alkaline fens) was already reported for the area; in this work, however, it was for the first time accurately surveyed and mapped, leading to the discovery of an unexpected number of small fen fragments – raising a number of management issues.
Finally, we outline some critical interpretation issues (e.g. the delimitation criteria for mapping 9210* beech forests vs. non-Annex 1 beech forests; or for discriminating the priority and non-priority sub-types of 6210 grasslands) and some management problems (mainly concerning grasslands and wet habitats).

A detailed monograph with accompanying notes and habitat descriptions was produced and is freely available, together with the two sheets of the map, at http://www.parcoabruzzo.it/pagina.php?id=612 ("Aggiornamento Carta degli Habitat 2022")

An integrated approach to the conservation of Annex I secondary grassland habitats in Maiella National Park (Central Italy)

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Secondary grasslands occupy a prominent position in the UE set of concerns (and hopefully efforts) for habitats conservation, also in the light of the discomforting outcomes of the recent European Red List of Habitats and of the 4th cycle of Annex I Habitats Monitoring and Reporting ex-Art. 17. As habitats with a semi-natural origin, the key management activities for their maintenance in favorable conservation status need an integrated approach, combining a floristic, phytocoenotic, and ecological understanding with the implementation of sustainable use and practices. The territory of Maiella National Park, one of the biodiversity-richest sites in Europe, stands as an emblematic area for both grasslands extent and land depopulation, as well as for the drastic, long-lasting trend of reduction in breeding activities and extensive livestock grazing. Therefore, the area is a challenging case study for the development of appropriate management measures, that take into account all these instances and, at the same time, contribute to the conservation of Annex I grasslands habitats. We present here a first overview of the results of an integrated study holding as its main objective that of analyzing the areas currently covered by pasture (or former pasture) vegetation within the hilly, montane, and, partly, subalpine belts of the Park. We took into consideration their floristic composition and vegetation peculiarities, their ecological-environmental characteristics, as well as their pastoral value and their distribution, making use also of statistical models for the spatialization of productivity indices. Results allowed to identify 20 plant communities, that have been framed in the classes *Festuco-Brometea* Br.-Bl. et Tx. ex Soó 1947, *Nardetea strictae* Rivas Goday et Borja Carbonell in Rivas Goday et Mayor López 1966, *Molinio-Arrhenatheretea* Tx. 1937, and *Elyno-Seslerietea* Br.-Bl. 1948. A large rate of them belongs to the Annex I Habitat types 6210(*), 6230*, and (to a lesser extent) 6510 and 6170. An NDVI-based web interface, running on Google Earth Engine, has been implemented, as well, for near-real-time analysis of the vigor and phenological phases of the grassland vegetation, as a support for more rational and sustainable use of the areas by breeders. The present study intends to be a first contribution to the comprehensive development of an integrated management system of a large, diversified area where different interests, such as the environmental, economic, social, and cultural ones, meet, intersect, and sometimes collide, thus shaping the landscape and its territorial identity.

Plant species, habitats and landscapes of community interest in the Pantelleria island National Park (Sicily channel)

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The Pantelleria National Park, established in 2016, extends over 66,4 km^2, covers 80% of the island. This area, in the Mediterranean Sea, represents the emerged part of a volcanic land separating the African and the European continents. Pantelleria Island is dominated by the peak of the Montagna Grande (836 m), followed by Monte Gibele (700 m) and other inactive volcanic cones; the landscape is somewhat harsh and rugged, characterized by lava rocks and steep slopes, with rare flat areas, mainly consisting of calderic depressions.The local climate tends to change according to the altitude range and the exposure of the slopes; the coastal areas and the plains South-facing lowlands up to 150 m a.s.l. are subject to infra-Mediterranean thermotype, while most of the of the remnant surface of the island is characterized by conditions ascribable to the thermo-Mediterranean; only the top of the Montagna Grande is probably characterized by a meso-Mediterranean climate. The annual amount of precipitation is c. 400-500 mm in the lowest sector of the island, with strong interannual variations (from about 300 to more than 750 mm).
The National Park includes three sites of the Natura 2000 network, in particular two Special Areas of Conservation (SACs) [1) ITA010019 - Montagna Grande; 2) ITA010020 - area costiera e Lago di Venere] and a Special Protection Area (SPA) [ITA010030 - Isola di Pantelleria e area marina circostante]; the first two fall entirely within the Park, while the third one is only partially included (marine part excluded). The present work describes the methodological approaches implemented to anticipate the drafting of the National Park plan, identifying the emergencies of vascular flora, habitats of community interest (with related communities or plant associations) and the significant elements characterizing the landscape of the island. This is also due to the most recent changes in land use and dynamics of the vegetation and plant landscape. Particular attention was paid to rare or endemic plant species and vegetal communities, evaluating their potential vulnerability, risk factors or possible environmental alterations, aimed at drafting of specific conservation measures. The vascular flora is composed of about 600 infrageneric entities (BRULLO et al., 1977; GIANGUZZI, 1999), a rather small number compared to the extension of the territory; this is due to its young geological age and the geographical isolation under the Strait of Sicily. It includes several endemics – all neogenic – almost all exclusive to the island (*Anthemis cosyrensis, Serapias cossyrensis, Limonium cosyrense, Limonium secundirameum, Limonium parvifolium, Matthiola incana* subsp. *pulchella, Epipactis microphylla* subsp. *cossyrensis, Trifolium nigrescens* subsp. *dolychodon Senecio leucanthemifolius* subsp. *cossyrensis*), except *Logfia lojaconoi* (also present in Linosa Island). Among the other relevant species, some elements of phytogeographic interest – almost all with southern gravitation – such as *Pinus pinaster* subsp. *escarena, Periploca laevigata* subsp. *angustifolia, Genista aspalathoides, Carex illegitima, Limodorum trabutianum, Ophrys sphegifera, Brassica insularis, Crassula alata*, etc. are mentioned. Other rare species are localized in the fumarolic areas (*Linum radiola, Kickxia cirrhosa, Isoëtes durieui* e *Ranunculus parviflorus*); still

others are small ferns belonging to the genus *Asplenium* (*A. balearicum, A. marinum, A. obovatum* subsp. *obovatum* and subsp. *billotii*), settled on fresh and humid lava rocks. The habitats of Annex I of Directive 92/43/EEC represented in the territory are the following: 1150* - Coastal lagoons (*Cypero laevigati-Schoenoplectetum thermalis*); 1210 - Annual vegetation of drift lines (*Salsolo kali-Cakiletum maritimae*); 1240 - Vegetated sea cliffs of the Mediterranean coasts with endemic *Limonium* spp. (*Limonietum cosyrensis*); 3170* - Mediterranean temporary ponds (*Isoëto durieui-Ranunculetum parviflori* subass. *typicum* and *callitrichetosum brutiae*); 5210 - Arborescent matorral with *Juniperus* spp. (*Periploco-Juniperetum turbinatae* subass. *brassicetosum insularis*); 5330 - Thermo-Mediterranean and pre-desert scrub (*Periploco-Euphorbietum dendroidis*); 5430 - Endemic phryganas of the *Euphorbio-Verbascion* (*Matthiolo pulchellae-Helichrysetum errerae*); 6220* - Pseudo-steppe with grasses and annuals of the *Thero-Brachypodietea* (*Sileno sedoidis-Bellietum minuti, Crassulo tilleae-Sedetum cosyrensis*, *Trifolio dolychodon-Andryaletum cossyrensis*); 8220 - Siliceous rocky slopes with chasmophytic vegetation (*Asplenietea trichomanis*); 9340 - *Quercus ilex* and *Quercus rotundifolia* forests (*Erico arboreae-Quercetum ilicis* subass. *typicum* and *juniperetosum turbinatae*); 9540 - Mediterranean pine forests with endemic Mesogean pines (*Pistacio lentisci-Pinetum halepensis* and *Genisto asphalathoidis-Pinetum pinastri*). Other peculiarities of the Pantelleria Island are its crops, such as the cultivation of the vine (*Vitis vinifera*) – whose sapling plants are listed among the UNESCO heritage - but also the caper (*Capparis spinosa* subsp. *rupestris*) and the olive ones (*Olea europaea* var. *europaea*), with the age-old cultivated plants with the branches "prostrate" on the soil, to protect them from the wind. It is an extraordinary landscape, dotted by peculiar anthropic elements – such as the "dammusi" (for human refuge), the "giardino" (for citrus cultivation) and the dry-stone walls (to maintain the terraced territory) – as the result of an ancestral relationship between the human activity and this amazing island.

