Interreg North-West Europe

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MONA

D1.4.1 - Monitoring framework

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1. About MONA

Nature areas in North-West Europe (NWE) face an increasing number of visitors (intensified by COVID-19) resulting in an increased pressure on nature, negative environmental impacts, higher management costs, and nuisance for local residents and visitors. The high share of car use exaggerates these impacts, including peak pressures. Furthermore, the almost exclusive access by car excludes disadvantaged people, specifically those without access to a car. At the same time, the urbanised character of NWE, its dense public transport network, well-developed tourism & recreation sector, and presence of shared mobility providers offers ample opportunities for more sustainable tourism.

Thus, MONA will stimulate sustainable tourism in and around nature areas in NWE which benefits nature, the environment, visitors, and the local economy. MONA will do so by encouraging a modal shift through facilitating sustainable transport modes, providing inclusive routing to and within nature areas, and nudging visitors and stakeholders towards more sustainable behaviour. These are the key solutions to manage visitor flows, reduce negative impacts, and stimulate inclusive access. 8 nature areas and 3 knowledge & dissemination partners work together to:

- Assess the impact of visitors & mobility on nature areas and develop strategies to reduce this impact
- Jointly pilot solutions on the modal shift, routing and nudging
- Provide capacity building for stakeholders across NWE

Nature areas, destination marketing organisations, tourism & mobility service providers, local and regional authorities and (potential) visitors of nature areas all benefit from the strategies and solutions for, and revenues of, sustainable tourism. MONA develops and promotes a mindset around sustainable tourism which is balanced, inclusive, and socially and environmentally sustainable. This is made possible by the projects' multidisciplinary approach, for which the transnational partnership and expertise is essential.

2. About this document

This document is aimed at identifying a set of monitoring tools that assist in assessing the current situation in nature areas in a holistic way, covering visitor experiences, nature qualities, and transportation choices. The aim of the document is to combine general with project-specific indicators in order to serve both a direct and indirect impact assessment of interventions.

As described in the MONA proposal, the monitoring framework provides an initial approach that will be further developed with partners in order to provide a custom advice for each nature area, leading to a continuously improving assessment framework that will serve as an input for the Guidebook on Sustainable Tourism in Nature Areas.

The document is structured around a preliminary review of existing frameworks, briefly discussing the history of monitoring approaches from carrying capacity frameworks, to recreational opportunity spectrum, limits of acceptable change, visitor impact management, and visitor experience and resource protection. Next, a general outline of monitoring needs and approaches is developed, from a high-level view of near-universal indicators for recreation in nature areas. This exercise is supplemented by project-specific indicator needs, based on the strategic actions of MONA partners.

The final part of the document sets out to provide proofs-of-concept of indicators and measurement approaches, in each case outlined through an example of one MONA partner. This serves as a basis for the full monitoring development across all MONA partners.

3. Introduction to MONA monitoring framework

The MONA monitoring framework is described in the proposal as a coherent set of monitoring tools to assess both the current situation in the participating nature areas, as well as monitoring future effects of the pilot interventions. The proposal particularly recognizes the need to assess impacts on the social, environmental, and ecological qualities, although it is further advisable to acknowledge for an economic component as well in order to provide sufficient coverage for the well-known three-pillar structure of sustainable development.

The proposal text highlights the connection between activities 1.1, 1.2, 1.6, 1.7 and 1.8 of MONA Work Package 1, as well as refering to other potential quantitative and qualitative tools, methods, data, and indicators that are available on the market and described in the literature. The monitoring framework delivered in this document only forms the starting point with which to develop custom advice and collaborative learning with the nature areas with the aim to achieve a living, evolving framework that is optimized at the end of the MONA project, serving as input for the Guidebook on Sustainable Tourism in Nature Areas (WP3). Figure 1 shows the links between the monitoring framework and other activities of the MONA project, as well as relevant tertiary resources.

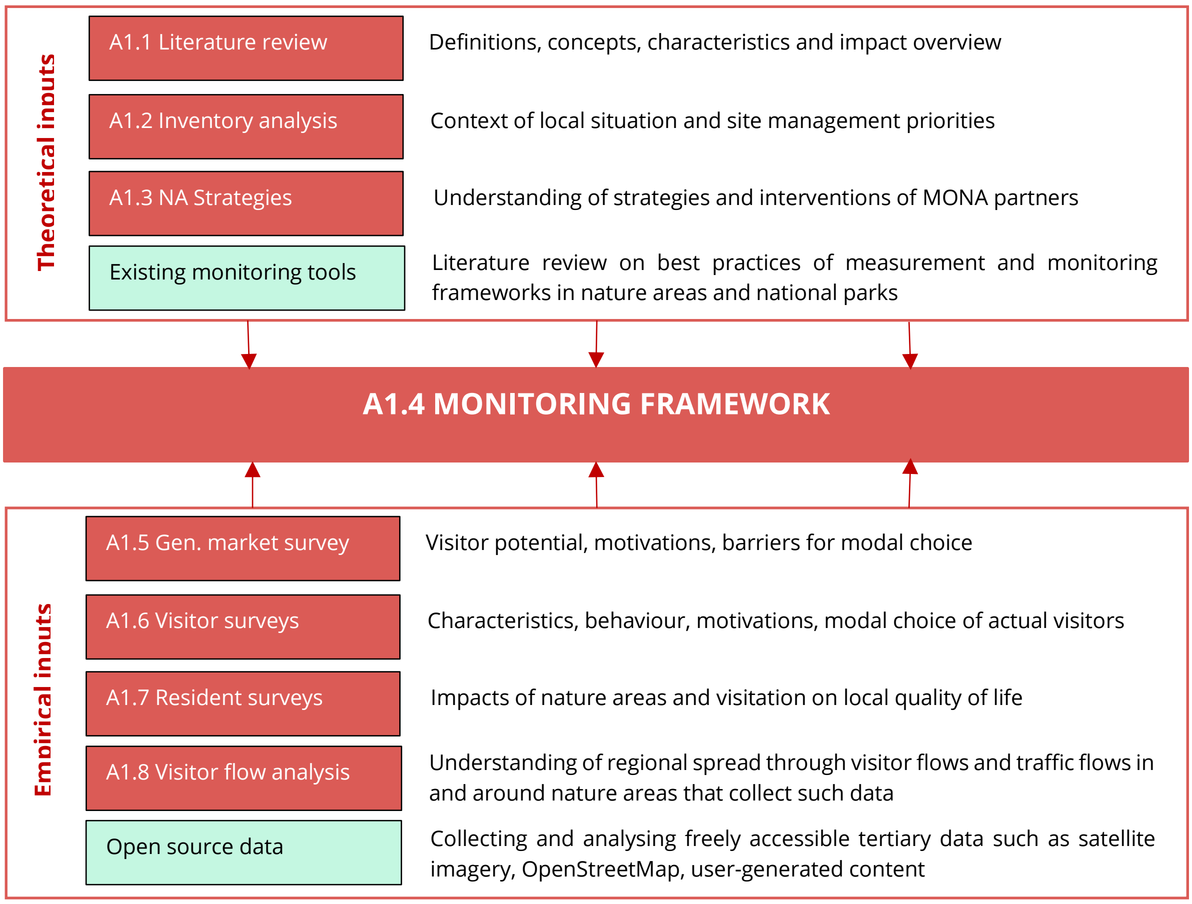


Figure 1: Connection between Monitoring framework and other MONA activities

The document, and by extension the MONA monitoring framework, is developed around a number of key principles around content and data collection. Firstly, in terms of content:

1. A high-level conceptualisation of the monitoring framework provides a baseline of data that would be largely relevant for all nature areas, irrespective of chosen strategies or pilots.
2. The monitoring framework should be multidimensional and cover both environmental, social, and economic indicators.
3. Apart from this homogeneous basis, for each nature area additional indicators are identified that are directly linked with individual nature area strategies. These will often require a dedicated data collection.

Secondly, in terms of data and data collection:

4. The monitoring framework maximally integrates the data collected in activities 1.5, 1.6, 1.7 and 1.8 of the MONA project.
5. The data is supplemented whenever possible by open source data of non-commercial nature, thereby not being dependent on commercial data providers.
6. Any additional data collection from the point of view of nature area partners should be minimised.

The remainder of the document will be structured as follows. First, a summarizing overview if given of historically adopted monitoring philosophies and frameworks. Next, based on a general understanding of potential impacts and needs, critical general monitoring dimensions and monitoring strategies are discussed, after which the individual strategies of the MONA-partner will be analyzed in order to identify additional local needs. Finally, the last part of the deliverable operationalises relevant and available indicators for different MONA-partners, as a proof-of-concept for holistic, continuous monitoring.

4. History of monitoring protocols

4.1 Introduction

Nature areas and national parks need to balance a dual objective of resource protection on the one hand, and public access on the other hand. Tourism and recreation is an important function provided by nature areas, with documented benefits on quality of life, health, and wellbeing. However, recreational visitation also inevitable degrades natural resources (Marion et al., 2016).

Leung et al. (2011) recognize two main bodies of literature focusing on this recreation-protection dilemma: recreation ecology and recreation social science. While the former predominantly highlights associated environmental impacts, the latter field includes (negatively) impacted visitor experiences. Earlier studies attempted to identify use limits within carrying capacity frameworks, which are still relevant as protective measures for sensitive subsystems within nature areas and national parks. since the 1980s the attention shifted towards broader indicator-based management frameworks rather than strict threshold values. This follows from Manning's (2002) observation that, while there is an impressive literature base for capacity-based systems, their determination and application invariably runs into the issue that some decline or change in the quality of park resources and visitor experience seems inevitable as a result of the substantial demand, making the question one about acceptable decline and change and the formulation of management objectives and indicators of standards of quality. The best-known frameworks to have been implemented according to this philosophy are Limits of Acceptable Change (LAC), Visitor Impact Management (VIM) and Visitor Experience and Resource Protection (VERP). All of these share important similarities, such as the identification of zones and management objectives, the development of indicators and standards, and the establishment of monitoring actions.

