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HUMANITA

D2.2.1 Report on testing and data collection in

Significant landscape Lower Kamenjak and the Medulin Archipelago

Version 2

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Author: Barbara Floričić (PIK)

PILOT ACTIONS – TESTING PHASE

PROJECT PARTNER: Public Institution Kamenjak (PIK – PP9)

LOCATION: Significant landscape Lower Kamenjak and the Medulin Archipelago, Croatia

PILOT SITES: Significant landscape Lower Kamenjak and the Medulin Archipelago, Croatia

PILOT ACTIONS: This pilot action focuses on creating and evaluating innovative techniques to measure the impact of tourism on nature, enhancing understanding of tourism's effects on natural assets, and improving management strategies within the protected area. It includes pollution monitoring, wildlife monitoring, soil fragmentation monitoring, vegetation monitoring, and tourist flow monitoring, with strong community involvement and collaboration with partners.

VISITORS MONITORING

STARTING DATE

The project was contracted and initiated in July 2024 and was completed at the end of September 2024.

METHODOLOGY DESCRIPTION

Monitoring tourist flows involved significant Thirteen solar power plants were installed at three new locations, along with eight solar panels to upgrade the existing ones. The project included acquiring 10 cameras and a large LED display, which were rented and set up at the entrance. Furthermore, 10 smaller LED displays were purchased and installed in front of each zone. This initiative successfully implemented, monitored, tested, and improved methods for research and visitor management.

To evaluate visitor activity, a model was developed that integrates data from Strava Metro with other available datasets.

RESULTS AND OBSERVATIONS

The investment includes the following components:

- 10 cameras for site monitoring
- 13 solar power plants for three new locations, along with 8 solar panels to enhance the current eight solar power plants
- 10 small LED panels featuring two colors
- 1 large LED panel for rent
- Infrastructure works, including the installation of 3 pillars
- Provision of an internet connection and hotspot within the site
- Data is being collected in the Lower Kamenjak area on the number of vehicles daily, classified by vehicle types.

The installation of LED panels is designed to inform visitors about the availability of parking zones and to direct them accordingly. Additionally, cameras powered by solar panels will monitor vehicle entry and exit using laser technology, transmitting data to nearby small LED panels as well as a main LED panel located at the entrance (see Figure 1).

Figure 1. Installation of LED panels and solar-powered cameras at the entrance of the Lower Kamenjak area. The LED panels provide real-time information about parking zone availability, while the cameras monitor vehicle entry and exit using laser technology, ensuring efficient visitor management.

Infrastructure work includes the installation of three new pillars specifically for the cameras and solar panels, while existing pillars will be repurposed for the remainder of the setup. This system aims to enhance visitor experience and optimize parking management. A display indicating the occupancy of parking zones is installed before the main entrance to the area, showing whether a particular parking zone is available or not. Furthermore, in front of each parking zone, green/red signaling also indicates whether the spaces are available or occupied.

FUTURE DEVELOPMENTS

These investments aim to enhance monitoring capabilities and improve infrastructure at the designated location. In the upcoming months, we will continue to gather data on the performance of the new systems to better understand visitor behavior and dynamics within the park. Long-term data collection on visitor patterns is crucial for enhancing management strategies and ensuring the sustainability of tourism.

Strategic placement of cameras and effective monitoring protocols are crucial for maximizing data quality. We anticipate that the findings will benefit not only our project partners but also other conservation efforts. Regular maintenance and updates of the monitoring systems are recommended to ensure their effectiveness in guiding visitors and managing parking zones.

VEGETATION MONITORING

STARTING DATE

The monitoring started in June 2024.

METHODOLOGY DESCRIPTION

The monitoring aims to engage visitors in mapping the locations and abundance of invasive alien species along trails. The iNaturalist platform will be utilized, allowing visitors to input data on species names, locations, dates, abundance, and habitat descriptions. An equipment location map will be provided if available.

Data collection is based on visitor input on the platform and evaluation for accuracy and completeness.

RESULTS AND OBSERVATIONS

Our monitoring efforts in the Lower Kamenjak area have identified several significant invasive species: *Ailanthus altissima* (Tree of Heaven), *Aster squamatus*, *Carpobrotus acinaciformis*, *Conyza canadensis*, *Phyllostachys sp.*, and *Robinia pseudoacacia* (Black Locust), as depicted in Figure 2.

To date, we have recorded the presence of these species, which pose a threat to local biodiversity. Their rapid spread displaces native plants, alters natural habitats, and reduces biodiversity, leading to detrimental effects on ecosystem processes.

