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HUMANITA

Monitoring **Tourism Impacts in Conservation Areas**

Catalogue and Toolbox of Practical Monitoring Methods

Impressum

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Foreword

Conservation areas are increasingly expected to fulfil multiple roles. They safeguard biodiversity and ecosystem functions while also providing opportunities for recreation, tourism, and regional development. As visitor numbers grow and recreational activities diversify, conservation area managers are faced with the **challenge of balancing public access with the protection of sensitive natural environments.**

Understanding how tourism activities affect ecosystems is an essential first step toward effective management. Reliable information on visitor behaviour, environmental pressures, and ecological change allows managers to identify emerging problems, evaluate management measures, and make well-informed decisions. However, selecting suitable monitoring methods can be challenging, particularly when resources, time, and technical expertise are limited.

This catalogue was developed within **the Interreg CENTRAL EUROPE (CE) project HUMANITA** to support conservation area managers in addressing these challenges. It brings together a **selection of innovative and practical monitoring approaches** that help assess the environmental impacts of tourism in protected areas. The presented solutions have been tested in pilot areas across Central Europe and cover a wide range of monitoring needs, including **visitor monitoring, trail and erosion monitoring, wildlife health monitoring, and pollution monitoring.**

To complement the catalogue, the **HUMANITA** partnership developed a **Monitoring Tool-Box**, which provides descriptions of **22 feasible monitoring methods and instruments** suitable for **short and mid-term environmental monitoring.** The toolbox is integrated into an online demonstrator application that allows users to explore monitoring tools through thematic and keyword-based searches and **supports the development of monitoring programmes using the IUCN Monitoring Global Guideline (MoniGloG).**

The aim of this catalogue and toolbox is to provide **practical guidance and inspiration for conservation area managers** who wish to strengthen their monitoring activities. By making existing tools more accessible and easier to navigate, the **HUMANITA** project hopes to support the development of **evidence-based monitoring programmes** that help detect environmental changes, understand the impacts of tourism, and guide adaptive management.

We invite **conservation managers, practitioners, and stakeholders to explore the monitoring approaches** presented here and to use the toolbox as a starting point for developing monitoring programmes tailored to their own protected areas. Strengthening monitoring capacity is a key step toward ensuring that protected areas remain resilient landscapes where nature conservation and sustainable visitor use can coexist in the long term.

Catalogue of monitoring methods

The following **pages** present a selection of **eight monitoring methods** that were developed and tested within the Interreg CE project **HUMANITA** to better understand the environmental impacts of tourism in **conservation** areas. The **methods cover different monitoring objectives and spatial scales,** ranging from **visitor monitoring** and analysis of recreational activity patterns to the assessment of ecological pressures such as **trail erosion, wildlife health, and environmental pollution.** Together, they illustrate how modern technologies, digital data sources, and field-based ecological methods can complement each other to provide a more comprehensive picture of how tourist activities interact with natural systems.

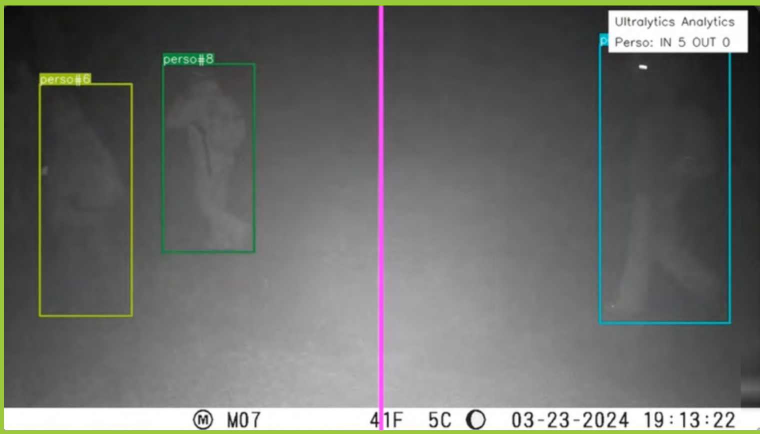
Each method is described in a concise and practical format to support conservation area managers in evaluating its applicability for their own monitoring programmes. The descriptions include a **short overview of the method,** its **potential applications, key requirements** for implementation, possible **constraints,** and **considerations regarding environmental impact.** Monitoring activities performed during the **HUMANITA** project are presented as **best practice** examples. The aim is to provide a clear orientation and practical entry point for managers and practitioners who wish to explore suitable monitoring approaches and integrate them into their site-specific monitoring strategies.

Visitor monitoring

AI-based visitor counting from photo and video data (small scale)

Use of AI-based image and video analysis software to automatically detect and count visitors from camera data, supporting **continuous and non-intrusive monitoring of visitor numbers and flows** in conservation areas.