4.2 Carrying capacity

Carrying capacity has a rich history in more technical applications (e.g., as an application of load-bearing capacity of engineering systems), as well as wildlife and range management, where it referred to the number of animals that could be maintained in a given habitat. Carrying capacity approaches have proven popular within conservation biology, where they are associated with the 'overshoot and collapse' phenomenon in cases of improper ecosystems management, simplified in the following equation:

$$\frac{dN}{dT} = rN\left(1 - \frac{N}{K}\right)$$

whereby N is the number of individuals, r the intrinsic growth rate, and K refers to the upper limit of growth. As mentioned by Chapman and Byron (2018) though, there is no such thing as a collective approach to measuring carrying capacity and a wide range of definitions and approaches exist that hinder a unified framework. This is partly due to the wide range of ecosystem types, subject areas, and scales of ecological organisation it can be applied to. For instance, Scanlan et al. (1994) estimate a safe carrying capacity for cattle-grazing pastures in North-Eastern Australia and Cupul-Magaña and Rodríguez-Troncoso (2017) investigated carrying capacity of the Islas Marietas National Park coral reefs in light of damage by scuba diving and snorkelling.

Its first application to park management with a visitor-based focus occurred in the 1960s. While carrying capacity originally focused on the unilateral impact of visitors on natural park resources, it quickly became apparent that the visitor experience – and therefore the social dimension of carrying capacity – needed to be considered as well, complicating the application due to the inherent psychological basis of social carrying capacity. Prato (2001) therefore introduces a management model that combines both a biophysical and a social carrying capacity. This approach can also be seen in Cifuentes' methodology (Cifuentes, 1992), which has been suggested by the IUCN and which defines a physical, real and effective carrying capacity. Physical Carrying Capacity (PCC) is defined as the maximum number of visitors that can physically fit a specific space and time:

$$PCC = A \times \frac{V}{a} \times Rf$$

where *A* is the publicly available area, *V/a* is one visitor per m² and *Rf* is the rotation factor, formulated as the total opening period divided by the average time per visit. The Real Carrying Capacity (RCC) is defined as the maximum permissible number of visits after using corrective factors:

$$RCC = PCC \times \frac{(100 - Cf_1)}{100} \times \frac{(100 - Cf_2)}{100} - \cdots - \frac{(100 - Cf_n)}{100}$$

With the corrective factors (*Cf*) being linked to the specificities of each site and obtained by bio-physical, environmental, ecological, and management variables. For instance, applying a carrying capacity study to hiking trails in the Azores, Queiroz et al. (2014) take into account daylight, precipitation, accessibility – related to the degree of difficulty according to slope, range and soil type – and quality of visitation – measured by group size of maximum 15 people and a and minimum distances of 250m between groups. The corrective factors are expressed in percentages as:

$$Cf = \frac{M_l}{M_t} \times 100$$

With M_l being the limiting magnitude of the variable and M_t the total magnitude. Finally, the Effective Carrying Capacity (ECC) adds the management capacity to the equation:

$$ECC = RCC \times MC$$

Sayan and Atik (2011) provide an example of this method by calculating the recreational carrying capacity of Termessos National Park while the study of Cupul-Magaña and Rodríguez-Troncoso (2017) revises the method for specific use in the case of marine environments. In the study of Queiroz et al., six hiking trail capacities are measured for the Sáo Miguel and Flores islands in the Azores with, for instance the Praia-Lagoa do Fogo hike having a PCC of 16,935 visits a day but a RCC of just 176 visits a day.

4.3 Recreational Opportunity Spectrum

The Recreational Opportunity Spectrum (ROS) has seen a broad application in nature areas, redirecting the focus from pure capacity measurement and management to balancing the questions of recreational needs and experiences, with natural resources, and management facilities. The system therefore classifies recreational opportunities based on physical, social, and managerial criteria. In its most basic application, ROS identifies six classes (Clark & Stankey, 1979; Joyce & Sutton, 2009):

- Primitive: Defined as an area three miles or more from all roads and trails, being of essentially unmodified nature. Such areas need to be of sufficient size (5000 acres or more) and allow for limited social interaction, with no more than 6 parties encountered on a trail.
- Semi-primitive non-motorized: An area that is half a mile from roads and trails with motorized use and is – typically – at least 2500 to 5000 acres. The area can include some primitive hiking trails, thus allowing for small modifications to the nature area. The social setting should be limited to encountering 6 to 15 parties per day in order to preserve a wilderness experience.
- Semi-primitive motorized: Of similar size and distance to main roads as the previous category. In this case, trails allow for motorized use, though, showing more evidence of man-made alterations, even though additional facilities provided are still sparse.
- Roaded natural: These areas are typically at most half a mile from larger roads and motorized trails, with relevant recreational modifications such as signage, established trails, interpretation signs, and benches. The setting allows for moderate to high frequency of contact.
- Rural: In these areas there are substantial modifications to the nature area, potentially including campsites, fishing spots, information centres, convenience stores, and resorts. Other hikers and recreationists are potentially constant in view.
- Urban: Urban areas are by definition outside of nature areas due to their highly developed character and as such represent the development surrounding park boundaries.

The model thus advocates a zoning approach whereby different zones provide varied levels of wilderness experience, which ought to be coupled with differences in accessibility and availability of facilities, and the type of visitor that is attracted. The ROS is compatible with a carrying capacity approach, since it highlights a need for locally relevant capacity management.

4.4 Limits of Acceptable Change

Efforts to determine multifocal carrying capacity estimates to nature areas have typically been hampered by the difficulty to establish optimal numbers, among others due to the psychological nature of social carrying capacity, and the adaptability of visitors. Furthermore, given the substantial demand for public park use, some decline or change in both natural and social conditions is to be expected and inevitable as a result of the open access nature of many parks and natural areas. The classical carrying capacity approach therefore received criticism, both for its apparent vagueness, contextual differences depending on its application, and the lack if sufficiently including interdependencies (Dhondt, 1988), and due to its apparent search for a 'magic number' of optimal visitor use (McCool & Lime, 2009).

While more contemporary approaches to carrying capacity calculations have attempted to relax the rigid assumptions and have been increasingly based on a combination of normative perceptions and resource-based limitations, authors such as McCool and Lime (2009) instead proposed the use of Limits of Acceptable Change (LAC) or Visitor Experience and Resource Protection (VERP) as alternative measures, which implies the decision on an appropriate or acceptable level of decline. In essence, LAC approaches the two conflicting goals of nature areas and national parks – protection of environmental conditions and visitor experience, and unrestricted access for recreational use – as objectives that need to be compromised to a certain extent, contingent upon constraints. In its operationalization, the constraining factor will always be the minimally acceptable conditions for the environment and visitor satisfaction, that will then help to define the open access conditions and restrictions.

LAC establishes a management framework that is equally prevalent in other environmental management approaches[1], including (i) a description of desired future conditions for natural and cultural resources, as well as the visitor experience, (ii) identification of key performance indicators, (iii) establishment of standards to define minimum acceptable conditions, (iv) the formulation of monitoring techniques to determine when management actions must be taken, and (v) the development of management actions to ensure that specified quality standards are maintained.

[1] E.g., Visitor Impact Management (VIM), Management Process for Visitor Activities (VAMP), Visitor Experience and Resource Protection (VERP).

4.5 Visitor Impact Management

Visitor Impact Management (VIM) was developed by researchers working for the United States National Parks and Conservation Association with the goal of addressing problematic conditions, identifying potential causal factors, and suggesting effective management strategies. The VIM process is structured around a series of steps designed to systematically assess and manage visitor impacts. These steps include: (i) conducting a pre-assessment database review to gather existing data and information, (ii) reviewing management objectives to ensure alignment with broader conservation goals, (iii) selecting key indicators that reflect the conditions of concern, (iv) selecting standards for these key indicators to define acceptable limits, (v) comparing these standards to existing conditions to identify discrepancies, (vi) identifying probable causes of impacts to understand the root issues, (vii) identifying management strategies to mitigate or prevent these impacts, and (viii) implementing the chosen strategies (Tayler & Nilsen, 1997).

VIM shares clear similarities with the Limits of Acceptable Change (LAC) framework, on which it was partly based, particularly in its focus on defining acceptable conditions and monitoring changes over time. However, a significant and rather unique element of the VIM approach is its strong emphasis on understanding the probable causes of visitor impacts. This focus allows managers to address the root causes of problems rather than just the symptoms, leading to more effective and sustainable management solutions. Additionally, VIM provides a comprehensive framework for evaluating a range of management strategies, offering a structured approach to selecting the most appropriate actions based on scientific evidence and managerial judgment. This makes VIM particularly valuable for addressing site-specific issues in protected areas, where understanding and mitigating human impacts are critical for maintaining ecological integrity and visitor satisfaction (Tayler & Nilsen, 1997).

4.6 Visitor Experience and Resource Protection

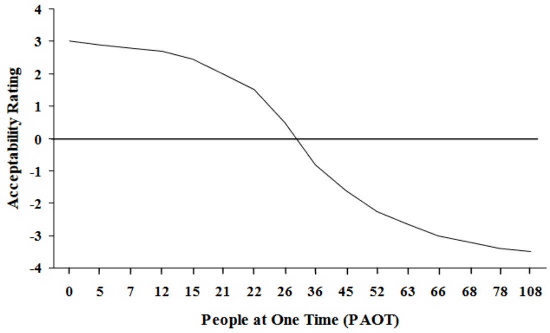
The Visitor Experience and Resource Protection (VERP) Framework began development by the National Park Service in the United States in 1992 and was first implemented in The Arches National Park, subsequently being adopted in many park units throughout the American continent. The development of VERP came forth from US law which requires the National Park Services to address carrying capacity in its national parks since 1978. However, as also noted by Hof and Lime (1997), there are no real conceptual differences between VERP and other planning frameworks such as LAC, VIM, Carrying Capacity Assessment Process (C-CAP), Visitor Activity Management Process (VAMP), etc., with all of them attempting to address questions of carrying capacity, impacts of recreational use, and appropriate visitor use through both an environmental and a experiential (social) lens. Nils and Tayler (1997) provide a comparative analysis of different management frameworks and discuss how VERP explicitly includes aspects of LAC, VIM, and other earlier approaches. The VERP is an essential part of the General Management Plans that each US national park is required to draft and which needs to qualitative address carrying capacity through zoning of the park according to desired visitor experiences and resource conditions.

Manning (2002) discusses the nine elements included in a VERP assessment:

1. Assemble an interdisciplinary project team;
2. Develop a public involvement strategy;
3. Develop statements of park purpose, significance, and primary interpretative themes;
4. Analyse park resources and existing visitor use;
5. Describe a potential range of visitor experiences and resource conditions (potential prescriptive zones);
6. Allocate the potential zones to specific locations in the park (prescriptive management zoning);
7. Select indicators and specify standards for each zone; Develop a monitoring plan;
8. Monitor resource and social indicators;
9. Take management action.