We encourage participation in our monitoring efforts. By using the iNaturalist app, users can report occurrences of invasive species, contributing to a growing database. Currently, there are 47 observations (Figure 3) of invasive species reported by community members in our project “Alien and Invasive Alien Species on Lower Kamenjak.” Since launching this initiative, we have observed an increase in engagement, underscoring the significance of community involvement in participatory monitoring activities.

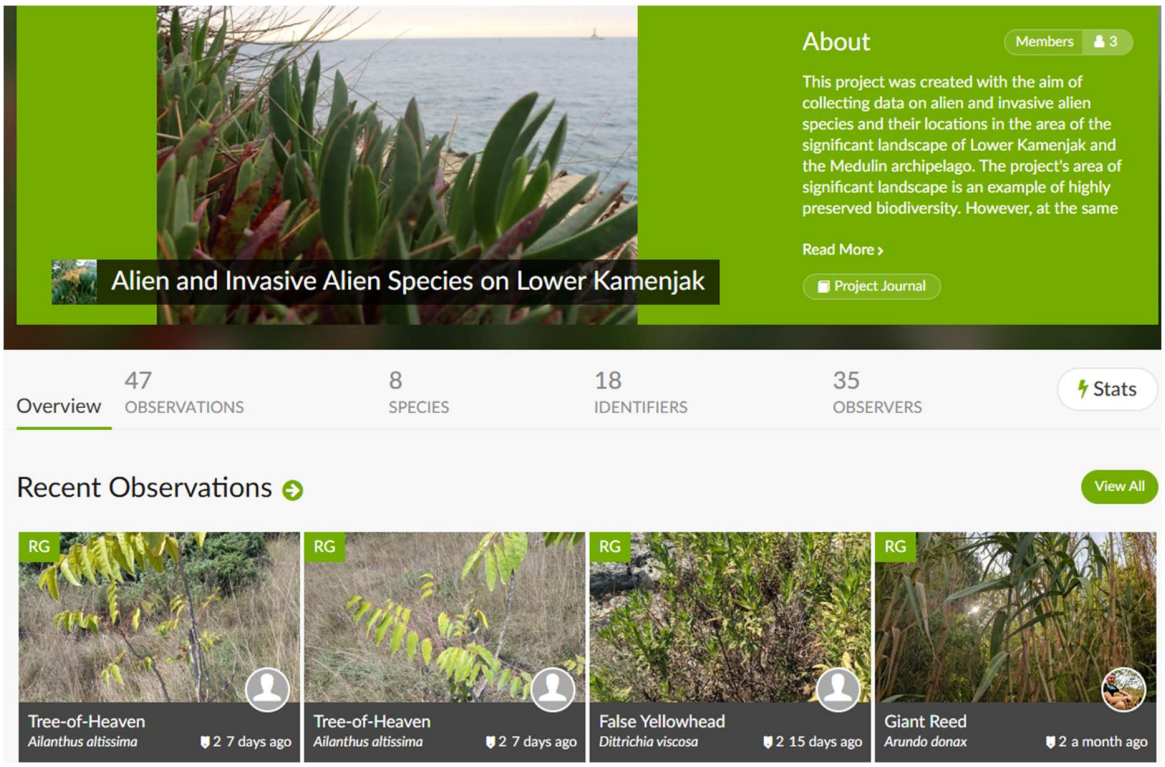

Figure 2. Photos of plants observed by iNaturalist observers

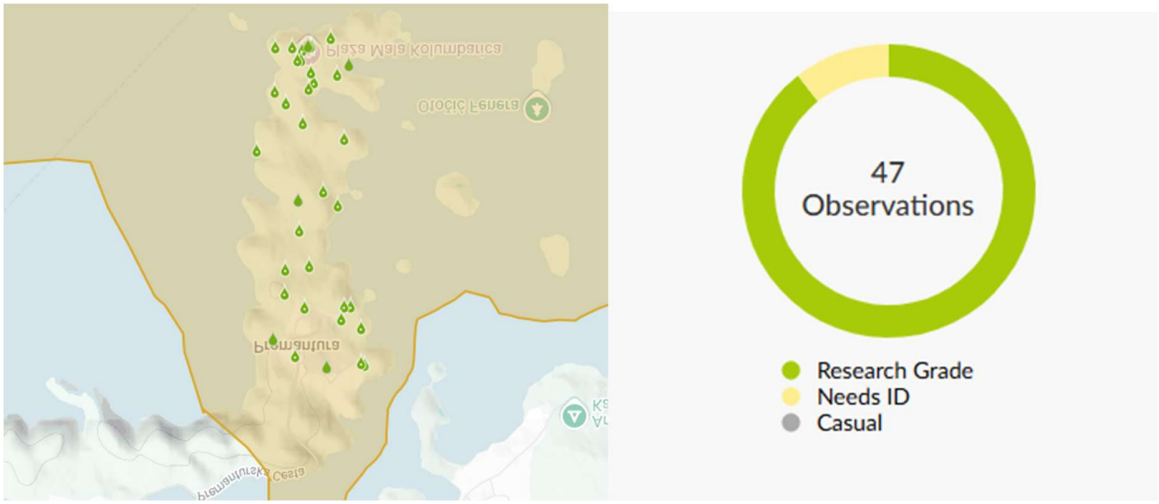

Figure 3. Map of iNaturalist observations in Significant landscape Lower Kamenjak and the Medulin Archipelago