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Analysis of the spatial distribution, the structure and floristic composition of mountain hay meadows (EU habitat 6520) in Lombardy

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The main objective of the Habitats Directive is the maintenance of favourable conservation status of habitat types, which evaluation is based on appropriate parameters such as spatial distribution, structure, functions, and future prospects of survival. However, the Natura 2000 network of protected areas does not always cover all the habitat surfaces in a territory, limiting a complete knowledge of their conservation status. In this study, we analysed the conservation status of the habitat type 6520 "Mountain hay meadow" inside and outside of the Natura 2000 network of the Lombardy region, based on the spatial distribution in the regional territory and its temporal evolution (1954-2019), and on the current state of the structure, functions, and future prospects.

The spatial distribution was examined with respect to the main environmental variables, interactions with the treeline and contacts with adjacent habitats, while the analysis of the historical distribution was divided by elevation belts and by provinces. We assessed the conservation status of the habitat 6520 based on groups of floristic-vegetational relevés identifying specific ecological conditions such as altitudinal variants of low-altitude hay meadows and mountain meadows at the border of the Lombardy region. For each group of relevés, the values of the indicators of structure, functions and future prospects were calculated, which were then compared with the reference thresholds for the habitat 6520 in Lombardy.

The results showed that the habitat is currently under-represented within the Natura 2000 network of Lombardy, i.e. a strong asymmetry has been found between the distribution of the habitat at a regional level and the protected portion within the Natura 2000 network. This asymmetry in particular was observed as a function of the altitude: most of the polygons attributed to the habitat below 1000 m are in fact located outside the Natura 2000 network. Our analysis also showed that the inclusion in the habitat 6520 of the altitudinal variants of low altitude hay meadows would negatively affect the parameters referring to the overall conservation status of the habitat. Spontaneous reforestation, following the abandonment of agricultural activities, is the main threat to the survival of the habitat 6520 in Lombardy, especially at a higher elevation, as further confirmed by the substantial decrease in the area occupied by the habitat 6520. This trend is also accompanied by a considerable increase in the number of polygons and by a decrease of more than 50 % of their average surface, indicating a substantial fragmentation of the habitat 6520.

The high naturalistic value of the habitat 6520 in Lombardy is thus seriously threatened, and its conservation status in future years can only be guaranteed by reversing the current trend of the abandonment of agricultural activities in the mountains.

An integrated approach to evaluate nature conservation in protected areas

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Assessing the performance of protected areas is a priority in global nature conservation agendas. The aim of this study is to investigate the effectiveness of conservation measures on the structural, functional, and floristic components of habitats, considering different levels of protection. We expect habitats undergoing stricter protection measures to be better conserved. The study area encompasses Asinara island with two levels of protection (National Park and SAC) and Stintino, in the north-west of Sardinia inside (one level of protection) and outside SAC. We selected as case study the habitat 5210-matorral arborescent of *Juniperus* spp. For each level of protection (absence, one and two levels), we considered 15 plots using a random stratification approach. In spring 2022, we collected structural parameters, species cover data, and plant traits. We analyzed if structural, functional and floristic features differed across the sites and found no great difference between one level of protection and its absence. In contrast, under two levels of protection, the habitat components resulted different. In terms of structure the habitat was characterized by less but larger *Juniperus* individuals with a more spheric crown. It also showed a higher species richness coupled with a major stratification of the herb layer. Regarding the shrub layer, the site under two levels of protection was characterized by a more stratified lower height. Finally, at the species level, it hosted a higher number of indicator species compared to the other two sites (absence and one level of protection). However, these indicator species ranged from unpalatable to alien and ruderal species. Our study case contributes to increasing the knowledge on the effectiveness of conservation strategies on three components of habitats i.e. structure, functions, and flora. We suggest that the designation and management of protected areas should be carefully assessed since their creation does not always imply a better nature conservation status.

The management of habitats of Community interest in the Gran Sasso and Monti della Laga National Park: Evaluation of the incidence and containment of invasive alien species

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1 Gran Sasso and Monti della Laga National Park

The Gran Sasso and Monti della Laga National Park Authority manages a territory of 150,000 ha (covering 3 administrative regions, 5 provinces and 44 municipalities) protected under Law 394/91 and perfectly coinciding with the ZPS IT7110128. It also contains within it 14 SIC of which it is therefore to all effects the managing body. On the territory, 41 habitat of Annex 1 and 5 plant species of Annex 2 have been surveyed
The goal of "maintaining or restoring the habitats of Community Interest in a satisfactory state of conservation" is pursued through the following actions:
- Suitable integration of the reference legislation for the territory (Park Plan, Regulations, Conservation Measures)
- Planning for the implementation of active measures (e.g. LIFE projects, Biodiversity Directive, National Program for increasing the resilience of natural and semi-natural forest systems)
- Studies and researches for the definition of distribution, conservation status, conservation measures of habitat and species
- Preliminary phase for the issue of VINCA and Nulla Osta opinions
- Awareness raising actions
- Surveillance

In this communication we will focus on a crucial phase, namely that of the Environmental Impact Assessment, and on one of the major threats currently encountered in the area, namely that of the large-scale expansion of invasive alien species with particular reference to Senecio inaequidens.
The preliminary phase of the VINCA Studies that arrive at the Park Authority presents some critical issues (for example the quality of the studies themselves can be improved and the enormous amount of requests to be dealt with which often makes it sometimes difficult to verify in the field) but it is, in our opinion, the most important phase for habitat management as it not only allows to identify any impacts, but also to increase knowledge on the distribution, conservation status and effectiveness of certain conservation measures. Over time, the Park Authority has developed a set of possible prescriptions aimed at minimizing or eliminating the impacts on habitats and species. Therefore, the possibility of being able to issue favorable opinions on certain interventions increases, thus reconciling the aspects of development and that of conservation. Naturally, in these cases, the surveillance phase, carried out with expertise and in close collaboration with the Park Authority, by the Carabinieri Forestali for the Park, plays a fundamental role.
One of the greatest threats to habitats is that of the expansion of alien species capable of entering natural habitats and altering the floristic composition. In the PNGSL, in recent years the tendency has been observed by Senecio inaequidens to interfere with various habitat of Community Interest including: 6110 *, 6210 *, 6220 *. To counter this trend, the Park Authority has undertaken various actions: mapping the presence, drawing up a potential diffusion map, eradicating large areas, raising awareness of citizens and institutions. The authorization phase assumes particular importance, in which the Authority, now in practice, prescribes, where land movements are planned, the monitoring for at least 2 years and the timely eradication of alien species that in all likelihood

would settle in the sites subject to intervention, then spreading to natural habitat including those of Community Interest.