Analysing the nine elements, it is clear that the first three steps provide a strategic foundation, rather than a monitoring directive and primarily amount to including a multidisciplinary view, relevant stakeholders, and define a general vision for the nature area. Step four is a historic/current analysis of the state of the nature area. The effective determination of VERP takes place in steps five to seven, which entail the identification of visitor experiences to offer, contingent upon relevant resource conditions, and their mapping across the nature area. For each zone and visitor experience, indicators and relevant standards then need to be established. Finally, steps eight and nine relate to the monitoring of identified indicators and management actions that would be needed if standards are violated.

Manning (2002) describes the early application of VERP in the Arches National Park, providing potential relevant social and environmental indicators. These indicators include: the number of people at front country attraction sites and along trails, the number of visitor groups encountered along trails and at campsites, the number of vehicles encountered, the number of social trails and associated soil and vegetation impacts, the level of trail development, and visitor knowledge of regulations regarding off-trail hiking. Standards of quality around these topics were at least partly based on visitor surveys, among others adopting photographs representing a range of impact conditions (such as number of visitors on trails) and asking visitors to rate images in terms of acceptability. Figure 2 provides an example of the results of this approach for the specific attraction of Delicate Arch, with the results indicating an acceptable standard level of 30 people at one time (PAOT).



Source: Manning (2002, p.311)

Figure 2: Visitor evaluation of alternative use levels at Delicate Arch

The work of Bacon et al. (2006) on the application of VERP for the Merced River in Yosemite National Park can provide further inspiration for the selection of indicators and standards of quality. Three zones were developed in the VERP process: (i) wilderness, (ii) diverse visitor experience, (iii) developed. Ten indicators were utilized, combining social and ecological conditions, with standards of quality based on best practice and available scientific research, as proposed in Table 1.

Table 1: Indicators, measurement, and standards of quality

Indicators	Method of measurement	Standards of quality
Trail encounters	Number of encounters with other parties along trails in wilderness	Zone 1A: max. 1 encounter per day, 80% of the time. Zone 1B: max. 1 encounter per 4h period, 80% of the time
People at one time	Number of people at one time along the river	No net increase from 2005 baseline at selected sites along the river
Parking capacity	Occupied parking versus capacity at Camp 6 day use parking area	Full designated parking to occur on no more than X (standard not yet set) days per year and X hours on average/day
Facilities availability	Percentage of available picnic tables versus area capacity at selected sites	Visitors able to find an open table 70% of the time at concession food services and picnic areas during peak hours in June-October
Wildlife exposure to human food	Percent compliance with food storage regulations	>= 95% compliance with food storage regulations in campgrounds and parking areas
Number of social trails	Number of social trailheads originating from roadside pull-outs	No net increase in number of social trailheads from 2004 baseline. No social trails for wetland features
Length of social trails	Length (m) of social trails through meadows	No net increase in length of social trails from 2004 baseline
Riverbank erosion	Condition-class assessments of riverbank	No net increase from 2005 baseline in linear extent of riverbank erosion that is accelerated or caused by human use

	erosion accelerated or caused by human use	
Ethnobotany	Extent/magnitude and usability of four plant species gathered by local tribe groups	No alteration of characteristics of the traditional cultural resources that make them eligible for listing on the National Register of Historic Places
Water quality	Total dissolved nitrogen, nitrate, total phosphorus, total dissolved phosphorus, fecal coliform or E. coli bacteria, and petroleum hydrocarbon content	Anti-degradation for each segment, for fecal coliform, nutrients, and petroleum hydrocarbons per sampling period

Source: Bacon et al. (2006, p.75-76)

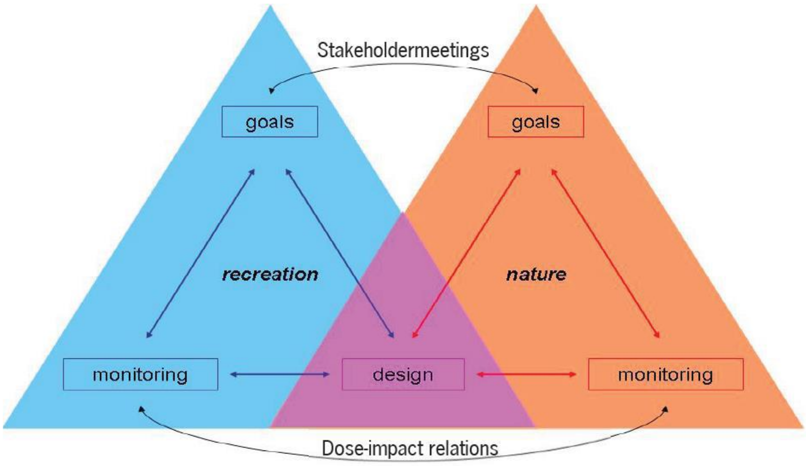
4.7 Other management frameworks

The Flemish *Agentschap Natuur & Bos* (Agency of Nature & Forestry) proposed a framework for recreational use of forests and nature areas in 2010, taking into account the ecological carrying capacity of an area. Central in the framework is the evaluation of the current level of ecological disruption and the estimation of expected disruptions as a function of:

- The vulnerability of present (or potentially present) fauna and vegetation types;
- Disruption due to specific types of recreation and the cumulative effect of different forms of recreation;
- Frequency of use and visitation;
- Environmental conditions caused by abiotic factors such as soil, humidity, and elevation;
- Period of use.

This framework therefore shows similarities to the previously discussed frameworks in that it highlights the needs for the identification of comparative resilience of different parts of nature areas and selected choices in the sort of recreation to allow and the zones where to allow it. At the same time, the model does not try to establish universal indicators and sees the approach towards ecological carrying capacity as a qualitative, rather than a quantitative exercise.

The PARENA schematic of Henkens et al. (2012), visualized in Figure 3 follows a similar logic, starting with a mapping of both recreational goals and ecological bottlenecks, connecting recreational activities with ecological carrying capacities through dose-impact relations that are supported by design and monitoring of activities and states.



Source: Henskens et al. (2012, p. 89)

Figure 3: PARENA-model

5. Monitoring needs and approaches

5.1 Identification of general monitoring needs and methods

As seen in the previous chapter, most monitoring frameworks highlight the importance of accounting for individual park characteristics, strategies, and stakeholder priorities. This could lead to a situation where there is a near complete lack in homogeneity of indicators and standards of quality. However, there are underlying principles to nature area recreation management that are relatively similar across different parks. Most importantly, the central concept of nature areas – and in particular national parks – is the combined focus of protection/conservation, and enjoyment by the public. For instance, as stated in Chapter 8 of the Management Policies of American National Parks and enshrined in legislation (National Park Services, n.d.): "National parks belong to all Americans, and the National Park Service will welcome all Americans to experience their parks. The Service will focus special attention on visitor enjoyment of the parks while recognizing that the NPS mission is to conserve unimpaired each park's natural and cultural resources and values for the enjoyment, education, and inspiration of present and future generations. The Service will also welcome international visitors, in keeping with its commitment to extend the benefits of natural and cultural resource conservation and outdoor recreation throughout the world." As such, there are clear dual, general monitoring needs on visitor experiences, on the one hand, and nature impacts, on the other hand – which is quite explicitly seen in the VERP-acronym itself.

5.1.1 Indicators related to visitor experiences

With regard to the monitoring of visitor experiences, important recurring indicators are visitor numbers, visitor satisfaction, visitor behaviour, and the availability and quality of facilities (Leung et al., 2018).

Visitor numbers and visitor flows

Visitor numbers, are a relevant aspect to monitor both due to their potential effect on the natural environment and due to their impact on the visitor experience of others. Visitor numbers can be (i) measured in totality (e.g. number of visitors per day), (ii) measured at specific points in the nature area – typically described as 'people at one time' (PAOT) at specific highlights, or (iii) measured in terms of number of encounters with other parties along trails. The latter becomes related to the analysis of visitor flows where the focus is less on absolute numbers but more on spatial and temporal spread of visitors across a larger area. Cessford and Muhar (2003) provide an overview of different measurement and monitoring strategies and the objectives different methodologies might serve. The research also discusses contextual differences that might inspire choices for particular measurement approaches. Street (as cited in Cessford & Muhar, 2003) mentions how use-level estimates in US National Parks Service is now primarily achieved via vehicle counters on key access roads, due to the vastness and remoteness of many US National Parks.

Cope and Hill (1997), and Cope et al. (2000) describe how, on the other hand, thanks to the relatively dense population in the UK, manual counting and visitor survey techniques often still lead to acceptable results. In Australia, McIntyre (1999) describes common combinations of car counts, automatic counters, ranger observations, and fee collection. In many cases, a blend of techniques are used with the choice for a particular method often being more opportunistic than systematic.

Cessford and Muhar (2003) identify four broad categories of counting techniques: (i) direct observations via staff, on-site camera recordings, or remote sensing via air photos by plane or satellite; (ii) On-site counters, devices recording and storing visitor counts at sites such as pressure, seismic or vibration plates and tubes, optical recording devices, magnetic sensing, or microwave sensing; (iii) Visit registrations through permits or visit registers, and (iv) Inferred counts via tertiary data such as car park counts, litter, trail deterioration, or interviews with visitors and/or park rangers. As seen from the overview given in Table 2, there are no uniquely optimal solutions, with low-technology options outperforming automatic monitoring systems in terms of collecting additional visitor characteristics, but on-site counting devices offering more stable, continuous visitor counts.

Table 2: Overview of different monitoring methods

Table 5. Coverage capacities of the different monitoring methods – what kinds of data they can normally collect.
A tick '✓' = a direct Yes; a question mark '?' = an indirect Yes (if hardware and software are specifically configured and calibrated to do so, and a specific sampling approach is taken), a dash '–' means No – this method cannot normally collect this.