AI-based software for photo and video analysis uses computer vision and machine learning algorithms to automatically detect, classify, and count visitors captured by fixed or mobile cameras installed along trails or access points. In addition to **pedestrian** counting, the technique can identify and distinguish **different types of vehicles** (e.g. bicycles, cars, other motorized or non-motorized vehicles), supporting a more detailed characterization of visitor flows and modes of access in conservation areas.



Best practices

Within the Interreg Central Europe project **HUMANITA**, AI-based image analysis was tested to automatically detect and count visitors from camera data. The implemented configuration combined a **YOLOv11-based object detection model for identifying and classifying visitors and vehicles** with a custom algorithm that established a virtual "gate" within the camera's field of view. Objects crossing this predefined line were automatically counted, allowing for the estimation of visitor flows along trails or access points.

The approach can be adapted to different monitoring objectives by selecting appropriate image formats (photo or video) and by training or adjusting detection models according to specific environmental conditions or target objects.

Requirements

- Fixed or mobile cameras with suitable resolution and field of view
- AI software trained or configurable for outdoor and natural environments
- Computing infrastructure for data processing (local or cloud-based)

Constraints

- Requires advanced technical expertise for system setup, model configuration, training, and result interpretation
- Performance depends on image quality, lighting conditions, and camera positioning
- Large amount of collected data, requiring adequate memory storage and/or data retrieval options
- Potential biases related to algorithm training data (e.g. vehicles recognition)
- Privacy and data protection constraints may limit deployment and data storage

Pointers

- Carefully plan camera placement to ensure adequate coverage while minimizing the capture of identifiable personal features. Related to this, consider the implementation of additional algorithms to anonymize the subjects (e.g., pixelation)
- Verify in advance which elements the AI model is able to recognize and classify (e.g. pedestrians, bicycles, cars, other vehicles) and assess their relevance for monitoring objectives.
- Pay particular attention to data retrieval and management, considering automated data transfer solutions due to the large volume of photo and video data collected. For the same reason, especially in case of camera traps usage, verify the possibility of adapting the quality and duration of the acquisition process to optimize the tool efficiency.

Tool Impact

AI-based photo and video analysis may raise privacy concerns related to the recording of visitors, even when data are anonymized or processed automatically. The installation and maintenance of cameras can cause localized disturbance to vegetation and fauna, particularly if repeated site visits are required.

Visitor monitoring

Outdoor and Fitness App Data Analysis (large scale)

Analysis of outdoor and fitness app data (e.g. **GPX** tracks and **metadata**) to identify spatial patterns of recreational activities and estimate the relative use of trails in protected areas.

Digital platforms for outdoor activities **provide valuable data sources for understanding visitor behavior** in protected areas. Many outdoor apps allow users to upload and share tour suggestions, GPS tracks (.gpx files), points of interest, and other **user-generated content.** These tours may be uploaded by official tourism organizations, Alpine associations, protected area administrations, or individual community users. Some platforms also generate route suggestions automatically based on algorithms.

By collecting and analyzing this information, protected area managers can gain insights into the **spatial distribution of promoted routes and recreational activities.** GPX tracks and tour descriptions can be downloaded and integrated into a GIS environment, where they can be analyzed in relation to existing trail networks. By counting and mapping the number of promoted tours along individual trail segments, managers can identify **digital hotspots of recreational activity** and estimate the relative use of different routes.

In addition to route data, many platforms provide metadata such as page views, downloads, user ratings, or the number of times a tour has been used. These indicators can be combined and weighted to estimate the relative popularity of specific routes.

A complementary data source is **Strava Metro**, a data service based on anonymized and **aggregated GPS activity data** recorded by users of the Strava fitness app. Strava users track activities such as walking, running, cycling, or hiking via GPS-enabled devices. Strava Metro aggregates these activities into datasets and heatmaps that **reveal movement patterns, route usage frequency, seasonal variations, and types of activities**. For protected areas, this information can help identify frequently used trails, detect emerging routes or unofficial paths, and analyze temporal patterns of recreational use.

Together, outdoor app data and Strava Metro datasets provide valuable insights into visitor flows and spatial patterns of recreation. When used in combination with traditional monitoring tools such as visitor counters or surveys, these digital data sources can **support evidence-based visitor management and infrastructure planning.**

Best practices

Within the Interreg CE project **HUMANITA**, data from several outdoor and fitness apps (including **Bergfex, Komoot, Outdooractive, Trailforks,** and **Strava**) were analyzed to identify spatial hotspots and low-use areas in pilot regions. Tour data from the platforms were systematically collected and integrated into a GIS environment. This approach enables conservation area managers to detect frequently promoted routes, identify unofficial activities, and **assess potential areas of visitor pressure or emerging recreational trends.**

Requirements

- Access to outdoor app data or partnership with data providers (e.g. Strava Metro)
- GIS software for spatial analysis and data integration
- Optional use of built-in dashboards provided by some platforms
- Awareness of sampling biases and clear communication of uncertainties
- Privacy-compliant data handling
- Comparison with additional monitoring data sources recommended

Constraints

- User base is not representative of the overall visitor population (e.g. often younger, male, and sport-oriented users).
- Certain activities may be overrepresented (e.g. cycling or running), while others such as leisure walking or short excursions may be underrepresented.
- Frequently used sport-oriented routes may appear more prominently than short tourist trails or viewpoints.
- Only a fraction of total visitor activity is captured, limited to users actively recording or sharing their activities.
- Data resolution may be limited due to privacy regulations; small activity counts are often aggregated or not displayed.
- Access to certain datasets (e.g. Strava Metro) requires partnerships or institutional agreements.
- The method should be used as a complementary monitoring approach and not replace traditional visitor monitoring tools.