Leaflets about alien and invasive alien species in the Lower Kamenjak area are printed in four languages (in German, English, Italian, and Croatian), along with a digital version (see Figure 4), and distributed to visitors.

Figure 4. Leaflets on alien and invasive alien species in the Lower Kamenjak area

FUTURE DEVELOPMENTS

Future plans will include expanding the outreach to attract more participants and enhancing data collection methods. Recommendations will focus on providing additional training for participants and promoting ongoing engagement in conservation efforts.

WILDLIFE MONITORING

STARTING DATE

The monitoring activity in the field began in 2020, focusing on the presence of earthworm species in the Significant Landscape Lower Kamenjak area.

METHODOLOGY DESCRIPTION

The primary aim of this monitoring is to assess the biodiversity of earthworms, particularly the newly identified species *Octodrilus istrianus*, and to evaluate the ecological health of the habitat in Significant Landscape Lower Kamenjak with a special focus on the impacts of microplastics in the soil. The monitoring utilized a combination of soil sampling tools and molecular identification methods.

- Data Collection and Evaluation:

Data were collected through systematic sampling across different habitats at Lower Kamenjak in the spring 2024. Soil samples were collected from 50 sites, in a total of 150 samples, with precise GPS coordinates recorded. Following collection, samples were dried and treated with 30% hydrogen peroxide to eliminate organic matter. Microplastics were isolated using flotation in a 5M zinc chloride solution, then filtered and stained with Nile Red for enhanced visibility (Figure 5). High-resolution images of the samples were analyzed using ImageJ software to quantify the microplastic particles, providing insights into their distribution and environmental impact. Laboratory analysis confirmed species identification and assessed the ecological parameters of the soil.

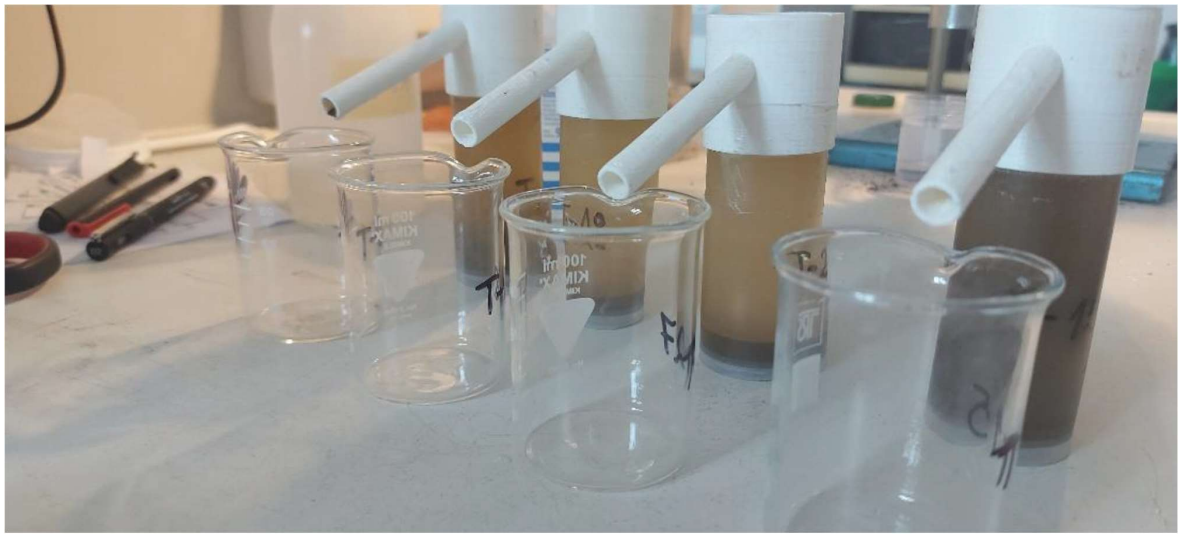

Figure 5. Extraction of microplastic particles through flotation with $ZnCl_2$ (Photo: Lorena Galzina).