Count methods	Visitor no's	Date & time	Travel direction	Route taken	Spatial distribution	Group size	Visitor features	Visitor behaviour
Observations								
– Roaming observers	?	✓	✓	?	?	✓	✓	✓
– Fixed observers	✓	✓	✓	?	?	✓	✓	✓
– Video recordings	✓	✓	✓	–	?	✓	✓	✓
– Time-lapse photo/video	✓	✓	✓	–	?	✓	?	?
– Aerial/satellite imagery	?	✓	–	–	?	?	–	–
On-site count devices								
– Mechanical	✓	?	?	–	?	?	–	–
– Pressure	✓	?	?	–	?	?	–	–
– Seismic/vibration	✓	?	?	–	?	?	–	–
– Active light beam	✓	?	?	–	?	?	–	–
– Passive IR sensor	✓	?	?	–	?	?	–	–
– Magnetic field	✓	?	?	–	?	?	–	–
– Microwave beam	✓	?	?	–	?	?	–	–
Visit registrations								
– Voluntary registers	?	?	?	?	?	?	?	–
– Compulsory registers	✓	✓	?	?	?	?	?	–
– Permits/bookings/fees	✓	?	?	?	?	?	?	–
Inferred counts								
– Indicative counts	?	?	?	?	?	?	?	?
– Interview counts	?	✓	✓	✓	?	✓	✓	✓

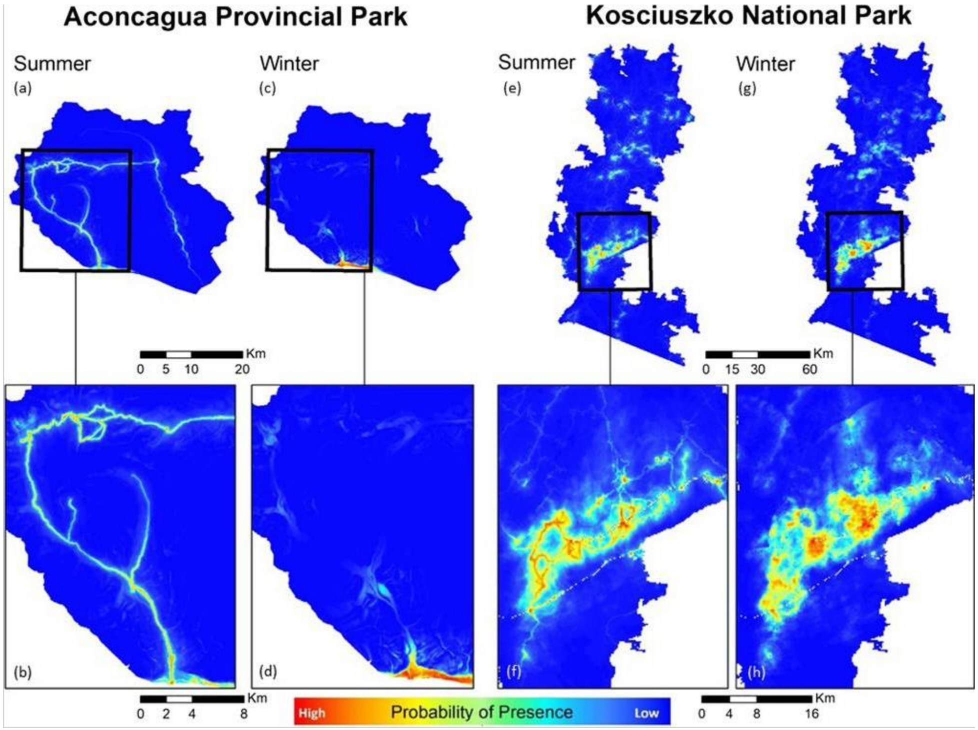
Source: Cessford & Muhar (2003, p.245)

One limitation of many non-GPS based counting strategies, is the lack of information on visitor flows and taken routes. Lawson et al. (2003) propose the use of computer travel simulation model, aimed at estimating a daily social carrying capacity and test a scenario analysis for the implementation of a bus system. In order to tweak the parameters of the model, questionnaires predated the simulation to understand general visitation behaviour – including questions on group size, the time spent traveling on the park roads, the places they paused at, how long those pauses lasted, and the route of the trip, marked on a map of the park. These visitor characteristics could then be adopted on data of traffic and trail counters in order to model travel routes.

Since Cessford and Muhar's (2003) overview, a rise in studies using GPS technologies has been observed. Such methods have the advantage of offering detailed data on routes taken and local hotspot analysis, therefore being uniquely capable of assessing visitor flows across larger areas. On the other hand, these methods underperform in the area of actual visitor counts, since extrapolations on the data are required in order to estimate amounts of users, rather than user spread. For instance, Orellana et al. (2012) provide a case study of GPS technology to produce information on the movement of people in Dwingelderveld National Park, Hallo et al. (2012) investigate the opportunities in Floyd and Patrick Counties, and Korpilo et al. (2017) apply smartphone tracking to Keskuspuisto to explore visitor spatial spread, off-trail movement, and local hotspot areas. While these methods are promising, challenges remain in terms of collecting such data. Past studies have either used GPS-trackers, which were temporarily handed to a sample of visitors, or collected data from mobile phone apps – both commercial and non-commercial.

Another relatively novel approach towards assessing total visitation, not discussed in the overview of Cessford and Muhar (2003), has been the use of location-based social media. In their literature review covering 58 studies that used social media resources, Wilkins et al. (2021) identified 20 research papers that attempted to measure visitation by comparing the user-days of social media posts (e.g., photos, tweets) with other data sources such as surveys, trail encounters, or agency-reported data. Social media analysis therefore always require a comparative alternative data-source for extrapolations. In the majority of cases, visitor numbers are aggregated across an entire park or nature area, not providing spatial or temporal patterns.

Wilkins et al. (2021) note how over half of studied papers using social media as data source, focus on spatial distribution of visitors, potentially coupled with an analysis of local attributes affecting visitor patterns. Such studies take advantage of social media data with geotagged locations, being based on Twitter, Flickr, Instagram or Strava. For instance, Walden-Schreiner et al. (2018) used geotagged photos on Flickr for two nature areas, Aconcagua Provincial Park, and Kosciuszko National Park, and compared these to traditional visitor data via entry permits, registration books, surveys, and/or traffic counters in order to identify whether geotagged images could serve as a proxy of visitor numbers and visitor distributions. The authors found significant correlations between the number of photos and the total number of visits, particularly in terms of seasonal trend. While the spatial pattern could not be directly compared to other data sources, the research findings linked most geotagged photos to places at or near visitor infrastructure, revealing hotspots at visitor centres, as well as main trails, and campsites (see Figure 4).



Source: Walden-Schreiner et al. (2018, p.788)

Figure 4: Seasonal presence of photos based on geotagged locations

Similarly, Barros et al. (2019) use geotagged photographs and GPS tracks from Flickr and Wikiloc to outline visitor characteristics such as spatial distribution, points of interest across the itinerary network, and temporal distribution in the Teide National Park. While such analyses could therefore be relevant and have the advantage of being low-cost, there are notable limitations as well. Representativeness of the sample might be skewed based on the social media platform that is selected, identified spatial patterns tend to be aggregated across time, therefore not allowing specific temporal scales, and data collection can be difficult since most social media platforms do not make their data easily available.

Visitor satisfaction

Visitor satisfaction is a defining characteristic of the quality of experience provided by nature areas. While simple in concept, the indicator can still be challenging to measure. Yüksel and Rimmington (1998) and Oliver (1993) discuss the importance of measuring satisfaction levels both at the level of attributes or dimensions and at the overall level. Furthermore, most studies conducted on satisfaction within the tourism industry are built on the premises of the expectancy-disconfirmation model (Oliver, 1980) and the perceived-performance model (Tse & Wilton, 1988), which suggest that users evaluate an experience against their prior expectations. Within the service industry, the SERVQUALinstrument has therefore been proposed to capture expectations and perceptions across five dimensions: reliability, assurance, tangibles, empathy, responsiveness (Parasuraman et al. (1988). While Naidoo et al. (2011) propose an application of SERVQUAL to nature-based tourism attractions, its embeddedness in the service sector, and its need for a relatively large questionnaire make it less applicable for integration in on-site visitor surveys at natural and recreational sites. As such, visitor surveys more often adopt simple experiential scales, asking to rate their experiences on a Likert-scale from 1 to 5 or 1 to 7, potentially subdividing the evaluation across a range of relevant experiences and highlights. For instance, Sæþórsdóttir and Hall (2021) adopt a questionnaire approach to measure visitor satisfaction in Landmannalaugar, approaching satisfaction both holistically – via a direct question "How satisfied or dissatisfied are you with your stay in Landmannalaugar?" – and a series of sequential encounters on other site attributes that can contribute to satisfaction – with questions on crowding perception, perceptions of environmental conditions and appropriate structures.

Another approach toward measuring visitor satisfaction, popularized in the last two decades, is to equate satisfaction with loyalty in terms of repeat visitation or intention to recommend (Pearce & Dowling, 2019). A popular metric, due to its simplicity in use and communication, is the net promoter score (NPS), as adopted from market research. Calculation of the NPS only requires a single survey question, asking respondents to rate the likelihood that they would recommend a product, company or experience to a friend or colleague on a scale from 0 to 10. The NPS is then measured by subtracting the percentage of 'detractors ' – respondents with ratings of 6 or lower – from the percentage of 'promotors' – giving a rating of 9 or 10.

Apart from approaches requiring visitor surveys to collect data from customers, there is an increased interest in investigating possibilities of extracting online user generated content to map visitor experiences and satisfaction. Such approach has the advantage of being non-intrusive, efficient, larger in scope, with potential for longitudinal applications. On the other hand, these methods require more data proficiency and are generally limited in terms of potential visitor segmentation, since additional questions on visitor expectations and behaviour can – at best – only be inferred (e.g. through sentiment analysis) and are often completely absent. In their literature review on the uses and limitations of social media to inform visitor use management in parks and protected areas, Wilkins et al. (2021) identify three main topics of social media analyses: (i) estimate the total number of visitors, (ii) explore the spatial distribution of visitors, (iii) understand various aspects of the visitor experience. In terms of the latter topic, Stoleriu et al. (2019) combine a mixed methodology of qualitative narratives and computer analysis to examine visitors' experiences of the Danube Delta via the analysis of TripAdvisor reviews from 2011 to 2017, exploring both general satisfaction and main elements contributing to or detracting from this satisfaction. Similar approaches can be found in Niezgoda et al. (2020), who studied visitor satisfaction in the Tatra National Park, and Sergiacomi et al.