Free session

Intra-specific variability of seed traits of coastal dune engineering species at European scale

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Within-species variation is a key component of biodiversity, and linking it to climatic gradients may significantly improve our understanding of ecological processes. High variability can be expected in plant traits, but it is unclear to which extent it varies across populations under different climatic conditions. Here, we investigated seed trait variability and its environmental dependency across a latitudinal gradient of two widely distributed dune-engineering species (*Thinopyrum junceum*, *Calamagrostis arenaria*).
Seed germination responses against temperature and seed mass were compared within and among six populations exposed to a gradient of temperature and precipitation regimes (Spiekeroog, DE; Bordeaux, FR; Valencia, ES; Cagliari, IT, Rome, IT; Venice, IT).
Seed germination showed opposite trends in response to temperature experienced during emergence in both species: with some expectation, in populations exposed to severe winters, seed germination was warm-cued, whereas in populations from warm sites with dry summer, seed germination was cold-cued. In *C. arenaria*, variability in seed germination responses disappeared once seed coat was incised. Seed mass from sites with low precipitation was smaller than that from sites with higher precipitation, and was better explained by rainfall continentality than by aridity in summer. Within-population variability in seed germination accounted for 5% to 54%, while for seed mass it was lower than 40%.
Seed trait variability can be considerable both within- and among-populations even at broad spatial scale. The variability may be hardly predictable since it only partially correlated with the analysed climatic variables, and with expectation based on the climatic features of the seed site of origin. Considering seed traits variability in the analysis of ecological processes at both within- and among-populations level may help elucidate unclear patterns of species dynamics, thereby contributing to plan adequate measures to counteract biodiversity loss.

Within-community spatial organization of understory plants along forest succession: from coppice to primeval forests

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Temperate forest understory poorly contributes to forest biomass but may contain 90% of plant diversity and contributes significantly to ecosystem functions such promoting litter decomposition and nutrient cycling. Furthermore, the understory is extremely sensitive to disturbance, including forest management practices, which may alter resource amount/heterogeneity. We applied fine-scale sampling to explore changes in alpha and beta diversity along a forest successional gradient capturing various levels of habitat heterogeneity. Our research may appeal to conservation practitioners tackling the challenge of applying sustainable management practices whilst promoting the conservation of biodiversity.

The successional gradient consisted of beech forest stands from coppiced forests of the Central Apennines (Italy; n = 5), old-growth forests of Sasso Fratino and Valle Cervara (Italy; n = 9), and primeval forests of the Carpathian Mountains (Ukraine, n = 2). Herein, we sampled vascular species of the understory (<2 m height) along transects in contiguous sample units (sized 10 × 10 cm or 20 × 20 cm). We measured alpha (i.e., average number of species) and beta diversity at different spatial scales along the successional gradient using the comspat R package. To measure beta diversity, we used a special case of Shannon Diversity, called compositional diversity (CD), which considers the number and relative abundance of species combinations.

Our results showed that CD is more sensitive than alpha diversity indices in distinguishing the different stages of forest succession. CD produced a U-shaped pattern along the successional gradient. The primeval forests of the Ukrainian Carpathian Mountains showed very high values of CD, significantly higher than Sasso Fratino and Valle Cervara, indicating that many centuries are required to re-establish complex and close-to-nature species assemblages.

Assessing the effect of vegetation sampling on the response curves estimated by plant distribution models

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Species distribution models (SDM) rely on species occurrence (presence/absence) or abundance data and environmental variables to estimate species response curves. Therefore, the quality (and quantity) of species and environmental data determines the quality of the outcomes, e.g. estimate of the species-environment relationship, which we can obtain from these tools. In this regard, SDMs are seldom fitted on data collected strictly for that purpose, while information available from previous sampling is often 'recycled'. Here, we aimed at assessing how the sampling strategy affects the quality of species response curves estimated by SDMs. To this purpose, we simulated the occurrence of two virtual plant species across the Abruzzo region. We assumed that the two plants were similarly affected by precipitation, but one had a wider temperature optimum than the other. Then, we sampled occurrence data of the two species through 5 different strategies: random, stratified, systematic, topographic (performed within the geographic space); and uniform (performed within the environmental space). Furthermore, we simulated a spatially biased sampling by collecting occurrence data close to roads. Environmental data were sampled together with species data, and the obtained datasets were used to fit SDMs on the same model used to generate the virtual species. To account for the effect of sample size, we simulated the sampling of an increasing number of units. In total, we ran 500 replicates for each combination of sampling design and number of sampled units. For each replicate, we extracted the model coefficients for precipitation and temperature, and evaluated the quality of the estimated response curves computing the following measures: bias (for accuracy); variance (for precision); and mean squared error (for accuracy and precision). Our results suggest that a proper estimate of the species response curve can be obtained when the choice of the sampling strategy is guided by the species' ecology. In particular, the response to environmental drivers of generalist species could be better described using data uniformly sampled within the environmental space, while the systematic sampling may be more suitable for specialist species. Finally, sampling close to roads may provide poor estimation even when species presence negatively correlates with road distanc

Inter-annual dynamic of vegetation and the pastoral value in Mediterranean grasslands

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Mediterranean climate is characterizsed by inter-annual meteorological variability. This contribution aims to explore how this inter-annual variability affects the vegetation dynamic and the Pastoral Value (PV), which is a proxy of one of the most relevant ecosystem services of grasslands, forage production, in Mediterranean grasslands.
The research was performed in the framework of the Life Regenerate project (LIFE16 ENV/ES/000276), which aims to improve biodiversity and ecosystem services in Mediterranean agro-silvo-pastoral systems.
The experimental design includes two permanent grasslands, one at low altitudes (PG_la), one at high altitude (PG_ha), and a wooded grassland (WG) located in the Municipality of Santu Lussurgiu (Sardinia, Italy).
The vegetation surveys were carried out with the "point quadrat" method along permanent linear transects (50 m) at regular intervals (1 m) randomly located within each survey area, placed in 2018. The measurements were repeated six times in different seasons: from spring 2018 (time 0) to spring 2021 (time 6). The PV was assessed according to Daget and Poissonet [1;2].
In PG_la were recorded 162 plant species; in PG_ha 145 and in WG 91.
In PG_la among the excellent forage species *Lolium rigidum* was the most abundant (Specific Percentage Contribution CSP 7%-12%). *Trifolium subterraneum* CSP was stable year by year (7%). *Medicago hispida* appeared only during the seond year (CSP 12%). In PG_ha, the most abundant species was *Pteridium aquilinum* (CSP 23%-26%). *Holcus lanatus* was always present which a variable cover (CSP 6%-18%). The excellent forage species *Trifolium pratense* reached maximum CSP (10%) in Autumn 2021. In WG, the most abundant species were good and excellent forage: *Avena barbata* (CSP 13%-21%) and *Trifolium subterraneum* (8%-23%).
In PG_la PV varied between 34 and 50, in PG_ha between 28 and 37; in WG between 40 and 52.
The great variability of CSP and PV will be discussed in the light of inter-annual meteorogical fluctation

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Exploring the drivers of species diversity and composition of arable plant communities across Italy

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The changes of agriculture led to deep transformations of arable plant diversity, whose conservation is crucial to maintain biodiversity in agroecosystems [1]. The drivers shaping arable plant communities are many and diverse, including anthropic, environmental, and geographic factors [2]. Understanding the relative importance of such drivers is essential for conservation and restoration purposes. Thus, in this work we assessed the effects of agronomic, climatic, geographic, and landscape factors on α-diversity, β-diversity, and composition of winter arable plant communities across continental Italy, a European hotspot of arable plant diversity.
Using redundancy analysis and variation partitioning, we observe that the selected groups of variables explained a restrained to moderate proportion of the variation in diversity and composition, depending on the response (5.5% to 23.5%). We confirm previous evidence that climate and geographic location stand out in determining the features of arable plant communities in the Country [3], followed by the type of rural area. The surrounding landscape has a subordinate influence, but affects both α and β-diversity. The α-diversity is higher in traditional agricultural areas and in landscapes rich in patches of natural vegetation, while it is lower in warmer areas. Species composition is determined by climate, latitude, and the type of rural area, but it is not affected by landscape features. The total β-diversity is mainly explained by climate and latitude, and subordinately by the agricultural context and landscape. Its components are explained by latitude and climate (replacement) and agricultural context and climate (richness difference). The analysis of the local contribution to β-diversity of single sites suggested a good conservation status of the studied communities.
Our findings will be a basis for the definition of conservation and restoration strategies of vanishing arable plant communities, which are often neglected in conservation policies.