Pointers

To estimate the relative use of trails, a **"Tour Score"** can be calculated using weighted metadata indicators available on different platforms. This score allows the comparison of routes based on their digital popularity.

Example weighting schemes used in **HUMANITA** project:

Outdooractive
Tour Score (PVV) =

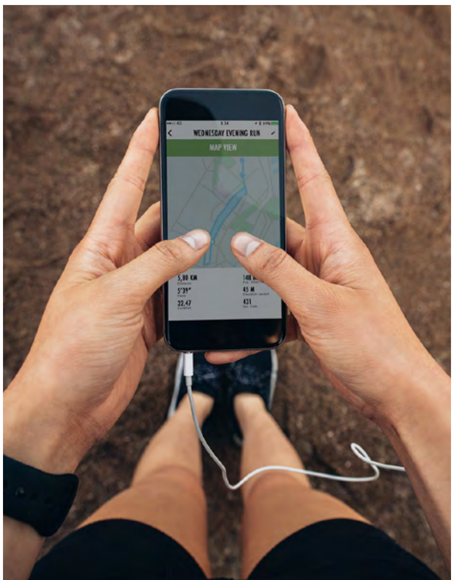
- 0.17 × normalized page views per day
- 0.45 × normalized printouts and downloads per day
- 0.35 × normalized actions per day
- 0.03 × normalized teasers per day

Komoot
Tour Score =

- 0.60 × normalized used by
- 0.15 × normalized rating
- 0.15 × normalized number of ratings
- 0.10 × normalized actuality

Tool Impact

Although the analysis itself has no direct environmental impact, publicly shared route information on outdoor platforms can unintentionally promote visits to sensitive areas or unofficial trails. Community-generated content may highlight routes that pass through protected zones, potentially increasing disturbance to wildlife or pressure on fragile habitats. Some protected areas therefore actively monitor and manage digital content on these platforms and employ "digital rangers" to inform users about restrictions or sensitive zones.



Erosion monitoring

Backpack 360° panoramic camera for erosion monitoring (small scale)

Mobile **ground-based spherical imaging** performed with a 360 photogrammetric sensor carried by an operator along a selected trail to map the terrain.

Terrestrial spherical photogrammetry relies on 360 cameras operated from the ground **to acquire immersive imagery along trail corridors**. The method is particularly suitable for **areas with dense vegetation** where aerial photogrammetry or satellite imagery is ineffective. Images can be processed to extract geometric information, trail width and structure, vegetation conditions, and obstacles, providing a detailed and repeatable record of trail morphology and use conditions.

Best practices

Bruno, N., Valletta, A., Segalini, A., and Roncella, R. (2024.: *Low-cost techniques for soil erosion monitoring on mountain trails*. Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci., XLVIII-2/W8-2024, 53–60, https://doi.org/10.5194/isprs-archives-XLVIII-2-W8-2024-53-2024.

This study, developed within the Interreg CE project **HUMANITA**, explores **cost-effective geomatics techniques for monitoring soil erosion on mountain trails**. Among the tested approaches, ground-based spherical photogrammetry using 360 cameras proved particularly suitable for surveying narrow, vegetated trails where aerial methods are limited. The research demonstrates how portable and relatively low-cost monitoring technologies can provide detailed and repeatable data to **support erosion assessment and sustainable trail managemen**t in conservation areas.

Requirements

- 360 camera with sufficient image quality and GNSS receiver
- Appropriate support to carry the equipment (i.e., backpack)
- Software for spherical image processing

Constraints

- Limited spatial coverage compared to aerial methods
- Accuracy depends on camera positioning and operator movement
- Requires post-processing workflows that are still semi-standardized

Pointers

- Operators should adapt their walking pace to the image capture rate of the panoramic camera to ensure uniform spatial coverage and consistent data quality.
- Adjust camera parameters, such as shutter speed, according to the technical characteristics of the device and the desired area coverage and image clarity.
- Verify the availability of suitable mounting or carrying systems for transporting the panoramic camera during field surveys. Depending on the camera size, weight, and stabilization requirements, it may be necessary to design or adopt custom-made supports (e.g., modified backpack) to ensure safe handling and consistent data acquisition.

Tool Impact

Terrestrial spherical photogrammetry has a very low direct impact on surrounding ecosystems, as data acquisition is carried out by operators moving along existing trails. Physical disturbance to vegetation and soil is minimal and comparable to standard ranger or monitoring activities.