(2022), who reviewed user-generated content for Plitvice Lakes National Park. All three studies used TripAdvisor as the basis for their analysis. A different data source was used by Plunz et al. (2019) who conducted a Twitter sentiment analysis for New York City Parks in order to measure their contribution to general well-being. While these studies underline the potential of user-generated content, there can be valid concerns around sample representativeness, biases, and accessibility of the data.

Visitor behaviour

Visitor behaviour aims to observe visitor activities to ensure compliance with park rules, promote environmentally responsible behaviour, and avoid conflicts between user groups. Visitor behaviour can be analysed indirectly via interviews with local experts (e.g., park rangers), assessed via visitor surveys, or be inferred from photo analysis. By far the most common method for tracking visitor behaviour is through the use of questionnaires. For instance, Smith-Sebasto & D'Costa (2010) developed a Likert-type scale to predict environmentally responsible behaviour across a range of 187 behaviours across six different categories. Gao et al. (2021) used a simplified scale to assess environmentally responsible behaviour in Shennongjia National Park and study its correlations with environmental knowledge and situational factors, finding that situational factors, environmental interpretation, and staff guidance all had a positive moderating effect on the relationship between environmental knowledge and pro-environmental behaviour in the park. Kim et al. (2011) similarly investigated effects of interpretation on visitors' environmental attitudes and behaviour in the coastal area of Lulworth in England via an on-site visitor survey. The authors found that while interpretation fostered visitors' awareness and support for management policies, the effectiveness varied in relation to the types of environmental behaviour and local conservation issues. Another practical example of measuring visitor behaviour can be found in The People and Nature Survey for England, from Natural England (2020), which includes 21 questions on pro-environmental visitor behaviour, as well as additional questions on pro-environmental attitudes in general.

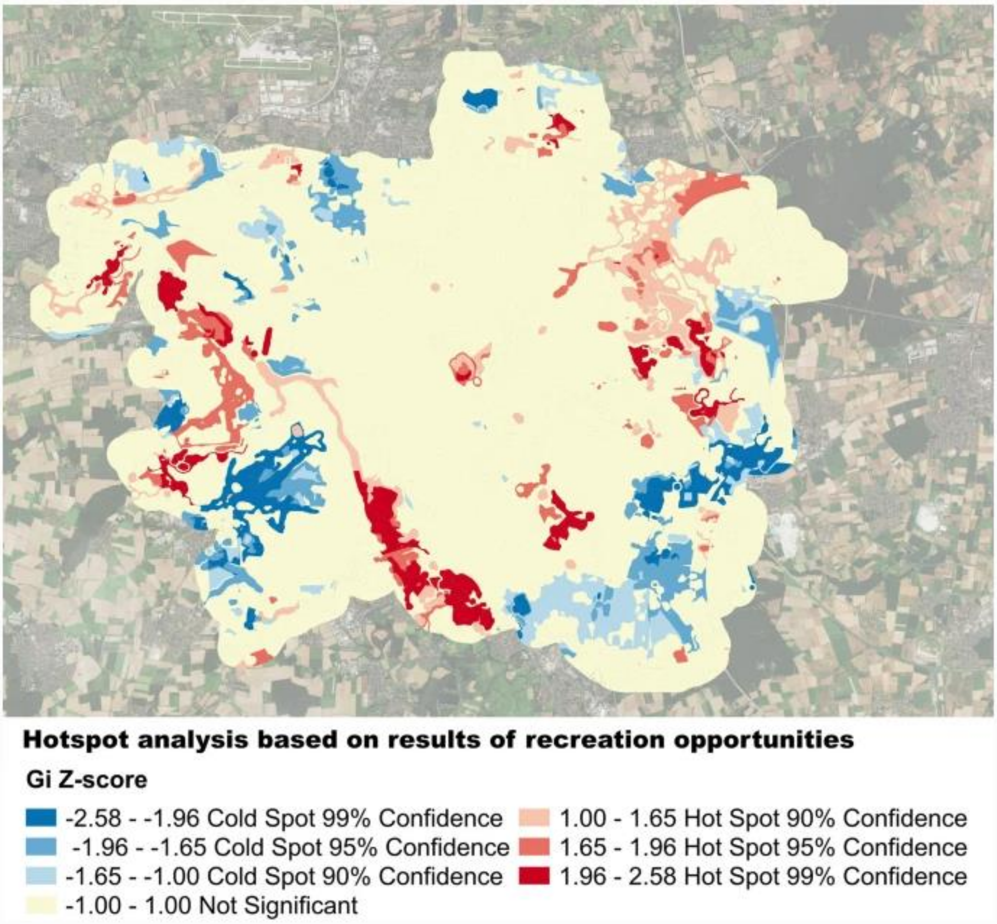
Liang et al. (2019) propose an alternative to traditional surveys by leveraging user-generated content and analysing unwanted visitor behaviour in the Greater Kruger National Park through monitoring of online tourist photographs. The authors collected 15,968 Instagram images for the nationally owned and 19,331 images for the privately owned parks within the Greater Kruger National Park area, of which a random sample of 6000 was selected for further analysis by a rater. Unwanted behaviour was based on the Kruger National Park regulations and included: (i) out of car, (ii) protruding from car, (iii) close contact, (iv) alcohol, (v) litter, and (vi) other dangerous behaviour such as sitting on a driver's lap, sitting on a fence, etc. Due to the limitation of photographic evidence, some unwanted behaviours could not be included in the analysis, such as driving on no-entry roads. All photos were categorized across normal and unwanted behaviour, with the authors finding that approximately 7% of photographs depicted instances of potentially unwanted behaviour.

While the proposed use of online photography has the advantage of large-scale, unobtrusive data collection, the method can become very cumbersome when manual rating is required. Väisänen et al. (2021) propose an alternative rating methodology, exploring human-nature interactions with social media via computer vision analysis. Applying their analysis on photographs taken in Finnish national parks, the authors report good results of automatic categorization, even though their methodology is limited to establishing more general visual themes. The reliability of applying such methodology to investigate distinct visitor behaviours rather than general landscape elements remains unexplored. As a result, even though online photography can offer insights into types and frequency of unwanted behaviour, there are clear limits in the types of behaviour that are detectable, which is coupled with potential self-selection bias in captured behaviour and a relatively time-intensive analysis.

Availability and quality of facilities

Mapping the availability and quality of facilities, can offer insights into areas where tourism development is more concentrated and supporting facilities might improve visitor experiences – at least for visitors not specifically seeking out solitude and true wilderness experiences. This type of exercise is important for developing a Recreational Opportunity Spectrum (ROS) within nature areas and ensure appropriate links between visitor segments, and available facilities (Yun et al., 2022). Oishi (2013) highlights the importance of proper trail classification to combine ecological conservation efforts and quality of the visitor experience. The author uses a ROS-approach to determine park visitors' preferences and their experiences with actual trail conditions based on seven parameters: access, remoteness, naturalness, facilities and site management, social encounters, visitor impact, and visitor management. Generally speaking, areas with better facilities and accessibility can cater to larger demand and mainstream visitation, while more niche-based visitors aiming for a wilderness experience can better be diverted to areas with less facilities.

The presence of adequate facilities is particularly important in terms of improving accessibility to nature for people experiencing certain disadvantages – ranging from mobility poverty to physical disabilities or lowered physical capabilities. Wen et al. (2022) focus on the needs of elderly people for nature-based recreation, assessing demand, recreation potential, and opportunities through a spatial framework, including landscape aesthetics, various types of facilities, and proximity. The authors overlay a variety of thematic maps from various official sources and OpenStreetMap. A hotspot analysis, shown in Figure 5, then maps the areas with high to low development potential for this particular segment of users.



Source: Wen et al. (2022, p.12)

Figure 5: Hotspot analysis of nature-based recreation opportunities

5.1.2 Indicators related to ecological conditions

In terms of selecting and monitoring ecological conditions of the park, it is useful to briefly reflect back on the main potential ecological impacts related to recreation and tourism development in nature areas, as was also discussed in MONA D1.1.1. Main potential impact types and potential mitigation/exacerbation factors are highlighted and repeated in Table 3.

Table 3: Potential ecological impacts

Impact categories	Type of potential impacts	Potential mitigation/exacerbation
Soil	- Soil compaction, increase in soil density - Prevention of germination, plant root penetration, water permeability - Formation of puddles and contribution to trail muddiness - Erosion	- Soil structure - Slope of terrain - Use level - Type of use
Vegetation	- Decrease in vegetation cover	- Plant resistance

	- Changes in species composition with graminoids replacing herbaceous plants	- Plant resilience
Water	- Flow alteration, shoreline erosion, turbidity - Introduction of non-native species - Increase in bacteria and protozoa - Nutrient impacts on oxygen levels - Pollution from soaps, sunscreen, food particles, waste	- Type of visitor activities - Slope of terrain near shoreline
Wildlife	- Death or injuries to wildlife - Temporal or permanent spatial displacement - Changes in animal behaviour - Effect on reproductive ability	- Animal type - Visitor behaviour

Monitoring of ecological quality and potential recreational effects can be complex and is often very location-dependent. We can therefore distinguish between more general, high-level approaches to indicator collection and monitoring, and locally relevant, often resource-intensive data collection.

Vegetation cover and health

Methods to measure vegetation cover and health broadly fall under two categories: via on-site segment sampling, or via remote sensing techniques. The former approach can take different, relatively similar forms. Quadrat sampling places a square or rectangular frame on the ground, recording all species and abundance of plants within it, providing a systematic way of sampling vegetation – count, cover, density frequency – in defined areas. Quadrat sampling is generally more limited in scope, typically selecting random sampling plots of 100m² (Hao et al., 2020). Plot-based sampling follows a similar methodology of dividing areas in different plots, but tends to involve larger plots of land in which vegetation characteristics are recorded in more detail. Since plot-based sampling techniques or quadrat methods are time-consuming and the plot pattern – size, shape, direction – are an important issue for the fieldwork, plotless sampling techniques have been developed, replacing quadrat-based measurements with linear recordings. As such, line and belt transects, or point-intercept methods, take a more linear approach. Within a line and belt transect approach, a line or belt is laid out across the study area, recording vegetation along the line. Quite similarly, point-intercept methods involve placing rods at regular intervals along a transect, recording all vegetation species along the line. By reducing the sampling unit to a starting point, problems of size and shape of plots are avoided (Amagnide et al., 2021; Crum et al., 2021).