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Effect of spatial scale on taxonomic and functional components of beta diversity in grassland habitats

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Beta diversity refers to the heterogeneity in the distribution of biological entities across space, time or any other gradient of variation and nowadays is one of the most pervasive concepts in ecology and biogeography. Recently the consideration of the functional dimension on beta diversity has gained importance, with an increase in the informativity provided by multifaceted studies on biodiversity, together with the approaches of partitioning beta diversity in nestedness and turnover components. These approaches are pivotal in revealing the contribution of different mechanisms that drive the taxonomic and functional diversity of communities. Within this study, we aimed to investigate how the beta diversity components varied in a calcareous semi-natural grassland habitat (i) along a latitudinal gradient and (ii) across multiple spatial scales. We found that the nestedness component of beta diversity is higher in the taxonomic facet than in the functional one, while the turnover component tends to increase with scale for both facets of diversity. Moreover, we found no clear pattern of beta diversity along the latitudinal gradient considered, underlining the evidence that for this grassland habitat environmental variables, such as climate or edaphic characteristics, are more important as drivers for biodiversity.

Poster

The project cli-p-on: plant response to climate change in Mediterranean temporary ponds

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The conservation of the habitat 3170*-Mediterranean Temporary Ponds (MTPs) is highly precarious because their recognition has been historically neglected, and their degradation and disappearance have increased continuously during the last centuries (Bagella et al., 2016). Despite an improving public perception of wetlands over recent years, they are overlooked and exposed to perturbations or destruction (Schwartz and Jenkins, 2000).
Climate changes, resulting in modification of the seasonal and annual temperatures and precipitation patterns and amounts, affect the hydrological regimes, which control the ecology of MTPs.
To evaluate the perspectives of MTPs in the third millennium, the project "Plant response to climate change in Mediterranean temporary ponds – Cli-P-on" is addressed to assess the responses of vascular plants of MTPs to the variations of hydrological regimes.
Although the plants living in MTPs are highly specialized for surviving under different environmental conditions, drastic changes in the hydroperiod length and water availability related to inter-annual fluctuations in temperature and precipitation patterns could adversely impact. Indeed these can result in a progressive impoverishment in the seed/spore bank, in a deep alteration of the phenology of characteristic sward species, and in modifying the ecological structure of these ecosystems.
We are carrying out long-term monitoring and manipulative experiments in the project framework. Long-term monitoring includes assessing plant cover and different meteorological indices such as the evapotranspiration and the synthetic agrometeorological indicator. The manipulative experiments are carried out in the laboratory on the seed bank by combining factors simulating different hydrological regimes (e.g. water depth, duration of inundation period and frequency of flooding).
The first results confirm that meteorological fluctuations affect plant species composition and vegetation dynamics in MTPs and that sensitivity of specialist species could make them particularly vulnerable to climate change (Caria et al., 2021).

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Biodiversity effect on coastal dunes ecosystem functioning

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Worldwide, ecosystems are facing dramatic alterations and biodiversity decline due to a variety of global drivers of change. Consequently, increased concern about the potential effects of changes in diversity patterns on aboveground and belowground ecosystem functions has emerged. Over the last two decades, most studies agreed that species diversity begets ecosystem processes and functions over time. However, these findings have been mainly supported by experiments performed on artificial assemblages of species or communities randomly manipulated, which poorly represent real-world ecosystems. Furthermore, there is a growing consensus that other facets of biodiversity, i.e. phylogenetic and functional components, rather than species richness per se, may play a crucial role in ecosystem functioning in the context of global change. Finally, community provisioning of ecosystem functioning also varies significantly according to local climates, land use and more in general environmental gradients.

Against this background, we aimed to study the biodiversity-functioning relationship on coastal dunes ecosystems, which are among the most threatened ecosystems in Italy and the Mediterranean basin. Specifically, we explored the effect of taxonomic, functional, and phylogenetic diversity facets on one aboveground (productivity) and one belowground (decomposition) function. Moreover, we further investigated whether the biodiversity effect on ecosystem functions varies along the sea-inland gradient, where many different coastal dune habitats succeed.

Data were collected in 109 plots (2 x 2 m^2) of the Lazio region in the herbaceous habitats of the coastal dune zonation: the beach drift-lines, the shifting dunes, and the dune grasslands. We consider plots highly invaded by non-native species (cover > 30%) as an additional category. In each plot, we collected aboveground plant biomass as a proxy of productivity and performed the Tea bag index protocol (Keuskamp et al., 2013) to assess decomposition rate (K) and organic matter (OM) stabilization factor (S). Concurrently, we recorded the abundance of all vascular plant species in each plot to calculate species richness, evenness, functional and phylogenetic Rao index. We applied mixed effect models to test the biodiversity effect on decomposition indicators and plant biomass along the sea-inland gradient.

We found phylogenetic diversity to enhance OM stabilization but not biomass production, which on the contrary increased with species richness and functional diversity. In addition, we observed an increase in OM stabilization and biomass production along the coastal dune zonation. OM stabilization was low in the drift-lines habitat and increased in shifting dunes, dune grasslands and invaded plots. Similarly, the lowest biomass production was found in the drift-line habitat and shifting dunes, followed by dune grassland. Yet, the highest biomass was in the invaded plots. On the other hand, the decomposition rate was not influenced by either plant diversity or habitat type. These results highlight the importance of maintaining high levels of multiple facets of biodiversity, in order to ensure functioning across endangered coastal dune habitats.

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A sampling strategy for assessing terrestrial habitat at large spatial scale

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Achieving a relevant and measurable improvement in the conservation status of habitats is one of the target of Nature 2000 network furthermore, one of the European 2030 Biodiversity Strategy' goal is to improve the effective management of sites and habitats that show declining trends. Under such framework, it is essential to achieve quantitative and affordable measures of ecosystems quality indicators. Here we present a two-phase sound statistical sampling scheme to estimate the coverage of EU terrestrial habitat types. We used 9 habitats distributed among different EU countries using the whole Italy as a case study. Simulation study was performed to check the precision of the coverage estimators accounting for the lack of sampled data (nonresponse treatment), subregions and real constrains. Territory is covered by a collection of 3.491 10 km x 10 km quadrats (M), some of them lying partially outside the territory (e.g. sea). For each habitat type, its presence or absence inside the quadrat is known. Each quadrat is composed by 10.000 (N) cells of 1 ha to be surveyed for detecting the presence of the investigated habitat type, therefore the totality of cells, quantified as the product of all the quadrat multiply for all of the cells (M x N) is the population to be sampled. In the first stage of the first phase, the set of the M quadrats was partitioned into *m* clusters of neighboring quadrats in order to achieve a spatially balanced sample, subsequently in accordance with the sampling scheme referred to as the one-per-stratum sampling (OPSS) a quadrat was selected in each cluster with probabilities proportional to a score indexing the suitability of the cell to contain habitat (HSS), determined by models or by habitat experts. Then, in the second stage, a sample of cells is selected within each quadrat selected in the first stage, obtaining a first-phase sample of cells. Finally, in the second phase, a sample of cells out of those selected in the first phase within each quadrat is selected. The presence and absence of habitat in the sample was assigned by sorting the cells with respect to their HSSs and coverage estimate computed. Results show that adopting a small sampling fraction of the survey area the relative standard error values ranged from 7 to 15% for commons habitat having strong correlation between habitat suitability scores and presence previously known. The possibility to apply the strategy at European scale could be an applicative and standardized achievement in building a shareable approach for maintaining a favourable conservation status of the Nature 2000 terrestrial habitat network.