- Equipment Location Map:

Using QGIS software, detailed maps were created to show the spatial distribution of earthworms and microplastic particles in the study area (see images in the following chapter). Various layers were utilized, including CORINE Land Cover for detailed land use information and habitat maps providing precise data on species and habitat types present. This combination allowed for accurate representations of distribution, enhancing the understanding of the relationship between earthworms and microplastics across different habitat types.

RESULTS AND OBSERVATIONS

Initial findings confirmed the presence of five earthworm species, notably the significant detection of *Octodrilus bretscheri/kvarnerus* and *O. istrianus*, as detailed in Table 1. with a single species dominated most samples, consistent with ecological expectations for the habitat. Only one sample contained three species: *Aporrectodea rosea*, *Octodrilus bretscheri/kvarnerus*, and *Octodrilus istrianus*, recorded in a low-vegetation habitat.

Table 1. Species Sampled in the Lower Kamenjak Area

Species	Frequency in Samples (%)
Aporrectodea rosea (Savigny, 1826)	2.17
Aporrectodea trapezoides (Dugès, 1828)	2.17
Murchieona minuscula (Rosa, 1905)	2.17
Octodrilus istrianus Mršić, 1991	19.57
Octodrilus kvarnerus Mršić, 1987 (*O. bretscheri*)	73.91

- First Evaluation, Results, and Findings:

  The diversity of earthworm species reflects the rich biodiversity of the area, which is influenced by its unique dry limestone grassland ecosystems. However, vegetation succession due to changes in land use is observed, threatening these habitats.

- Problems and Obstacles:

  Challenges encountered included difficult terrain outside of established paths, leading to access issues, as well as the impact of increased tourism and vegetation changes on sampling locations. Further studies are needed to explore its unique genetic characteristics and potential implications for biodiversity in the Kamenjak area.

FUTURE DEVELOPMENTS

Continued monitoring is planned to assess changes in species diversity over time, particularly concerning environmental pressures such as tourism and land use changes.

For future research, it is essential to expand scientific studies on earthworm populations and their ecological roles to better understand the threats they face and their dynamics. Establishing a systematic monitoring program for *Octodrilus istrianus* and other soil organisms will be crucial for tracking their status and assessing the effectiveness of conservation measures.

It is recommended to integrate earthworms into conservation policies, emphasizing their importance for soil health and ecosystem services. Implementing strategies such as low-intensity grazing and managing wild boar populations can significantly contribute to the preservation of earthworm habitats. Additionally, developing sustainable tourism practices, including marked trails and educational signage, is vital to mitigate negative impacts on soil ecosystems. Through awareness-raising programs and the creation of educational materials, visitors will be informed about the importance of soil biodiversity and the role of earthworms, fostering a stronger commitment to the conservation of this unique ecosystem.

EROSION MONITORING

STARTING DATE

The monitoring started in September 2023

METHODOLOGY DESCRIPTION

The primary objective of this monitoring effort is to identify critical areas of trail formation and soil fragmentation in protected dry grasslands (Figure 7), intending to prevent the emergence of new “wild” trails. Key activities include a low-altitude UAV survey utilizing photogrammetric and LiDAR sensors across five selected areas, combined with a ground-based photogrammetric survey of a forest trail near the entrance, and the transfer of knowledge regarding drone operation and route setup.
The UAV-based erosion monitoring approaches were implemented at the Significant Landscape Lower Kamenjak to assess the development of 'wild' paths within the pilot site. Multiple UAV-based photogrammetric surveys conducted during the summer of 2023 resulted in a complete orthophoto of the entire pilot area (Figure 6).

***Figure 6**. UAV-based photogrammetric survey of Nature Park Kamenjak*

RESULTS AND OBSERVATIONS

A drone survey in the area of Lower Kamenjak was started in September 2023 by UNIPR and UNIZA, providing a solid foundation for future monitoring efforts.

Second monitoring was carried out in May 2024 by UNIPR during their second work visit. The second drone survey focused on dry grasslands and encompassed the entire area, utilizing a 360° camera for an in-depth examination of the educational path. In May 2025, the third drone survey was carried out by PIK.