Erosion monitoring

UAV-based photogrammetry (large scale)

Aerial photogrammetric survey aimed at determining **soil erosion on existing trails** and identifying **unofficial paths** due to trampling.

Drone-based photogrammetry uses Unmanned Aerial Systems (UAS) equipped with high-resolution cameras to **generate orthophotos and 3D surface models** (DSM/DTM) of trail networks and surrounding terrain. In protected areas, this technique allows the **quantification of soil erosion processes, detection of trail widening, incision,** and the **identification of informal or newly created paths** not included in official trail inventories. Repeated surveys enable change detection over time, supporting impact assessment of visitor pressure and the evaluation of mitigation measures.

Best practices

Within the Interreg CE project HUMANITA, UAV-based photogrammetry was applied to document and monitor erosion processes in selected pilot areas. At the Kamenjak pilot site (Croatia), the University of Parma implemented a monitoring program to detect the formation of informal (wild) trails and soil fragmentation in protected dry grasslands.

Repeated UAV surveys will enable the identification and spatial documentation of emerging paths and progressive surface degradation. The generated orthophotos and 3D surface models provide a detailed basis for assessing the development and expansion of wild trails over time, supporting targeted management interventions and conservation planning.

Requirements

- Licensed drone pilot and authorization from authorities
- UAS platform with sufficient spatial resolution and flight stability
- Ground control points or RTK positioning for accurate georeferencing
- Photogrammetric processing software and trained personnel
- Data storage and backup capacity for large datasets

Constraints

- Legal and administrative restrictions on drone flights in protected areas
- Weather dependency (wind, rain, low light conditions)
- Limited effectiveness under dense canopy cover
- Need for ground control points to achieve high positional accuracy
- Data processing can be time-consuming and computationally demanding

Pointers

- It is strongly advised to create a flight plan for the area of interest to use it for multiple surveys in the same area to ensure consistent data acquisition across monitoring campaigns.
- Depending on the specific objective of the monitoring activity, the flight altitude can be adapted to survey wide areas (more indicated for heavy erosion processes and trampling detection) or focused on a linear trail.
- If high accuracy is required, consider the integration of a GNSS receiver on the UAS, and the use of a RTK antenna to improve the survey reliability.
- If the area of interest is densely vegetated (e.g., survey of a trail under trees canopy), verify the presence of proximity sensors on the UAS and set them accordingly to avoid crashes when flying through narrow paths.

Tool Impact

Drone-based photogrammetry can cause temporary disturbance to wildlife, particularly birds and other fauna sensitive to noise and aerial presence. Repeated flights or operations during sensitive periods (e.g. breeding or nesting seasons) may increase stress or avoidance behavior in affected species. Inappropriate flight planning may also increase disturbance over areas outside the intended monitoring targets.

Erosion monitoring

Backpack LiDAR scanner for erosion monitoring (small scale)

Mobile ground-based LiDAR system for high-resolution 3D mapping of terrain and small-scale surface changes.

Backpack LiDAR technology is a mobile, ground-based remote sensing system designed for **high-resolution mapping of terrain and surface features.** The system integrates a LiDAR sensor with Global Navigation Satellite System (GNSS) positioning and an inertial measurement unit (IMU), all mounted in a lightweight backpack configuration that can be carried by a single operator.

As the operator walks through the area of interest, the system continuously collects **three-dimensional point cloud data**, capturing detailed terrain morphology, micro-topography, and vegetation structure. The integration of GNSS and IMU enables spatial referencing of the collected data, producing georeferenced 3D models suitable for further analysis.

Backpack LiDAR is particularly suitable for **monitoring erosion processes, trail degradation, soil surface changes,** and other small-scale geomorphological features in areas that are difficult to access or where airborne surveys (e.g., UAV-based LiDAR) are restricted or impractical.

Best practices

Within the Interreg CE project **HUMANITA**, erosion monitoring in Malá Fatra National Park (Slovakia) primarily relied on repeated UAV-LiDAR acquisitions to improve understanding of digital elevation model (DEM) uncertainties and to capture terrain morphology along selected hiking trails before and after the tourist season. Measurements were conducted twice annually to detect seasonal changes.

Backpack **LiDAR technology was tested once as a complementary method**. Due to the low positioning of the LiDAR sensor above ground level, the spatial extent of acquired data was limited. The dataset proved insufficient for comprehensive post-processing and large-scale analysis in this case.

However, the **method demonstrated potential for targeted, small-scale surveys in locations where UAV-based data acquisition is restricted** (e.g., dense canopy cover, flight limitations, or legal constraints). It may serve as a supplementary tool for localized terrain assessment.

Requirements

- Portable LiDAR system integrated with GNSS and IMU.
- Reliable GNSS correction services to ensure spatial accuracy.
- Sufficient battery capacity for planned field surveys.
- Trained personnel for system operation and survey route planning.
- Specialized software and adequate computing capacity for point cloud processing, calibration, and analysis.
- Regular system maintenance and sensor calibration.
- Careful planning of survey timing and environmental conditions.