Restocking actions within the habitat 3150: a case study in the Battista lake (Maiella National Park)

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Il territorio del Parco Nazionale della Maiella, in virtù della conformazione calcarea del massiccio è povero di specchi d'acqua permanenti. Uno di questi è il piccolo Lago Battista sui Monti Pizzi che ospita diverse specie vegetali rare nell'habitat comunitario 3150 (Laghi eutrofici naturali con vegetazione del tipo *Magnopotamion* o *Hydrocharition*). Il piccolo lago, situato in una radura all'interno di una faggeta ben conservata, è dimora dell'unico popolamento della rara lentibulariacea *Utricularia australis* R.Br. Questa specie, nuova per l'Abruzzo, è stata scoperta nel 2013 dai ricercatori dell'Università dell'Aquila e dai botanici del Parco all'interno del piccolo Lago Battista; fino al 2013 la specie in Italia era nota per tutte le regioni ad eccezione di Marche, Abruzzo, Molise, Basilicata e Calabria: il ritrovamento in Abruzzo colma, quindi, una delle lacune peninsulari. Nel Lago Battista, la specie è presente con numerosi individui, associata a numerose altre specie acquatiche come *Potamogeton natans* L., *Lemna trisulca* L. e *Alisma lanceolatum* With.
Le piante carnivore, un tempo ampiamente diffuse sul nostro territorio, sono oggi considerate specie rare, minacciate dall'urbanizzazione, dal disboscamento, dall'agricoltura e dall'allevamento. E proprio per l'elevata sensibilità che dimostrano agli agenti inquinanti e all'eutrofizzazione delle acque, sono valide indicatrici della qualità ambientale, oltre a elementi importanti per la biodiversità. Per tali motivi presso il Giardino Botanico 'Michele Tenore' di Lama dei Peligni (Chieti) è stata avviata sin dal 2015 una riproduzione *ex situ* presso le strutture della banca del germoplasma e giardino stesso. Nel corso degli anni si è riusciti a coltivare e portare a fioritura la specie ed a moltiplicare il materiale vegetale.
Per implementare la popolazione di *U. australis* nel lago Battista, a dicembre parte del materiale vegetale riprodotto in giardino è stato reimmesso nel lago seguendo le indicazioni delle "Linee Guida per la traslocazione di specie vegetali spontanee", emesse nel 2013 dall'allora Ministero dell'Ambiente e dall'Ispra (Istituto Superiore per la Protezione e la Ricerca Ambientale).

The first Italian long-term monitoring site for exotic and native species in the global MIREN

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Gli ambienti montani e di alta quota sono caratterizzati da una biodiversità unica e forniscono cruciali servizi ecosistemici. Ad oggi, questi ambienti risultano fortemente minacciati dai cambiamenti climatici e dai cambiamenti d'uso del suolo, che possono favorire l'introduzione e l'invasione di specie esotiche e, allo stesso modo, l'espansione di specie native termofile [1]. Diversi studi hanno dimostrato come le strade di montagna siano i principali corridoi per la dispersione di specie esotiche lungo i gradienti altitudinali [2]. Con lo scopo di approfondire il ruolo delle strade in questo meccanismo di espansione, nel 2005 è stato fondato Il network globale *Mountain Invasion REsearch Network* (MIREN; http://www.mountaininvasions.org/) con l'obiettivo principale di monitorare globalmente l'espansione delle specie esotiche e native in ambiente montano, attraverso studi osservazionali e sperimentali lungo i gradienti altitudinali per valutare e quantificare i processi e i meccanismi che plasmano le comunità vegetali montane su scala regionale e globale [2]. Inoltre, è correlato ad altri importanti progetti di ricerca quali GLORIA e SoilTemp [3]. Ad oggi, il network MIREN include 28 siti montani distribuiti in tutti i continenti, ma ancora nessuno nelle aree montane italiane. Emerge quindi l'importanza di effettuate monitoraggi a lungo termine che permettano di studiare i processi di espansione delle specie vegetali esotiche e native nell'Appennino centrale. In questo contesto, si propone l'istituzione del primo sito MIREN di monitoraggio ecologico a lungo termine per approfondire i processi sopracitati nelle montagne del Mediterraneo centrale.
Le ricerche sono in corso di svolgimento in Appennino Centrale dai ricercatori dell'Università di Roma Tre e da quelli dell'Università del Molise. Le montagne e le catene montuose individuate sono: Monte Terminillo, Massiccio del Gran Sasso e Massiccio della Majella, coinvolgendo il personale tecnico del Parco Nazionale del Gran Sasso e Monti della Laga e del Parco Nazionale della Majella.
Il monitoraggio delle specie vegetali esotiche e delle specie native termofile segue il protocollo di campionamento stratificato lungo le principali strade di accesso alle alte quote proposto da MIREN. Lungo ogni strada sono stati individuati 20 siti uniformemente stratificati per altitudine. Ogni sito è costituito da tre plots di 2 m x 50 m, un primo plot parallelo alla strada e gli altri due plot perpendicolari alla strada, uniti a formare una "T". Per ciascun plot saranno registrate in campo le variabili ambientali, le specie di flora vascolare presenti (aliene e native), la loro copertura ed abbondanza. I dati raccolti verranno poi inseriti nel database condiviso del MIREN. Inoltre, verranno installati dei datalogger per il monitoraggio della temperatura dei suoli, i dati rilevati saranno successivamente integrati nel database del network internazionale SoilTemp [4].
I risultati di tali ricerche consentiranno di allestire un database unico nelle montagne mediterranee e di definire aree permanenti utili al monitoraggio ecologico a lungo termine sui processi di invasione biologica e espansione delle specie native termofile negli ecosistemi montani ed altomontani italiani.

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New data on marshy vegetation of montane and submontane areas of Northern Apennines (Italy)

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Despite the acknowledged importance of wetlands for biodiversity conservation (Dudgeon et al. 2006; Hrivnák et al. 2014; Janssen et al. 2016), numerous Italian peninsular submontane and montane areas are still little investigated from the phytosociological point of view, even if this is crucial for the identification of Directive 92/43/EEC habitat types. We here present the preliminary results of a vegetation survey concerning marshy plant communities of the Tuscan-Romagna Apennines. We analysed, by means of cluster analysis, more than 120 vegetation relevés that were surveyed in natural, semi-natural and artificial wetlands. Our analysis identified 19 different vegetation types. The most common phytocoenoses of the marshy areas surrounding the water bodies or distributed along the edges of the streams (class *Phragmito-Magnocaricetea*) resulted to be formed by medium-sized species, such as *Eleocharis palustris* subsp. *palustris*, *Glyceria notata, G. fluitans, Cardamine amara* or *Berula erecta.* These community types can be assigned at the alliances *Eleocharito-Sagittarion* and *Glycerio-Sparganion*. Larger helophytes communities, belonging to the alliance *Phragmition communis,* were dominated by *Phragmites australis* or *Typha latifolia*. Behind these formations, phytocoenoses typical of humid meadows trampled by cattle, often dominated by *Juncus effusus* or *J. inflexus*, were found, together with megaforbs communities of fresh and shady soils, mainly characterized by *Petasites hybridus*. Various sedge communities, belonging to different syntaxonomic classes, were also identified in various habitat types, including marshy *Carex vesicaria* coenoses, *Carex hirta* communities, common in disturbed humid environments, and small meadows dominated by *Carex remota* in the humid depressions of the forest clearings. Other peculiar marshy vegetation types, such as *Caltha palustris* communities, were also found in the study area.
As already reported for aquatic vegetation (Viciani et al. 2022), our study highlights the importance not only of natural wetlands, but also of semi-natural and artificial ones, in maintaining marshy plant communities, together with the corresponding habitat types, in the Northern Apennines.