An alternative approach to consistently measure density and health of vegetation via non-intrusive, low-cost measures, is the use of remote sensing for the calculation of indices, such as the Normalized Difference Vegetation Index (NDVI), as proposed by Kriegler et al. (1969). The NDVI is a widely-used metric to calculate the health and density of vegetation via spectrometric data at red and near-infrared bands. It has been found to be effective for expressive vegetation status and quantified vegetation attributes (Huang et al., 2020; Rhew et al., 2011), while also being easy to interpret and compare. Values of the metric range between -1 and 1. Negative values correspond to bodies of water, while values close to zero generally correspond to barren areas of rock, sand, snow, or concrete surfaces. Positive values relate to vegetation including crops, shrubs, grasses, and forests, with greater values implying more extensive green vegetation (Jones & Vaughan, 2010).

The reason behind the NDVI calculation lies in the fact that green plants absorb solar radiation within the photosynthetically active radiation (PAR) range for photosynthesis. Meanwhile, leaf cells have adapted to re-emit solar radiation in the near-infrared spectrum. Consequently, live green plants tend to appear darker in the PAR due to absorption, and brighter in the near-infrared due to reflection. The impact on light wavelengths increases with the number of leaves. In contrast, clouds and snow exhibit the opposite pattern, appearing brighter in red wavelengths and darker in the near-infrared. The NDVI is calculated based on these differences as:

$$NDVI = \frac{(NIR - Red)}{(NIR + Red)}$$

In general, if there is much more reflected radiation in near-infrared wavelengths than in visible wavelengths, then the vegetation is likely to be dense.

Landscape fragmentation

Landscape fragmentation is a critical indicator to monitor in nature areas due to its significant impacts on wildlife migration, erosion, and ecosystem health. Fragmented landscapes disrupt the continuity of habitats, creating isolated patches that can hinder the movement and migration of wildlife. This can lead to reduced genetic diversity, increased vulnerability to predators, and challenges in finding food and mates. Fragmentation also exacerbates soil erosion, as smaller, isolated patches may lack sufficient vegetation cover to stabilize the soil. Additionally, fragmented landscapes can alter water flow patterns, leading to increased runoff and potential flooding. Monitoring landscape fragmentation helps in identifying areas at risk, planning conservation strategies, and ensuring the long-term sustainability of natural ecosystems. As noted by Jaeger et al. (2007), there has been an increased interest in indicators concerning landscape fragmentation due to transport infrastructure and urban development. The most common approach to evaluating landscape fragmentation is applying remote sensing via satellite imagery and Geographic Information Systems to analyse land cover and landscape patterns. Metrics such as patch size, edge density, and connectivity can then be calculated.

The effective mesh size (m_{eff}) is such a measure of connectivity, expressing the probability of two randomly chosen points in a region being connected without separation by barriers such as roads, railroads urban zones, or any other criteria selected. The more barriers in the landscape, the lower the probability that random points will be connected, and the lower the effective mesh size will be, expressed as:

$$m_{eff} = A_t C = \frac{1}{A}\sum_{i=1}^{n} A_i^2$$

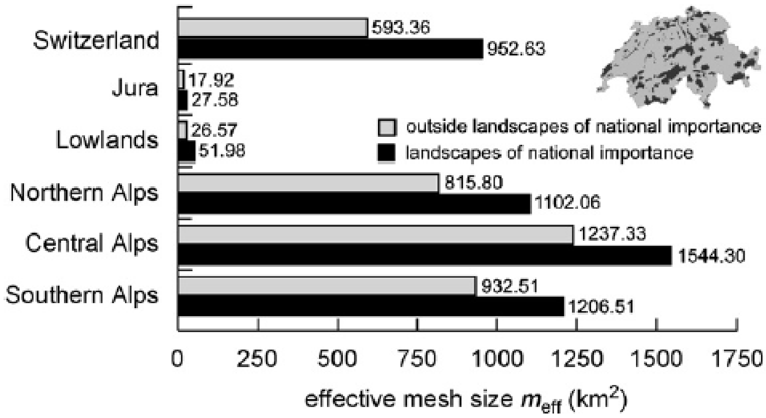
With the connection probability calculated as:

$$C = \sum_{i=1}^{n} \left(\frac{A_i}{A_t}\right)^2$$

The maximum value of m_{eff} is found for a completely undisturbed landscape, where the size of m_{eff} will equal the size of the total area, while the minimum value of 0 km² would occur if an area is completely covered by transport and built structures. For an evenly divided landscape, m_{eff} will more or less equal the average size of these patches, albeit with larger weights being assigned to large patches.

The application of effective mesh size requires specification by the user on the types of landscape elements to be considered as causes for fragmentation which, together with the choice of regional scale, defines the fragmentation geometry (FG). This also implies that multiple effective mesh sizes could be calculated, depending on the type of barriers (e.g., only motorized roads and railways, motorized and non-motorized roads, hiking paths). For instance, in their application of m_{eff} for the entire country of Switzerland, Jaeger et al. (2007) adopt four fragmentation geographies, with the first FGs only taking into account anthropogenic barriers, and FG2, 3, 4 combining anthropogenic barriers with different natural elements such as rivers, lakes and mountains. In terms of anthropogenic barriers, all landscape elements were included that have been shown to impede the movement of animal species and/or limit recreational opportunities or act as a source of emissions (Forman et al., 2003; Trombulak & Frissell, 2000). These elements included motorways, roads[2], railroads, areas of urban development and industrial zones.

[2] Including class 1 roads, defined as at least 6m wide and of national importance for road traffic, class 2 roads, defined as at least 4m wide, paved and providing relevant connections between towns, and class 3 roads, defined as being at least 2.8m wide, mostly paved and usable under all weather conditions.



Source: Jaeger et al. (2007, p.746)

Figure 6: Effective mesh size in landscapes of national importance

Use of m_{eff} for identifying landscape fragmentation of natural areas can be seen from Figure 6, where Jaeger et al. (2007) compare FG1 landscape fragmentation within landscapes of national importance, where the main objective is to preserve landscapes that are natural or close to natural, to other areas in the same region, noting that the m_{eff} is 60% to 95% higher in such ecological landscapes.

Informal trails: amount, length and patch sizes

Straying of designated pathways can exacerbate the effect visitors have on soil composition. As noted by Leung et al. (2011), visitor-created informal trails, also referred to as social trails, can create significant management challenges due to the lack of proper design and possible inappropriate trail locations. Their negative ecological impacts are related – albeit in smaller magnitude – to roads in that they lead to an increased habitat fragmentation which might particularly impact vegetation composition on threated paths, hydrology through the alteration of surface and subsurface flows, and present barriers for small wildlife.

In the VERP-application for the Merced River in Yosemite National Park, Bacon et al. (2006) propose relatively simple measurements for social trails, proposing both counts of the number of social trailheads originating from roadside pull-outs, and the length of these social trails through the meadows. However, such indicators require on-site evaluations since social trails are not available as simple route structure data but mostly require on-site measurement or high-resolution aerial photography.

Leung et al. (2011), propose two further indicators to measure meadow fragmentation as a result of informal trails: the Weighted Mean Patch Index (WMPI) and the Largest Five Patches Index (L5PI). WMPI is conceptually related to m_{eff}, with the main difference being – besides mathematical variations in computation – the selection of landscape fragmentation element, which uses social trails in WMPI as opposed to planned man-made route structures and developments. As such, it is more specifically designed for use in protected areas and vulnerable landscapes. WMPI is indicative of average size of undisturbed patches with consideration of overall habitat reduction due to informal trailing and is measured in hectares as:

$$WMPI = \left(\frac{\sum a_{ij}}{A}\right) * \left(\sum \frac{a_{ij}}{n}\right) * \left(\frac{1}{10000}\right)$$

With a_{ij} being the area (m²) of patch *ij*, *n* the total number of patches, and *A* the landscape/meadow total area. The latter metric is measured as a percentage as:

$$L5PI = \sum \frac{max5(a_{ij})}{A} * 100$$

While computationally relatively simple, the challenge in calculating the WMPI lies in identifying and mapping social trails.

Water quality

Many nature areas and national parks include significant bodies of water which are crucial for preserving the ecosystem, while also sometimes offering recreational opportunities. Due to human activities the quality of water can be negatively affected, for instance because of pollution by food waste, sunscreen, faecal matter, or increased turbidity when riverbanks become eroded or soil is kicked up. Monitoring water quality should therefore be conducted on a relatively frequent basis, combining physical measurements, including temperature, pH, and turbidity, with a chemical analysis testing for nutrients like nitrates and phosphates, and other chemicals, and biological monitoring to assess the presence and abundance of aquatic organisms.

While water quality would thus mostly require on-site sample collection and laboratory analysis, satellite and aerial imagery has found some use in monitoring large water bodies, particularly for tracking algal blooms, sedimentation and other large-scale changes (Jaywant & Arif, 2024; Raghul & Porchelvan, 2024).

Wildlife quantity, diversity, and behaviour

Monitoring wildlife and potential changes in wildlife composition and behaviour as a result of recreation and visitation requires a combination of techniques. Similar to vegetation assessment, quadrants and transect walks can be employed to create an inventory of animal species within sample regions. Given the territoriality of animals, results can depend strongly on the selected transects and plots. Furthermore, the methodology is not suitable for all species of wildlife. Regular field surveys are often combined with strategically located camera traps – particularly useful for monitoring nocturnal species – radio telemetry and GPS tracking, where animals are fitted with radio collars or GPS devices to track movements and behaviour, and acoustic monitoring, where recording and analysing animal sounds can help to monitor birds, amphibians, and insects (Petso, et al., 2022; Sharma, et al. 2023).

5.2 Links to individual nature area strategies in MONA

In this section, we focus on more specific monitoring needs of the nature areas that are consortium partners within the MONA project, reflecting on their general challenges and pursued strategies, as defined within Activities 1.1 and 1.3 of WP1. The nature areas are organized by pilot topics, since there is higher similarity in monitoring needs within similar pilot strategies. The MONA project is organized around three pilots: (i) modal shift, highlighting strategies aimed at improving the use of public transport – and particularly train stations – for visitation, (ii) routing, focusing on creating new and alternative entrances to nature areas to more evenly distribute visitors and visitor pressures, and (iii) nudging, developing actions to improve pro-environmental behaviour of users.