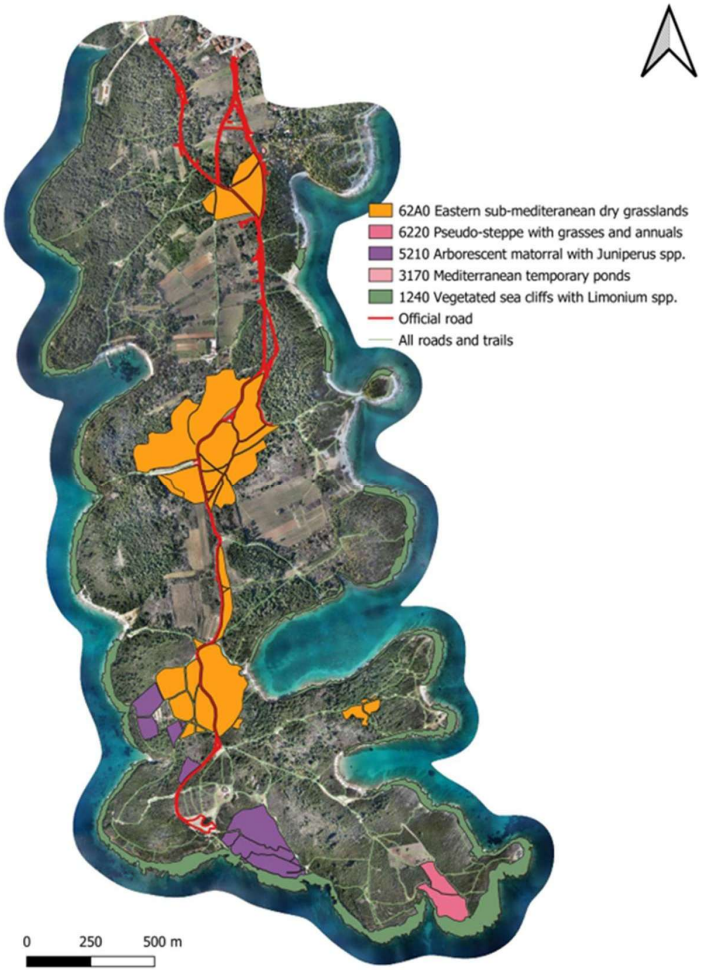

Figure 7. Drone survey of dry grasslands and the entire area

FUTURE DEVELOPMENTS

Critical areas of trail creation and soil fragmentation will be identified to prevent the formation of new "wild" trails. During the surveys, semi-automatic detection methods will be tested. LiDAR UAV and ground-based techniques will be utilized in LP1, while photogrammetric UAV and ground-based methods will be employed in PP3. Soil loss will be evaluated by comparing data from multiple scans in both LP1 and PP3. Drone monitoring of protected grasslands will continue in order to track their condition, and the monitoring will also be extended to other parts of the area to observe the situation on the ground.

POLLUTION MONITORING

This report summarizes the ongoing efforts to monitor pollution levels of microplastics and macroplastics in the Lower Kamenjak area. Two distinct forms of pollution monitoring are being implemented:

Microplastic Pollution Monitoring and Macroplastic Pollution Monitoring.

STARTING DATE

- Microplastic Pollution Monitoring:

  04/2024

- Macroplastic Pollution Monitoring:

  04/2024

METHODOLOGY DESCRIPTION

The Public Institution Kamenjak will engage experts from the Center for Marine Research at the Ruđer Bošković Institute to collect macroplastics on selected beaches to monitor pollution in coastal areas within the Significant Landscape of Lower Kamenjak. Monitoring soil composition will help reveal microplastic pollution in soils near 10 parking zones. Additionally, the impact of microplastics on the distribution of earthworms will be analyzed by experts from the University of J.J. Strossmayer in Osijek.

- Microplastic Pollution Monitoring:

This involves assessing soil contamination with microplastics and investigating their impact on earthworm distribution. Aim of monitoring is to assess the quantity of microplastic particles in the Lower Kamenjak area. Samples were collected in triplicate from 50 different locations to ensure data representativeness. The collected samples were analyzed for the presence and quantity of microplastic particles.

- Macroplastic Pollution Monitoring:

This focuses on the analysis of litter pollution on beaches, specifically at the island of Ceja and the bays of Školjić and Polje (Figure 8). The methodology aligns with the standards set by the Interreg Med Plastic Busters MPAs project, measuring litter density as the number of items per 100-meter stretch.

Surveys were planned to occur at least four times a year during optimal periods in January, April, July, and October.

Figure 8. The sampling location for microplastics is highlighted in the image, indicating where data collection will take place.

RESULTS AND OBSERVATIONS

- **Microplastic Pollution Monitoring:**

The assessment of microplastic particle concentrations in the Lower Kamenjak area involved the successful extraction of microplastic particles from a total of 150 soil samples, providing crucial insights into the level of microplastic pollution in Kamenjak. Samples were collected in triplicate from 50 different locations, ensuring data representativeness and precision in analyzing the spatial distribution of microplastics across the area (Figure 9).

Figure 9. Collecting soil samples by External Expert - University of Osijek/Dept. of Biology Method

Filtered samples reveal the presence of fluorescent microplastics, highlighting the pollution issue visually. The results indicated a wide variability in microplastic concentrations, ranging from 0 to as high as 14,800 particles per kilogram of dry soil, with an average of 2,460 particles. This significant presence underscores the environmental burden within the Lower Kamenjak ecosystem.