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Natural intelligence for robotic monitoring of EUforest habitats: first steps of an exciting challenge

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According to the Directive 92/43/EEC of the European Council (Habitats Directive), EU countries are required to periodically assess habitat monitoring campaigns to evaluate the effectiveness of conservation measures and the achievement of conservation targets, which is crucial for the preservation of biodiversity. In forest habitats, characterizing floristic composition, structure, and presence of typical species is complex and requires a high level of botanical expertise plus the ability to move for hours in wild unstructured environments. Nowadays, this task can be carried out only by highly trained human operators. The H2020 Project "Natural Intelligence for Robotic Monitoring of Habitats - NI " ("Research and Innovation boosting promising robotics applications") aims to develop quadruped robots able to move autonomously in the unstructured environment of several habitat types (dunes, grasslands, forests, screes). Our study case focused on beech forests (9110/9210 Annex I Habitats). We brought the robot to selected 9210 habitat stands in the Special Area of Conservation La Verna-Monte Penna (Arezzo, Italy) to conduct several tests. The robot successfully overcame multiple challenges, including autonomously moving on highly uneven, slipping, and irregular terrains, and managing unexpected contacts and impacts with deadwood and vegetation on the ground. The second round of tests aimed at proving the ability of NI robot to gather floristic and structural data, the two main challenges of environmental monitoring in these forests according to the Manual for Italian habitat monitoring [1]. In selected test areas, a plot-based vegetation (species cover) and structural (tree diameter at breast height and tree height) monitoring was carried out by trained botanists on 200 m^2 circular surfaces. At the completion of human monitoring, the robot scanned the same plot to create a 3D map using its Velodyne VLP-16 Puck LITE LiDAR. From this, it was possible to segment single trees and to measure their diameter. The robot ability to move in the study area during the laser scanning was another technological achievement for habitat monitoring. The sole comparable technology to such structural data acquisition is mobile laser scanning (MLS), which requires to be carried by human operators. The acquisition system was also directed upward to measure tree height. The robot was also equipped with RGB-D Intel Real Sense D435 camera on each side. The four cameras had a field of view of 77° x 69.4° x 42.5° and recorded full-HD photos and videos for a later identification of some key indicator species, useful to assess the habitat conservation status. Nevertheless, in the context of image recognition, autonomous mission planning and tree segmentation, the algorithm will require further improvements. Notwithstanding these actual limitations, we moved the first steps toward a fully functional robotic assistance in vegetation monitoring. From the botanical point of view, the exciting ongoing challenge is to develop a human-

robotic monitoring framework, that, although obviously not replacing the human botanical skills, might represent a precise quantitative support for those repetitive and time-consuming activities in habitat monitoring, offering a valuable benefit for biodiversity conservation.

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Lichen diversity patterns in managed vs abandoned old-growht chestnut stands in the Northern Apennine

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In the mountainous regions of southern Europe, the recent decline of traditionally managed old-growth chestnut (*Castanea sativa* Mill.) orchards represents a loss of biodiversity that should be countered. Aim of this study was to test the diversity patterns of epiphytic lichens in managed vs abandoned chestnut orchards in the northern Apennines.

Epiphytic lichens were sampled on a total of 240 old chestnut trees (Diameter at Breast Height ≥ 100 cm), in 12 managed and 12 abandoned chestnut stands, in a montaineous area of Emilia Romagna characterized by a long tradition of chestnut cultivation. On each selected tree, the presence of epiphytic lichen species was recorded in a 30 cm × 180 cm plot placed on the northern side of the trunk, with the shortest side at the base. Species richness (Mann-Whitney test), composition (NP-MANOVA and NMDS), indicator species (IndVal) and ecology of exclusive species were compared between the two environments, considering (1) all species, (2) macrolichens and (3) crustose lichens. GLMM models were performed to evaluate the effects of local variables, i.e. trunk diameter, and landscape, i.e. altitude and areas of chestnut-, beech- and oak-dominated stands at different buffers (500 and 3000 m) around the stand.

Results revealed that abandoned chestnut stands have higher species richness, perhaps due to a greater habitat heterogeneity resulting from years of traditional management followed by changes due to abandonment. Species composition was different between the two environments, which both included indicator and exclusive species, as well as species of conservation concern.

Overall, our results confirm the relevance of ancient chestnut stands for epiphytic lichens and suggest the need to conserve both managed and abandoned stands, because of the peculiar diversity supported by either habitat, to foster the highest level of lichen diversity.

Sub-Mediterranean Pinus nigra forests in Italy

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Natural *Pinus nigra*-dominated forests is a relict montane-Mediterranean vegetation type of Tertiary origin. In Italy, it occurs in the eastern Alps and central-southern Apennines. These stands are included in the priority habitat 9530 of the Habitats Directive and are classified into the sub-types of the Alpine-Apennines *Pinus nigra* subsp. *nigra* and of the *Pinus nigra* subsp. *laricio* forests, with four variants. Other forests are of artificial origin, which were established since the end of the 19th century in erosion-prone areas throughout the Italian peninsula, and are now undergoing natural dynamic processes. Large-scale studies on diversity patterns and dynamics of natural and artificial forests are still lacking for these forests in Italy. Thus, we collected 300+ relevés and stored them into the *CircumMed Forest Database* with the objectives: i) to classify natural pine forest vegetation through a cluster analysis and to identify diagnostic species with Indicator Species Analysis (ISA) for each cluster and ii) to analyse variation of diversity pattern along environmental gradients and between natural and non-natural forests, using multiple regression models. The cluster analysis for natural forests separated two main clusters which grouped stands found in the Alps and the Apennines, respectively. The second cluster further divided sub-clusters of the Etna, the Sila and Aspromonte, and the Pollino and Orsomarso massifs pine forests. Finally, a sub-cluster representing degraded forest stages was recognized for the Etna and Sila massifs. The results of linear models showed a negative and a positive relationship of number of species and diversity with elevation and latitude in both types of forests, respectively. The cluster analysis confirmed the Italian *Pinus nigra* forest variants reported in the Interpretation Manual of EU Habitats, but failed to separate Alpine-Apennine forests on carbonatic from those on crystalline or volcanic bedrocks into different clusters. The cluster represented by alpine *Pinus nigra* forests constitutes a distinct community with floristic affinities extending to the Slovenian and Austrian counterparts, whereas Apennines stands retain a very specific endemic character, though maintaining stronger biogeographic legacies with the Balkan forests. While we did not find a difference in the diversity pattern between natural and non-natural forests, the decreasing of species richness and diversity along elevation is a common pattern based on the effect of more constrained climatic conditions. Conversely, the increasing of diversity in relation to latitude suggests an effect of biogeographical processes being these forests closer to the Balkans and to central-Europe. Accordingly, the most diverse forests are located at the lower elevations of northern Italy, which are enriched by an array of ecologically wide-ranging species from the surrounding communities. These results can be a starting point to study the direction of future dynamic trends of both natural forests and old-established plantations and to understand whether the latter are floristically and ecologically similar to native forests.