Constraints

- Data quality depends strongly on GNSS signal availability, which may be reduced in dense forests, narrow valleys, or steep terrain.
- Coverage is limited to areas accessible on foot.
- Surveying large areas is time-consuming and labor-intensive.
- Operator walking speed and movement patterns influence point density and consistency.
- Lower sensor position above ground reduces spatial extent per survey pass.
- Post-processing requires specialized software and technical expertise.
- Equipment costs are relatively high compared to simpler field-based erosion monitoring methods.
- Weather conditions (rain, snow, extreme temperatures) may affect performance and data quality.

Pointers

- Plan surveys during stable weather conditions to ensure optimal data quality.
- Avoid data acquisition during rain, snow, or extreme temperatures.
- Ensure good GNSS signal availability; check satellite coverage before fieldwork.
- Maintain consistent walking speed to improve point density uniformity.
- Clearly define survey routes to enable repeatability in long-term monitoring.
- Use backpack LiDAR for small, targeted areas rather than large-scale mapping.
- Combine with UAV-LiDAR or photogrammetry for broader spatial context.
- Perform regular calibration and system checks before deployment.
- Allocate sufficient time and computing capacity for post-processing.
- Consider terrain accessibility and operator safety when planning routes in steep mountain areas.

Tool Impact

Backpack LiDAR technology has a low environmental impact, as it is operated manually on foot and does not require heavy machinery, permanent installations, or infrastructure. The method is non-invasive and does not disturb soil or vegetation directly. Minor impacts may occur due to trampling during repeated surveys, particularly along sensitive trail sections. When integrated into existing paths or erosion-affected areas, environmental disturbance remains minimal while providing highly detailed spatial data.

Erosion monitoring

UAV-based LiDAR scanning (large scale)

UAV-based LiDAR scanning for erosion monitoring enables detailed, **high-resolution mapping of terrain changes over time.** It allows accurate detection and quantification of erosion processes across large areas without the need for extensive field surveys.

LiDAR-based remote sensing using unmanned aerial vehicles (UAVs) is an effective method for detecting and monitoring erosion processes. LiDAR sensors emit laser pulses toward the ground and measure the time it takes for the reflected signals to return, allowing the creation of highly accurate three-dimensional models of the terrain. **By comparing elevation models from repeated surveys, even small changes in surface height can be identified**, allowing for the quantification of erosion rates and patterns over time. When applied to **hiking trails**, UAV-mounted LiDAR can precisely map **trail depth, ruts**, and **surrounding vegetation disturbance**, helping to distinguish natural erosion from tourist-induced impacts.

Best practices

In the Interreg CE project **HUMANITA**, erosion monitoring was carried out using repeated UAV-LiDAR acquisitions to improve understanding of digital elevation model uncertainties. The aim was to **capture the terrain shape along selected hiking trail sections** in Malá Fatra National Park (Slovakia) on specific dates, chosen to represent **periods before and after the tourist season**. Measurements were therefore conducted twice a year.

Data was collected using LiDAR mounted on a UAV, with GNSS used for georeferencing the system and determining the UAV trajectory. The system captured the terrain geometry as a georeferenced point cloud. Collected data were post-processed following a pre-set methodology to produce high-quality, georeferenced, dense point clouds with real texture. LiDAR360 and Inertial Explorer were used for processing raw data into georeferenced point clouds.

The **resulting point clouds support** vector and raster analyses to **detect terrain changes and identify deformations caused by erosion.** In addition, tourist counters were installed along the monitored trail sections to quantify visitor numbers. Combining LiDAR-derived terrain changes with visitor data enables estimation of the impact of tourist pressure on trail erosion. With point clouds from multiple epochs, spatially explicit topographic changes can be detected, including trail branching and the formation of new paths.

Requirements

- Access to a UAV platform equipped with a suitable LiDAR sensor and
- GNSS or IMU Positioning system to ensure high spatial accuracy
- Trained operators and pilots for flight planning, data acquisition, and compliance with aviation regulations
- Adequate software and computing capacity for data processing, calibration, and analysis of point clouds and digital elevation models
- Regular maintenance of the UAV and sensor, battery management, and calibration to ensure data quality and operational safety
- Legal permits and coordination with land managers or protected area authorities.

Constraints

- Requires specialized equipment and trained personnel, which can lead to increased operational costs
- Flight time and spatial coverage are limited by UAV battery capacity and weather conditions, particularly strong wind, rain, or fog
- Dense vegetation can partially obstruct laser penetration to the ground in forested areas
- Regulatory restrictions on UAV flights, especially in protected areas, may limit data collection
- Data processing and analysis are technically demanding and time-consuming, requiring advanced software and expertise.

Pointers

- Data acquisition processes need to be adapted to outdoor conditions such as temperature and rain or snow.
- The proper choice of timing and weather conditions is essential to ensure the required quality of the output data.