The distribution of microplastic particles (N/kg) shows that areas near popular trails, main roads, and tourist zones tended to have higher concentrations (see Figure 10). However, the data exhibited inconsistencies across locations, likely due to varying land types, local topography, wind impact, erosion, and seasonal human activities.

Figure 10. Distribution of microplastic particles (N/kg) across Lower Kamenjak. The number of particles is divided into quartiles.

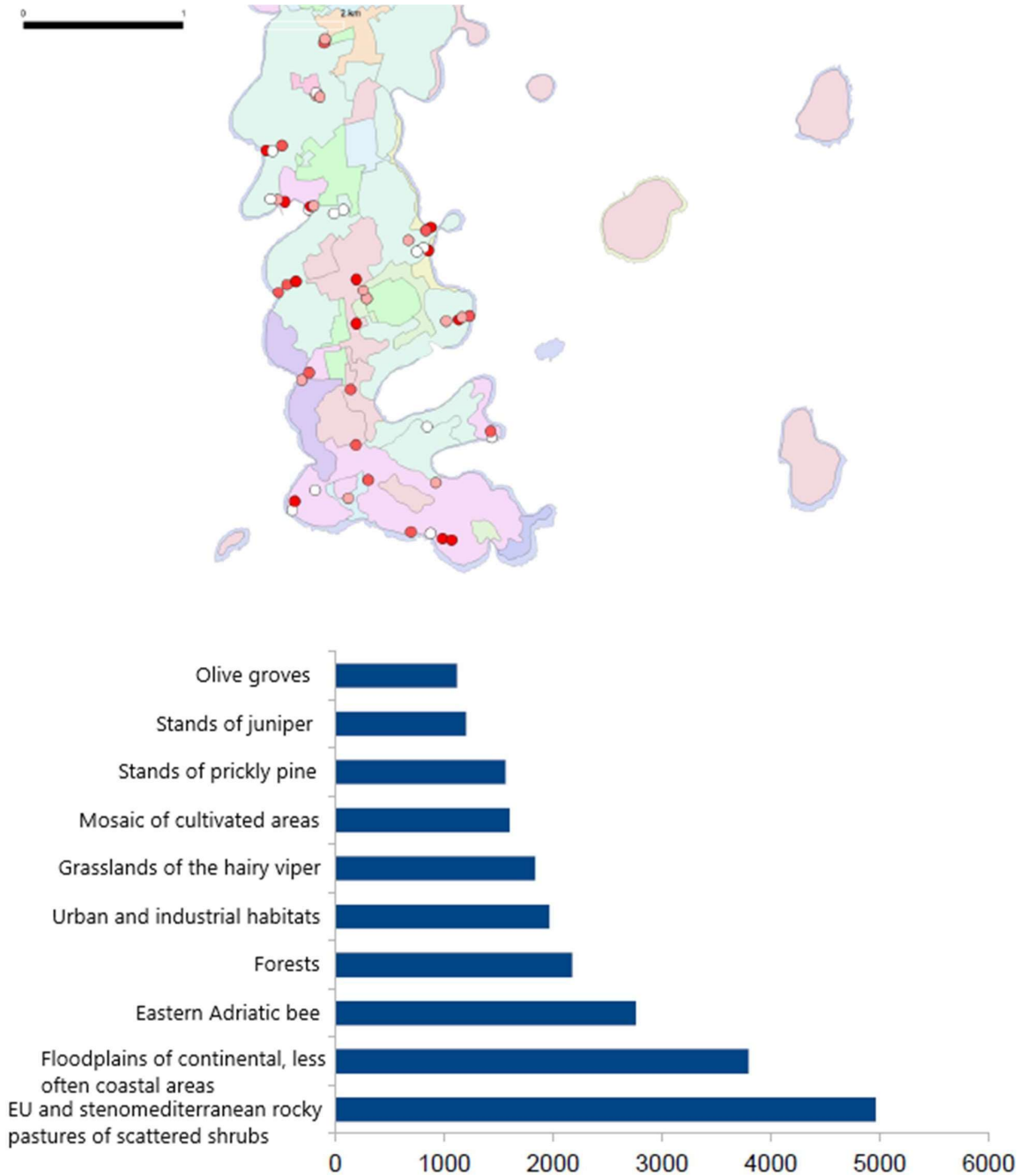

Figure 11. Distribution of microplastic particles by habitat type.