Long-term changes in plant communities in the Alpine belt of the Orobie Alps

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Gli ecosistemi montani delle alte quote risultano essere particolarmente vulnerabili alle modificazioni ambientali in seguito ai cambiamenti climatici e di uso del suolo.
Nello scenario attuale, gli ecosistemi alpini d'alta quota rappresentano siti idonei per compiere osservazioni sul mutamento della vegetazione conseguente ai cambiamenti ambientali.
Obiettivo del presente lavoro è stato lo studio delle variazioni subite da alcune comunità vegetali acidofile dell'Orizzonte Alpino delle Alpi Orobie (BG), in un arco temporale pluridecennale.
In particolare, si sono studiate le fitocenosi a dominanza di *Carex curvula* All. e le comunità di ghiaione, attraverso un confronto tra i rilievi fitosociologici effettuati agli inizi degli anni '90 per la stesura del piano dell'allora costituendo Parco delle Orobie ed i rilievi ripetuti nelle medesime località negli anni 2019-2021.
Sono stati considerati e ripetuti complessivamente cinquantacinque rilievi fitosociologici, distribuiti prevalentemente sul versante meridionale delle Alpi Orobie. Per la localizzazione dei rilievi sono stati considerati i dati stazionali, la cartografia disponibile in allegato ai rilievi e consultati direttamente gli autori originari. I rilievi sono stati eseguiti su una superficie di circa 50 m² utilizzando la scala di BRAUN-BLANQUET (1964) modificata da PIGNATTI, utilizzata anche nei rilievi originali.
I nuovi rilievi sono stati confrontati, considerando separatamente le comunità di ghiaione e le comunità di curvuleto, con quelli originali mediante *cluster analysis* eseguite sia sulla presenza/assenza delle specie che sulla loro copertura percentuale, interpretando le tipologie di fitocenosi identificate dai dendrogrammi sulla base delle specie presenti.
Il profilo ecologico dei rilievi vecchi e nuovi è stato definito mediante la consultazione degli indici ecologici di LANDOLT (2011), calcolando i valori medi di ogni rilievo pesati sull'abbondanza delle specie. I valori dei rilievi originali e quelli attuali sono stati confrontati rilievo per rilievo e considerando la media complessiva dei valori dei singoli indici considerati.
I risultati della *cluster analysis* hanno evidenziato numerose modifiche nei curvuleti, mentre le comunità di ghiaione sono risultate più stabili.
Particolarmente evidente è la comparsa di specie tipicamente legate al pascolo in alcune comunità di curvuleti, a formare una tipologia di vegetazione assente nei rilievi degli anni '90. Importanti cambiamenti sono avvenuti parallelamente nelle comunità di vallette nivali, che risultano ora molto impoverite e dimezzate come quantità di rilievi che originariamente le comprendevano. In generale, il gruppo di rilievi che in origine era riconducibile alle vere e proprie praterie a *C. curvula*, comprendente tre diversi raggruppamenti, risulta ora mutato, con numerosi rilievi che ora sono entrati a far parte di comunità differenti.
Gli indici ecologici di Landolt hanno mostrato una variazione complessiva nel tempo poco significativa. Si evidenziano però delle differenze tra ghiaioni, vegetazioni tipicamente azonali, e curvuleti. Complessivamente nei curvuleti i parametri che risultano maggiormente mutati sono Temperatura (**T**) e Luminosità (**L**). Osservando l'andamento di questi fattori, si nota che entrambi

forniscono elementi che suggeriscono un generale lieve innalzamento dei limiti dell'orizzonte Subalpino (abbassamento dell'indice **L**), verosimilmente influenzato da modificazioni ambientali quali il riscaldamento climatico (aumento dell'indice **T**). Nei rilievi condotti sui ghiaioni invece i cambiamenti ecologici più evidenti sembrano far capo a fattori edafici legati alla stabilizzazione degli stessi.

In conclusione, tutte le comunità individuate negli anni '90 risultano ancora presenti, con dinamiche più o meno marcate. Queste variazioni possono essere ricondotte a diversi fattori di cambiamento ambientale, e, in alcuni casi, a possibili imprecisioni nel ritrovamento del punto preciso del rilievo originale.

Reconstructing and analysing historical landscape to characterize the existing vegetation: a case of study in Brescia (italy)

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The aim of this study is to provide a high resolution reconstruction of the historical evolution of land cover in the Municipality of Brescia from the early 19th century (1807-1813), passing through of the mid (1954) and the end (1999) of 20th century, up to current situation (2018). The historical land registers dating back to the Napoleonic era were digitalised and implemented in a Geographical Information System (GIS). The scale of the digitalised historical maps is 1:2.000. Modern geospatial data of intended use of soil for the years 1954, 1999 and 2018 were represented in a map scale of 1:10.000. The time evolution of land cover was analysed through geospatial and statistical techniques. Results showed that the Municipality of Brescia has undergone a profound change during the last two centuries. In 1810, most of the plain area (below 200 m a.s.l.) in the current limit of the municipality was used for agriculture (arable land, meadows and pastures), nowadays this area it is mostly urbanised (65,0% of the plain). In hilly area forest regrowth was observed where meadows and pastures previously occurred. This study provides insight about the historical intended use of soil of a well-defined geographical space, allowing the reconstruction of the early 19th century landscape, the comparison with modern data of intended use of soil and the characterization of the present land cover. The derived knowledge can be also applied in the planning of the landscape in order to guide conservation strategies.

Creating habitats in rural and urban areas to promote animal-mediated pollination, insights from the LIFE PollinAction project (LIFE19 NAT /IT/000848).

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Loss of natural and semi-natural habitats, local and global environmental degradation, increased use of agrochemicals, parasites, and diseases are leading to pollinator crisis, with consequences to the functioning of terrestrial ecosystems. Destruction and fragmentation of formerly species-rich habitats, such as semi-natural grasslands, and the resulting decline of wildflowers are leading to a loss of nectar and pollen, as well as breeding, nesting, and overwintering habitats for pollinators, resulting in population declines and isolation. The project is creating a green infrastructure network of natural and semi-natural areas in rural and urban landscapes in North-Eastern Italy and Spain. Actions include converting cropland to grassland, improving species-poor grassland, and creating wildlife corridors for pollinators along roads, riverbanks, public spaces, and gardens.

Supervised classification of Quercus cerris L. and Q. pubescens Willd. dominated forests in the Chianti region through the analysis of phenological variation throughout the year

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The latest report of the Habitats Directive emphasizes the necessity of adopting more quantitative approaches and the implementation of technologies and tools that could contribute to the current monitoring systems. In this context, the analysis of remote sensing data, often freely available as satellite images, could be a cost-effective way to identify target plant communities. In this study, we adapted an existing methodology for classifying plant cover based on the variation of plant phenology to identify Quercus cerris and Q. pubescens dominated forests in the Chianti region in Tuscany (Italy). Firstly, suitable Sentinel-2 images spanning the years 2018-2022 were retrieved and the Normalized Difference Vegetation Index (NDVI) was calculated. Then, the Functional Principal Component analysis (FPCA) of the NDVI time series was performed to identify differences in the main seasonal variations, together with a PCA of lithological and topographical features. Lastly, we carried out a supervised classification on selected FPCA and PCA components, trained with gathered available field-based and vegetation map data. To validate the obtained classification, we carried out a internal validation which obtained an overall accuracy of 69.6% and an external validation round by means of groundtrhuthing on randomly extracted points, which reached an overall accuracy value of 71.7%. The results were considered satisfactory and the methodology successful in identifying and classifying the target cover types in the study area. This workflow can be further tuned for different plant communities and thus suitable to be included in the monitoring workflow of habitats identified in the Habitats Directive.