Tool Impact

LiDAR-based remote sensing using UAVs has a generally low environmental impact compared to traditional field-based monitoring methods. However, temporary disturbance to wildlife may occur if flights are conducted at low altitudes or during sensitive periods such as breeding seasons.

Wildlife monitoring

Amphibian Disease Monitoring Protocol

Molecular diagnostic **toolkit for detecting and monitoring amphibian pathogens** (chytrid fungus and ranavirus) in field-collected samples using **real-time PCR** methodology in relation to tourism impacts.

The Amphibian Disease Monitoring Protocol is a comprehensive methodology for detecting and quantifying pathogenic infections in amphibian populations, specifically targeting two major infectious pathogens: the chytrid fungus **Batrachochytrium dendrobatidis (Bd)** and **ranavirus**. The protocol combines field **sampling techniques with molecular laboratory diagnostics** to assess pathogen presence and infection intensity in relation to tourism impacts and visitor frequency in protected areas.

The toolkit employs non-invasive or minimally invasive swab-based sampling from living amphibians: **skin swabs from the yellow-bellied toad** (Bombina variegata) for **chytrid fungus detection**, and **oral swabs** from the **common frog** (Rana temporaria) for ranavirus detection. Real-time quantitative PCR (qPCR) methodology with known standard curves (1-1000 genome equivalents for Bd; 3-30,000,000 genome equivalents for ranavirus) enables precise detection and quantification of pathogen loads. All samples are processed with strict biosecurity protocols including equipment disinfection and single-use sterile materials to prevent cross-contamination between sites.

The protocol integrates amphibian pathogen data with visitor flow data derived from anonymized fitness app tracking **(Strava Metro)** to assess **correlations between tourism activity levels and pathogen infection rates.** This allows researchers to evaluate whether tourism-related disturbance and increased human traffic contribute to pathogen transmission within protected amphibian populations.

Best practices

The Interreg CE project **HUMANITA** experience demonstrates successful integration of amphibian disease monitoring with tourism impact assessment.

- **High chytrid prevalence** (54.16%) observed at **accessible hiking route** (Glóbusz út) compared to **lower prevalence** (23.81%, 11.90%) at **less-frequented sites**; however, wild ungulates and forestry vehicle traffic also significantly influence local pathogen distribution—tourism is significant but not sole driver
- **Ranavirus** was **not detected in field samples** despite previous disease mortality observations; oral swabbing may not capture all infections; consider supplementary sampling of moribund animals if available
- **Partnership access to molecular laboratory facilities** (CSIC, Oviedo University) was essential **for cost-effective processing** of sample batches

Requirements

In the field:

- Access to protected areas with target amphibian populations
- Field equipment: disinfectable boots, sterile gloves, hand sanitizer, collection containers
- Training in molecular techniques and animal handling with amphibian welfare compliance

In the lab:

- Access to reference laboratory with validated protocols (University of Oviedo, Spanish Research Network - CSIC recommended)
- Standard reference materials: Bd genome equivalents (1-1000 range) and ranavirus genome equivalents (3-30,000,000 range)
- Real-time PCR (qPCR) thermocycler and laboratory infrastructure
- Molecular biology equipment for DNA/RNA extraction (homogenizer, centrifuge, freezer capacity)
- Sterilization equipment (autoclave or equivalent disinfection supplies for field gear)
- Laboratory consumables: sterile swabs, extraction kits, PCR reagents, positive controls, primer sets
- Partnership agreement with Strava Metro for tourism data access (for tourism correlation analysis)
- Data management system for results tracking and statistical analysis

Constraints

- Sampling conditions dependent on amphibian activity patterns and seasonal availability
- Weather-dependent sampling success (activity patterns of target amphibian species affected by temperature and precipitation)
- *Bd* detection limited to species susceptible to chytridiomycosis; some species may be asymptomatic carriers
- Ranavirus detection in oral cavities may not capture systemic infection in all cases
- Sample collection requires trained personnel to ensure animal welfare and protocol compliance
- Requires specialized molecular laboratory facilities with real-time PCR equipment and expertise
- Limited to amphibian species accessible through non-lethal swabbing (primarily aquatic/semi-aquatic species)
- False negatives possible if infection is at very low intensity or below detection threshold
- Strava Metro partnership required for visitor data integration (not available to all research organizations)

Pointers

In the field:

- Seasonal timing is critical: spring sampling for breeding frogs (May-June) captures adult populations in accessible breeding habitats; autumn sampling (September-October) necessary to supplement insufficient spring breeding; toad populations remain accessible year-round if water is available
- Coordinate sampling with peak activity periods of target species (spring breeding for frogs; year-round for toads with water availability)
- Document weather conditions at time of sampling (affects amphibian activity and detection rates)
- Follow strict biosecurity protocol: disinfect boots and equipment between sampling sites using 70% ethanol or equivalent, establish detailed standard operating procedures for each field team
- Single-use sterile gloves changed between individual animals to prevent cross-contamination
- Consistent swabbing technique using firm circular motion for 10-15 seconds to ensure adequate cellular material collection
- Multiple sampling sites (2-3 per treatment level) recommended to account for local variation in infection patterns unrelated to tourism
- Maintain cold chain from field collection through laboratory processing