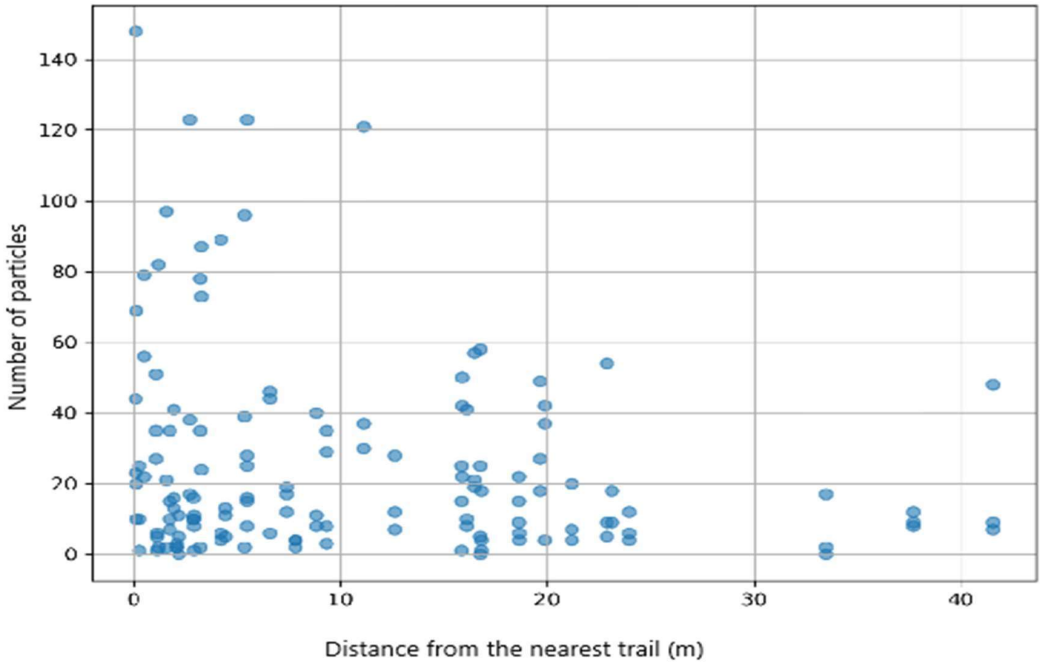

Figure 12. Relationship between microplastic concentration and distance from trails.

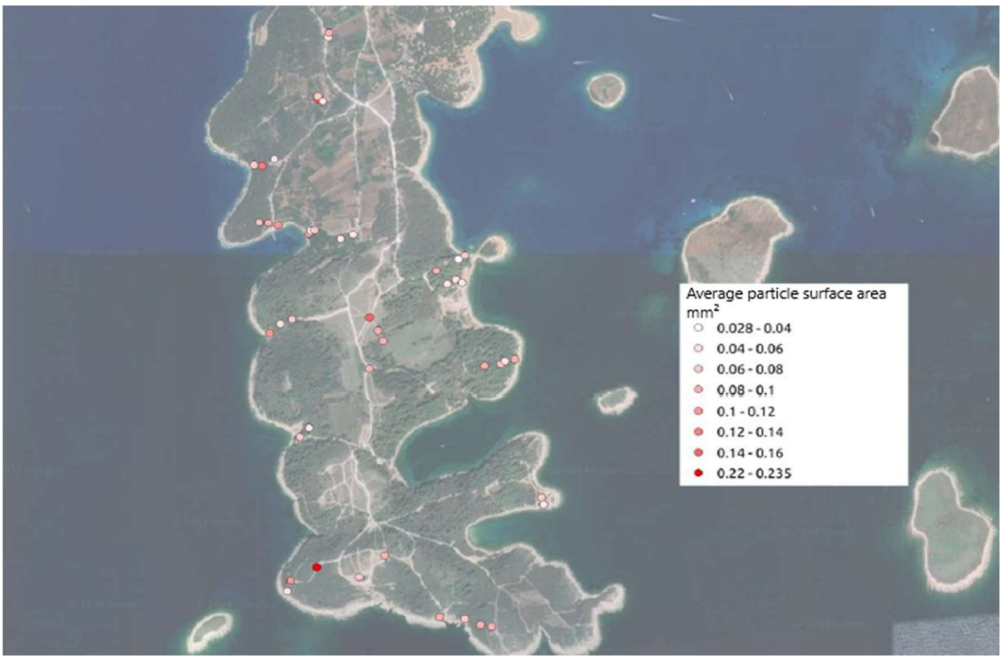

Figure 13. Spatial distribution of microplastic particle sizes.

Interestingly, microplastics were also found in relatively isolated locations not directly exposed to human activities, suggesting that these particles can be transported through wind, rain, or waterways. This complexity indicates a pressing need for further research to understand the mechanisms behind the transport and accumulation of microplastics in this region's soil.