5.2.1 Pilot A: Modal shift

The three MONA partners participating in Modal shift are Nationaal Park Utrechtse Heuvelrug, Grenspark Kalmthoutse Heide, and Montagne de Reims Regional Park. Analysing the stated objectives of these parks within the strategic documents of Activity 1.3, we see a strong similarity. All parks focus on improving facilities to support a modal shift by improving the attractivity and accessibility of train stations and their linkages with the national park as green entrances – possibly combined via shared mobility systems. Furthermore, the partners aim to improve visitor information in order to guide visitors towards more sustainable transportation choices, as well as alternative starting points. Finally, in order to develop a sustainable mobility strategy within a relevant regional framework, stakeholder participation and engagement is an outspoken objective.

Table 4: KPIs and measurement needs for Modal shift

Nationaal Park Utrechtse Heuvelrug	
Objectives	(i) Develop regional vision on sustainable mobility; (ii) Improve facilities to support modal shift; (iii) Improve visitor information for better guidance
KPIs	(i) Stakeholder engagement levels and feedback; (ii) Increased usage of train stations; (iii) Usage of shared mobility systems; (iv) Usage of digital starting point map
Measure-ment	- Stakeholder engagement tracked by active participation in regular meetings - Changes in percentage of visitors using public transport monitored via repeat visitor surveys or from direct metrics and monitoring of train station usage and shared mobility - Changes in visitors indicating lack of information as a reason for non-sustainable transportation choices can be identified via repeat surveys - Usage of digital starting point map can be inferred from visitor surveys or from direct measurement of web traffic
Grenspark Kalmthoutse Heide	

Objectives	(i) Enhance connectivity between train stations; (ii) Assess options for soft mobility; (iii) Transform train stations in "green entrances"
KPIs	(i) Increased use of public transportation (specifically trains); (ii) Decreased parking occupancy rates; (iii) Reduced parking disturbance for local residents; (iv) Increased use of bicycle parking facilities; (v) Increased use of shared mobility options; (vi) Increased use of digital visitor map and accessibility page
Measure-ment	- Increased use of public transportation and reduced parking disturbance for local residents measured through repeat surveys of visitors and residents - Decreased parking occupancy ideally measured through direct counting of parking use via (automatic) counters at entrance and exit - Higher usage of bicycle parking requires monitoring approach at parking level, either manually or via automatic counters or smart cameras - Increase in shared mobility assessed indirectly via surveying transportation choices of visitors, or directly via analytics of shared mobility systems - Website analytics of visitor access to website. Since increased use of digital visitor map and accessibility page are indirect factors serving higher-level motive of a more equal spread of recreational pressures, tracking visitor flows can provide additional information on the KPI
Montagne de Reims Regional Park	
Objectives	(i) Improve coordination with tourism stakeholders and mobility operators; (ii) Improve train use among visitors to reach the park; (iii) Implement measures to improve visitor information and visitor experience
KPIs	(i) Stakeholder engagement levels and feedback; (ii) Reduction in car use to reach different nature areas within the park; (iii) Increased visitor access with train to lesser-known and less fragile nature areas around stations
Measure-ment	- Stakeholder engagement and participation in project meetings - Reduction in car use and increased visitor access by train, measurable by repeat visitor surveys - Information from visitor counters and feedback from municipalities and stakeholders to observe increase in visitation to lesser-known nature areas around train stations

5.2.2 Pilot B: Routing

Three MONA partners participate in the Routing-pilot: VisitBrabant, Tourism Province of Antwerp, and Natuurmonumenten – National Park Veluwezoom. Similar to the parks participating in pilot A, there is a significant overlap in objectives and activities with the focus in this pilot being on the creation of a visitor entry points map, testing accessibility of different entry points, and creating zoning maps to declare priorities in visitor concentration or dispersion. Given the parallel in objectives, monitoring of these objectives can also take a similar form.

Table 5: KPIs and measurement needs for Routing

VisitBrabant

Objectives	(i) Create solutions to assist in visitor flow dispersion; (ii) Cooperate with stakeholders on sustainable visitor management and joint communication and promotion; (iii) Proven methods that can be scaled up to other areas
KPIs	(i) Stakeholder engagement levels and feedback; (ii) (Increased) usage of the starting point map; (iii) Reduction in visitor density in highly trafficked areas and increased visitor access to lesser-known areas; (iv) Facilities for disadvantages groups
Measure-ment	- Stakeholder engagement tracked by active participation in regular meetings - Tracking and analytics on the online entry-point platform, specifically assessing visitor flows and entry-point usage trends - Monitoring of visitor pressure across different nature areas by GPS data
Tourism Province of Antwerp	
Objectives	(i) Have an updated, high quality, hiking network, spread throughout the province, (ii) Have insights and lessons learned on monitoring visitors and defining pressure on nature, (iii) Improved stakeholder cooperation concerning sustainable tourism and visitor management
KPIs	(i) Increase of unpaved trajectories in updated hiking network (as a proxy for quality), (ii) Increase of data on recreational pressure, (iii) Higher stakeholder engagement levels
Measure-ment	- Stakeholder engagement tracked by active participation in regular meetings - Data analysis of starting points and route data via Geographic Information Systems - Monitoring of visitor and mobility flows in two pilot areas - Visitor data from routing applications and visitor surveys
Natuurmonumenten – National Park Veluwezoom	
Objectives	(i) Implement a proven package of project solutions (road closure, paid parking, relocation of parking lots), that help to create a sustainable visitor flow; (ii) Have verifiable less motorized traffic movement within the nature park; (iii) Have a framework of activities that can be copied and scaled up
KPIs	(i) Reduction in motorized traffic movements within the park; (ii) Reduction in the use of parking lots; (iii) Increase in the use of sustainable traffic methods; (iv) Increase in visitor satisfaction
Measure-ment	- Tracking/monitoring of visitor pressure by traffic study - Visitor satisfaction survey

5.2.3 Pilot C: Nudging

Finally, three MONA-partners work together within a pilot that is aimed at changing visitor behaviour towards being more pro-environmental via use of nudging. The partners involved are Montagne de Reims Regional Park, Regional Park Scarpe-Escaut, and Tourismus Zentrale Saarland. Similar to the other two pilot groups, there are similarities in objectives and scope, particularly related to stakeholder engagement and integration, and the nudging of visitors towards pro-environmental behavioural changes. Given the individual nature of experimental nudges, the direct effect of nudges will require an individual approach that cannot be holistically captured.

Table 6: KPIs and measurement needs for Nudging

Montagne de Reims Regional Park	
Objectives	(i) Develop a methodology and network for organising outdoor sports events in the park; (ii) Develop efficient nudging tools to encourage people towards pro-environmental behaviour; (iii) Develop an efficient communication campaign in order to raise awareness; (iv) Improve understanding of the challenges of preserving natural environments with visitors and sports practitioners
KPIs	(i) Engagement of event organizers to create responsible events; (ii) Number of nudges deployed and evaluation of their effectiveness; (iii) Engagement of individual practitioners for a sustainable and responsible practice; (iv) Acceptability of nudges as perceived by visitors
Measure-ment	- Number of joint actions with local partners, number of signatories of the charter for responsible events, and number of participants to the Technical Committee of Outdoor Activities - Surveys of visitors and practitioners to understand the engagement with sustainable and responsible sports practice - On-site analysis of impacts of experimental nudges - Number of (or hectares of) “quiet zones” being introduced in the park
Regional Park Scarpe-Escaut	
Objectives	(i) Experiment with nudges to promote behavioural change towards pro-environmental behaviour; (ii) Implement, evaluate, and create nudges that can inspire other organizations; (iii) Create a sustainable cooperation with stakeholders; (iv) Create an approach and activities that can be shared and scaled up
KPIs	(i) Visitors exhibiting more pro-environmental behaviour and following general guidelines; (ii) Nudges are assessed via appropriate assessment tool; (iii) Higher stakeholder engagement levels are achieved
Measure-ment	- Stakeholder engagement tracked by active participation in regular meetings - Behavioural change and perception towards pro-environmental behaviour is measured by visitor surveys - Number of views/spread of the package of nudging measures for sustainable tourism development
Tourismus Zentrale Saarland	
Objectives	(i) Provide recommendations to other stakeholders on the potential of nudges for different stakeholder groups; (ii) Also learn from pilot A and pilot B to make recommendations to local stakeholders
KPIs	(i) A package of nudging measures for different challenges and target groups is developed; (ii) Nudging measures are assessed; (iii) Recommendations are made for local stakeholders on how to implement nudges
Measure-ment	- Identifying common visitor behaviour and challenges via a visitor survey - Measuring acceptance of nudges (e.g., temporary shuttle bus to Orchid Area), via visitor survey or dialogue with local professionals

5.3 Combining general and specific monitoring needs

After the discussion on general monitoring needs and methods, and MONA-specific monitoring needs, related to the objectives and actions of the project partners, we now propose a holistic framework that combines both levels of measurement, framed within local contextual needs, and existing opportunities for data collection, as outlined in Figure 7.

First of all, the colour of the nodes warrants explanation. Red nodes delineate indicators that have already been collected, and that are briefly discussed in the next chapter. White nodes represent indicators for which data is not yet collected, but for which collection strategies are foreseen to take place in the coming MONA project period. Such indicators can therefore gradually be included in the monitoring framework during the running of the project. Finally, green nodes represent indicators that are only indirectly assessed – mostly via survey questions – rather than being directly measured.

From top to bottom, the figure identifies general monitoring needs and indicators to be collected for the different MONA partners, as well as a proposal on how these indicators can be operationalized. The nodes on the axis represent the nature areas for which specific indicators are – or can be – collected. Given the focus of MONA on nature-based recreation and transportation, multiple indicators are proposed to provide an overview of visitor flows, visitor behaviour, visitor satisfaction, and availability of recreational facilities. In terms of ecological conditions, while visitor impacts are indirectly measured through perceptions of visitors and residents – via surveys – a more direct approach is provided for indicators on vegetation cover and landscape fragmentation. While social trails could be important and significant to include, given the demanding nature of collecting such information, a proxy-approach is suggested, only collecting indication of the relevance of off-trail hiking through perception-based questions for visitors and residents. Noticeably absent are indicators on water quality and wildlife. These dimensions are excluded due to (i) the fact that significant bodies are not present in all study areas, (ii) the relatively limited expected wildlife impact of visitor activities in the study areas, and (iii) the resource-intensive nature of collecting data on such indicators, requiring chemical and/or biological expertise, while these topics are not central to the MONA project.