In the lab:

- Establish partnership with reference laboratory for protocol optimization and troubleshooting
- Validation against known positive and negative controls with every PCR run
- Duplicate testing of all field samples; only classify as positive if both reactions detect pathogen
- Establish baseline infection prevalence before interpreting temporal changes
- Include positive control sites (known high infection) and negative control sites (unimpacted reference areas) in monitoring design
- Quarterly quality assurance checks of PCR standards and primer functionality

For visitor monitoring:

- Cross-validate with site-specific visitor data (Strava Metro, automatic counters, mobile phone data) to account for confounding factors in infection patterns
- Visitor flow proxies (Strava Metro, mobile phone data) provide non-invasive baseline assessment of relative tourism pressure; absolute visitor numbers require calibration with ground-truthed counts
- Data integration requires careful interpretation—correlation between tourism and infection does not establish causation; consider alternative transmission vectors (wildlife, water chemistry, climate)

Tool Impact

The amphibian disease monitoring protocol has low direct environmental impact, as it relies on non-invasive or minimally invasive swab sampling of live individuals and does not require permanent infrastructure. Handling of amphibians may cause temporary stress, but impacts are minimized through standardized protocols and trained personnel.

Strict biosecurity measures (e.g., equipment disinfection and single-use sterile materials) are essential to prevent unintentional pathogen spread between individuals or sites. When properly implemented, the protocol poses minimal ecological disturbance and contributes to conservation by enabling early detection of infectious diseases linked to environmental pressures such as tourism.

Pollution monitoring

Soil microplastic pollution and its effect on earthworm distribution

Field sampling of soil at selected areas to better understand pressures and threats of microplastic pollution and its effects on earthworms and their habitats.

This methodology investigates microplastics pollution in terrestrial ecosystems and its impact on soil-dwelling organisms. It explores how **microplastic particles quantity and size** compare in different land use types, like agricultural land or green urban areas. Additionally, the **earthworm population presence** is investigated at the sampling sites to **compare the relation of microplastics pollution to earthworm population.**

Best practices

During **HUMANITA** project a microplastic and earth worm distribution survey was undertaken in the significant landscape of **Lower Kamenjak** pilot site (Croatia).

Further information on the sampling method can be retrieved under the following references:

Ćaleta, Bruno & Hackenberger, Davorka & Hackenberger, Branimir. (2022). Microplastics in Lumbricus terrestris middens/casts and surrounding urban soil

Scheurer, M., Bigalke, M., & Institute of Geography, University of Bern. (2015). Microplastics in Swiss floodplain soils. Institute of Geography, University of Bern

Requirements

- Soil corers/ soil augers
- Field notebook
- GPS device
- Earthworm sampling equipment (96% ethanol, markers, sterile containers for earthworm samples etc.)
- Soil sampling equipment (gloves, markers, sterile containers or bags etc.)

Constraints

- Soil samples represent only specific sampling points and may not reflect conditions across wider areas.
- Microplastic distribution is highly variable, so results may miss fine-scale spatial differences.
- Earthworm presence varies with weather, soil moisture, and time of day, which can affect detection rates.
- In-field species identification may reduce taxonomic accuracy compared to laboratory-based (e.g. genetic) methods.

Pointers

- Observed relationships between microplastic concentration and earthworm abundance may also be influenced by soil type, organic matter content, land use, and other environmental factors
- Since microplastic pollution monitoring is not standardized, results should be interpreted for each area/territory separately
- Comparing microplastic levels in various European regions is challenging since there are no standardized techniques for extraction and quantification, and thus, various extraction methods can significantly affect results
- To allow comparisons between sites or monitoring campaigns, soil samples should be taken at same depths and similar sample volumes have to be gathered

Tool Impact

Taking soil cores or digging small pits disturbs the soil profile. This can temporarily break soil aggregates, alter water infiltration and aeration locally and disrupt root systems of small seedlings. It can also have an impact on sensitive underground fauna, such as insect larvae. Unearthing earthworms during sampling may expose them briefly to predators or desiccation. Some individuals may be accidentally injured during digging and soil sampling.