Analysis of microplastic distribution by habitat type indicates that the highest concentrations were found in Euro-Mediterranean rocky pastures, averaging 4,966.66 particles per kilogram, while olive groves showed the lowest average concentration at 1,116.66 particles per kilogram (Figure 11). These differences can be attributed to land use, environmental exposure, and varying degrees of human activities.

Comparing microplastic levels in Lower Kamenjak to other European regions poses challenges due to a lack of standardized methodologies for extraction and quantification. Various extraction methods can significantly affect results, complicating direct comparisons between studies.

The relationship between microplastic concentrations and proximity to trails reveals that samples closest to trails contained the highest particle counts, while those further away showed reduced numbers (Figure 12). Each microplastic particle was measured for average surface area, ranging from 0.028 to 0.235 mm^2, with the spatial distribution of particle sizes indicating further complexities in understanding microplastic pollution (Figure 13).

The study emphasizes the ecological burden of microplastics in the protected Lower Kamenjak area, highlighting the need for measures to reduce their introduction and spread in the environment. Long-term data will be crucial for developing conservation strategies, educating the local population and visitors, and promoting sustainable management practices to preserve this unique Mediterranean ecosystem.

In conclusion, this study highlights the ecological burden of microplastics in Lower Kamenjak and emphasizes the need for further research into transport mechanisms and contamination sources. Higher concentrations near popular trails and tourist zones were observed, but isolated areas also contained microplastics, suggesting transport by wind or water. Standardizing extraction methods is crucial for better comparability across regions. These findings support the development of conservation strategies and public education initiatives to address microplastic pollution in this unique ecosystem.

- **Macroplastic Pollution Monitoring:**

Stranded litter on three selected beaches was monitored throughout all seasons by an external expert from the Center for Marine Research Rovinj, Ruđer Bošković Institute, following national and MSFD Descriptor 10 methodologies. All litter items larger than 2.5 cm were collected along the full length of the beaches and categorized into eight main groups (plastic, rubber, cloth, paper, processed wood, metal, glass, and other) across 291 item types. Table 2 shows the composition of the collected litter by category and proportion. The weight of litter in each category was recorded, and all collected litter was properly disposed of. Selected groups with more than 20 items per sampling (10 random items per category) were further analyzed for material composition using an Agilent 4500 Series Portable FTIR Spectrometer. Material analysis was conducted on a total of 690 items from the study, divided into individual groups. The most common material was xylon and olefin fibers (17.10%) (Table 3). Xylon and olefin fibers refer to types of fibers commonly used in the textile and other industries.

Table 2: Most Common Waste Categories Found in Beache Litter

Waste Category	Share
Plastic	85 ± 8%
Rubber	1 ± 1%
Textile	2 ± 2%
Paper	2 ± 3%
Wood	4 ± 4%
Metal	3 ± 3%
Glass	2 ± 1%
Other	0%

Table 3. Most common materials of items stranded on the beaches of the Kamenjak significant landscape area

MATERIJAL	%
XYLON, OLEFIN FIBER	17.10%
AMACO OLEFIN, OLEFIN FIBER	7.10%
STYRENEETHYLENE/ BUTYLENESTYRENE BLOCK COPOLYMER USED FOR ROLLER SKATE BREAK	5.80%
POLYETHYLENE PLASTICIZED #2	4.93%
POLYPROPYLENE	4.78%
POLYPROPYLENE, OLEFIN FIBER	3.77%
Linear Low Density Polyethylene film	3.33%
Polyolefin foam (high resilience, high flexibility, high grip)	2.32%
MS2A-RESIN	2.32%
CP 310 W (DRIED)	2.03%
HIGHLY FILLED AND SOFTENED COPOLYMER USED FOR BEACH SHOE FROM CHINA LOT#2	2.03%

FUTURE DEVELOPMENTS

- **Microplastic Pollution Monitoring:**

The following steps should be done next:

- Implement measures to reduce microplastic input into the environment.
- Enhance public awareness regarding microplastic pollution.
- Foster interdisciplinary collaboration to deepen understanding of microplastic effects on ecosystem health.

- **Macroplastic Pollution Monitoring:**

After analyzing the collected data, the following most appropriate measures for reducing pollution were recommended:

- "Adopt a Beach" – This measure is designed to encourage volunteers to 'adopt' beaches, clean them, and monitor them regularly throughout the year, thereby collecting valuable data on marine litter.
- Ban single-use items.
- Establish a network of waste collection and recycling points.

Continuous monitoring will be crucial for assessing the long-term impacts on local ecosystems and informing mitigation strategies.