Species richness decline in the calacareous steep slopes of high mountain grasslands in Central Appenines

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Gli ecosistemi di alta quota, distribuiti tra il limite superiore della vegetazione arborea (treeline) ed il piano nivale, sono ambienti ricchi di biodiversità (20% della flora mondiale) e possiedono una flora altamente specializzata per resistere alle basse temperature, ricca di specie endemiche e rare [1,2]. Tali ambienti sono tra i più sensibili e minacciati dagli effetti del cambiamento climatico [3,4], in quanto esposti a forti cambiamenti riguardo la loro biodiversità.
Il presente lavoro ha come obiettivo quello di esplorare, attraverso uno studio di re-visitation, i cambiamenti avvenuti negli ultimi 20 anni nella vegetazione di alta quota nell'Appennino Centrale. A tale scopo, sono state studiate due comunità che si sviluppano su versanti calcarei del Parco Nazionale della Maiella: 1) la vegetazione delle praterie discontinue a *Sesleria juncifolia* dell'alleanza *Seslerion apenninae* (seslerieto); 2) la vegetazione delle praterie chiuse climaciche a *Kobresia myosuroides* dell'alleanza *Oxytropido – Kobresion myosuroidis* (elineto), entrambe incluse nell'Habitat 6170 - "Praterie calcaree montane ed alpine" (Manuale di interpretazione degli habitat della Direttiva 92/43/CEE, 2013).
Sono stati rivisitati un totale di 25 rilievi fitosociologici, campionati per la prima volta con metodo random stratificato nel 2003, estratti dal Database Vegetazionale VIOLA (high mountain VegetatIon Of centraL Apennines, European Vegetation Archive code– EUIT-019) [5,6].
Al fine di determinare i cambiamenti temporali (T1: 2003 e T2: 2021) nella composizione floristica di queste due comunità le specie sono state divise in due gruppi usando l'indice ecologico di Temperatura (T) di Landolt: Alpine (T: 1 – 1,5) e Subalpine (T: 2 – 2,5). Mentre, le differenze temporali nella struttura della vegetazione sono state valutate attraverso le forme di crescita di Raunkier (1934). E' stata, quindi, effettuata un'analisi univariata, utilizzando il Kruskal-Wallis test for equal medians per determinare la presenza di differenze significative nella ricchezza specifica e nella copertura totale dei plot. Infine, sono stati analizzati i dati di temperatura del suolo dei data-logger della vetta GLORIA Global Observation Research Initiative in Alpine Environments) "IT CAM FEM" (2405 m a.s.l.), per valutare i cambiamenti della temperatura media annua ed autunnale nell'area di studio negli ultimi 20 anni.
I risultati hanno messo in evidenza una diminuzione significativa sia nella ricchezza che nella copertura totale delle specie per plot in entrambe le comunità analizzate. Nello specifico, per quanto riguarda il seslerieto si è osservata una diminuzione significativa delle specie alpine e delle specie afferenti alle forme di crescita delle Emicriptofite rosulate (e delle Emicriptofite scapose. Mentre, per quanto riguarda la comunità dell'elineto, si è osservata, al contrario, una diminuzione significativa delle specie subalpine e delle specie afferenti alle forme di crescita delle Camefite suffrutticose. Infine, i dati di temperatura dei data-logger di GLORIA hanno mostrato un aumento significativo della temperatura media annua negli ultimi vent'anni di 0,88°C e di quella autunnale di 1,29°C nell'area studio, suggerendo un aumento della durata della stagione vegetativa.

Tali risultati sono in controtendenza rispetto a quelli osservati nei gruppi montuosi non mediterranei [4,7] nei quali si è osservato principalmente un aumento nella ricchezza specifica e copertura della vegetazione dovuta ad un aumento delle specie termofile provenienti da piani bioclimatici inferiori, favorite dal cambiamento climatico. Inoltre, studi di re-visitation in altre comunità vegetali dell'Appennino centrale hanno evidenziato un aumento della copertura vegetazionale nelle ultime decadi [8,9,10,11].
La perdita di biodiversità e di copertura della vegetazione nelle praterie analizzate nel presente studio risultano simili a quanto recentemente osservato sulle vette calcaree mediterranee della Sierra Nevada [12] e di Creta [13], dove sono stati associati all'effetto combinato dell'aumento delle temperature e della diminuzione della piovosità. In Appennino centrale, infatti, è stata osservata e prevista una riduzione delle precipitazioni annue che si concentreranno nei periodi invernali con un conseguente aumento dello stress da aridità estiva [14,15].
Il seslerieto, che si sviluppa lungo i versanti calcarei acclivi, dove la ritenzione idrica dei suoli è bassa , risente probabilmente maggiormente della siccità, combinata all'allungamento della stagione vegetativa, e questo sta causando una perdita localedi biodiversità, anche tra specie endemiche e rare. E', quindi, importante continuare a monitorare questi ambienti dei versanti calcarei di alta quota, che sono risultati i più vulnerabili ai cambiamenti climatici in atto.

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Which ecological changes are induced by the invasion of the alien plant *Oenothera stucchii* in Adriatic coastal dunes vegetation?

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Invasive alien plants (IAPs) are considered to be the second major threat to biodiversity [1] and their negative impact on the integrity of plant communities and ecosystem has been observed and demonstrated worldwide [2,3]. IAPs increase the probability of unfavorable conservation status [4] and cause the loss of biodiversity and the alteration of species assemblage, and structural and functional features of native plant communities [2,5].
Coastal dunes ecosystems are widely colonized by IAPs and their invasion is promoted by the environmental heterogeneity and the high occurrence of anthropogenic pressures [6,7].
This study aims to find possible ecological changes in ecological guilds richness and cover due to the invasion of *Oenothera stucchii* in the native plant communities of Adriatic coastal dunes of Italy.
Vegetation sampling consisted of 63 pairs of invaded/not invaded plots by *O. stucchii* plants (1x1 and 2x2 m^2), randomly selected (paired plots), in foredune vegetation dominated by perennial plants and in transition dunes with herbaceous vegetation [8,9,10,11]. Invaded plots had a cover of *O. stucchii* at least 50% of the total plot vegetation cover [12]. During the period May-July 2021, for each plot, georeferenced by GPS, a complete list of vascular plants was compiled and species cover was visually estimated using the Braun-Blanquet seven-degree scale of abundance and dominance [13]. We classified the recorded species according to the following ecological guilds: diagnostic, generalist, alien plants and species of other habitats [8,14].
The statistical analysis was carried out using the PAST software 2022, version 4.09 [15].
The analysis of ecological guilds richness evidenced significant differences between invaded and non-invaded plots only for Northern Adriatic coast. The median richness of diagnostic species was significantly lower in invaded plots than in non-invaded plots instead IAPs richness (excluding *Oenothera*) was higher in invaded plots than in non-invaded ones.
The analysis of ecological guilds cover revealed that the median cover of diagnostic species in Central and Northern Adriatic coast was significantly lower in invaded plots than in the non-invaded ones. The cover of the species of other habitats was higher in invaded plots than non-invaded ones, only in Central Adriatic coast.
These results confirmed previous studies that showed how *O. stucchii* caused the decline of richness of focal species [16], the variation in plant community composition with alteration in native species abundance [17]. Additionally, the invasion of *O. stucchii* seemed to favor the entry of typical species of other habitats and IAPs into the invaded plots, leading natural ecosystems to a biotic homogenization [18].The loss of focal diagnostic species cover could hasten community degradation as detected in other studies carried out in coastal dune ecosystems [19, 20].

Therefore, detailed knowledge of plant invasion ecological processes can be very important to manage coastal dune habitats and plan effective restoration actions.

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