Monitoring Tool-Box

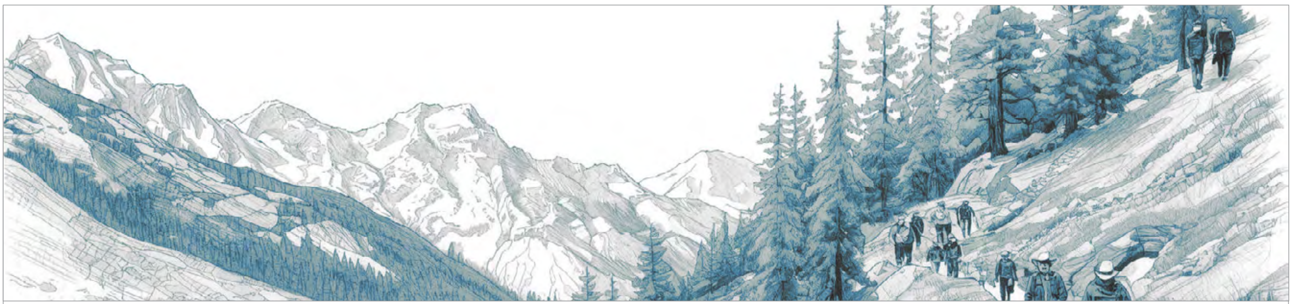
The **HUMANITA Monitoring Tool-Box** complements this catalogue by providing a broader collection of **22 tested monitoring methods and instruments** suitable for short- and mid-term environmental monitoring in conservation areas. While the present catalogue highlights eight selected solutions, the toolbox expands this perspective by offering additional monitoring approaches that can support conservation area managers in designing and implementing tailored monitoring programmes. It serves as a practical reference point for identifying appropriate tools to assess environmental conditions, visitor activities, and anthropogenic impacts on natural ecosystems.

The **Monitoring Tool-Box** is integrated into an **online demonstrator application** developed by the Carinthia University of Applied Sciences within the COIN BioMONITec project (2025) and further advanced through the Interreg CE project **HUMANITA**. The application allows users to explore monitoring tools through both thematic and keyword-based searches. The thematic search function organizes tools according to technological categories and their applicability in conservation area management, enabling users to **filter and identify monitoring methods suited to specific objectives.** Search results can be compiled and exported as an individual monitoring toolkit, supporting the development of site-specific monitoring strategies.

In addition, the demonstrator integrates elements of the **IUCN Monitoring Global Guideline (MoniGloG)** to support the structured design of monitoring programmes. A central component is the **Monitoring Concept Worksheet** (MCW), which guides users step-by-step through the process of defining objectives, indicators, and monitoring methods. The worksheet can be completed directly within the application or downloaded for use in workshop settings. Through this integration, the Monitoring Tool-Box links methodological guidance with practical tools, providing conservation area managers with a **structured pathway from monitoring planning to method selection and implementation.**

The online platform hosts the **complete monitoring catalogue of the 22 methods and instruments tested during the HUMANITA project**, ensuring long-term accessibility and discoverability of the tools beyond the project's duration. By building on the existing BioMONITec prototype, the long-term vision is to further develop the platform into a **comprehensive repository of biodiversity and environmental monitoring methods** for protected areas and conservation practitioners across Europe.

TO WEBSITE



HUMANITA Monitoring Catalogue

The HUMANITA project develops evidence-based, participatory tools that help regions monitor and assess how tourism affects conservation areas. Within the project, a range of monitoring methods has been tested to track the spatial and temporal distribution of visitors and to evaluate their impacts on erosion, vegetation, wildlife, and environmental pollution.

Following the IUCN's framework for monitoring biodiversity in protected areas and other effective area-based conservation measures (Dalton et al., 2024), we defined the scope and priorities of monitoring programs across our pilot regions. The resulting HUMANITA monitoring strategy forms the foundation for all project activities. Approved methods have been integrated into the BioMoniTec toolbox, allowing conservation practitioners to identify suitable technologies for monitoring visitors and their environmental impacts.

In addition to the toolbox, the HUMANITA Monitoring Catalogue offers an overview of 8 selected monitoring activities implemented throughout the project.

HUMANITA Toolbox **Monitoring catalogue**

Additional remarks

The project **HUMANITA** is supported by the Interreg CENTRAL EUROPE Programme 2021-2027 with co-financing from the European Regional Development Fund. It brings together 10 partners from Austria/Slovenia, Croatia, Hungary, Italy and Slovakia. Scientists were working together to develop and test innovative solutions to assess the impact of tourist activities on nature, with the objective to assist managers of conservation areas to safeguard the environment. Project outputs will help conservation area managers put the right measures in the right places, make smarter decisions, prevent negative impacts, mitigate human-nature conflicts and reduce risks.

The **output 2.2 "Jointly developed solutions assessing the impact value of different types of tourist activities on nature"** highlights different jointly developed innovative solutions (technological, methodological) to assess the impact of tourist activities on natural values with the aim to provide complex information on changes and trends in the condition of the environment.

The output 2.2 is connected to **Deliverable D 2.3.2 "Catalogue of monitoring methods and tool-box".** While the catalogue aims to inform conservation practitioners about selected practical solutions, the toolbox provides a description of 22 tested feasible methods and instruments for short- and mid-term environmental monitoring for PAs, with information about the tool's constraints, requirements, impacts on the environment, best practice information from our project as well as pointers for its use.