From bottom to top, the figure highlights more project-specific indicators, related to three central aspects: (i) modal transportation, (ii) starting point mapping and information dissemination for positive change, and (iii) stakeholder cooperation. For many of these indicators, their relevance is connected to the objectives of the nature area, therefore not necessarily collected across all nature areas. Furthermore, it is noticeable that many of the indicators are currently not yet measured, since they relate to ongoing or planned activities of partner areas for which actual monitoring has yet to happen.

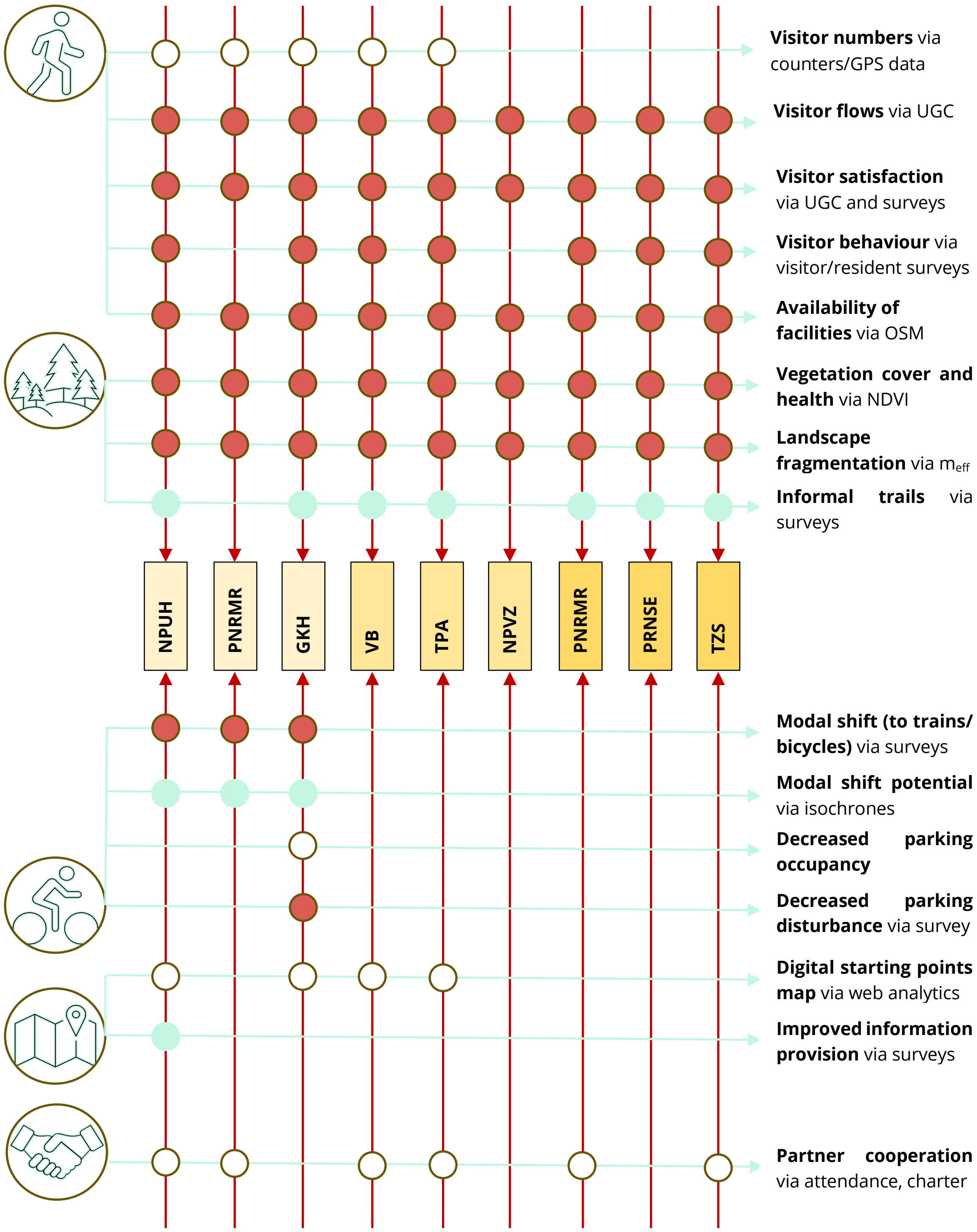


Figure 7: Holistic monitoring framework for MONA

It is also important to note that there can be overlap between the top part of the model (the general indicator sets) and the bottom part (the indicators related to nature area strategies and objectives). Particularly in terms of visitor dispersion and the creation of new entrance points to nature areas, relevant indicators are already included in the general indicator set.

6. Indicators and monitoring approaches in MONA

In this final section we propose different indicators and measurement approaches as applied to the MONA project, combining both general and project-specific indicators and methods and using a combination of primary data collection and secondary sources from user-generated content, website scraping, and remote sensing. The overview of monitoring items takes a single partner as proof-of-concept, but for the majority of indicators, monitoring will happen for all parks (see Figure 7). Furthermore, the indicators proposed here are based on the current situation. With multiple activities still being organized – in particular Activity 1.8 on visitor flow analysis – the monitoring approach will be expanded on whenever new information becomes available.

6.1 Visitor experiences

6.1.1 Visitor numbers and visitor flows

Within the MONA project, visitor numbers and visitor flows are being monitored in a number of ways. Activity 1.8 of WP1, will specifically analyse visitor flows in three participating parks, using varied types of visitor counters. These results will help to populate the monitoring framework with expansive data on park visitation, once available. However, not all parks have the opportunity or strategy to purchase counting instruments. Therefore, alternative approaches were followed to provide an indication of spatial spread: questionnaires, and analysis of user-generated content.

Visitor surveys

While visitor surveys are not the most accurate measures of visitor spread, they can allow for a broader understanding of the areas that are more popular among recreationists. Within MONA Activity 1.6 some nature areas opted to include an open-ended question in this regard, asking people about the areas that were visited. Underlying table provides the results collected in Utrechtse Heuvelrug, indicating that Bossen Lage Vuursche (43.5%) were the most popular area in Utrechtse Heuvelrug, followed by Amerongse Berg (29.1%), and Bossen Leersumse Veld. Importantly though, 18.0% of respondents mention that they are not aware of the locations they visited, showing the limitations of relying on recollection and recognition by visitors.

Table 7: Regional spread in Utrechtse Heuvelrug

Area	Percentage
Bossen Lage Vuursche	43.5%
Baarnse Bos	19.0%
Landgoed Groeneveld	16.7%
Kaapse Bossen	20.3%
Doornse Gat	12.4%
Bossen Leersumse Veld	22.2%

Amerongse Berg	29.1%
I don't know	18.0%

Source: MONA D1.6.1

User-generated content

In order to take advantage of available online route data for hiking and cycling-related activities, the MONA-project collected data from http://www.komoot.com. Komoot is a route planning app for outdoor activities, with an active user base of over 40 million registered users where users can find, share, plan and evaluate routes. The database can be searched by nature area, providing route collections for each of the MONA partners. In order to leverage the available data, we used KomootGPX, by Tim Schneeberger, Marcin Gryszkalis, Simon Legner, and Gerald Pape, to bulk download Komoot tracks and highlights as GPX files, and wrote a Python Selenium script to scrape additional information about each hiking route in terms of length, duration, experience level, ratings, number of hikers, and waypoints. Since the number of hikers provides an indication of the number of registered Komoot users that followed a particular route, the comparative differences between routes can be indicative of popularity – and therefore, visitor spread.

As a proof-of-concept, we provide the analysis for Wortel-Kolonie, one of the partnering nature areas of Tourism Province of Antwerp. The Komoot database includes 38 hikes within Wortel-Kolonie, 21 of which were labeled 'easy', 13 'moderate', and 3 'difficult'. The mean hiking distance was 9.07 km, with an average time of 137.79 minutes. Figure 8 provides an overview of the distribution of trails in terms of average distance and average hiking time, indicating that a majority of routes are below 10m and take a hiking time between 0 and 150 minutes.

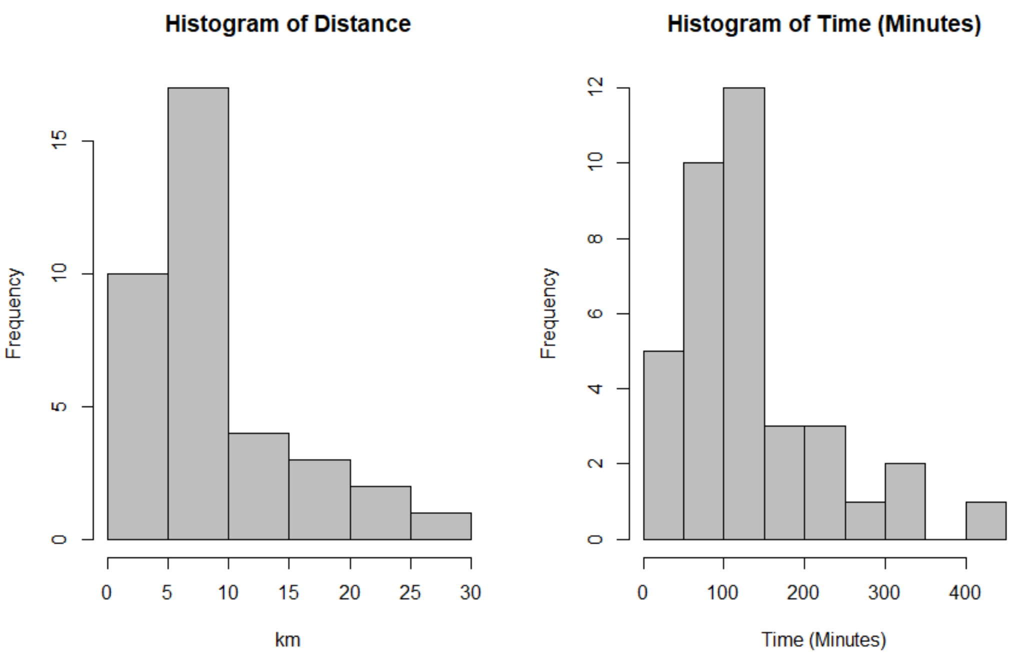


Figure 8: Distribution of distances and hiking time fort rails in Wortel-Kolonie

Figure 9 provides an overview of spatial spread based on the number of hikers that were registered to have followed one of the 38 hikes. The minimum number of hikers was 3, with a maximum of 415 and a mean of 42.3.

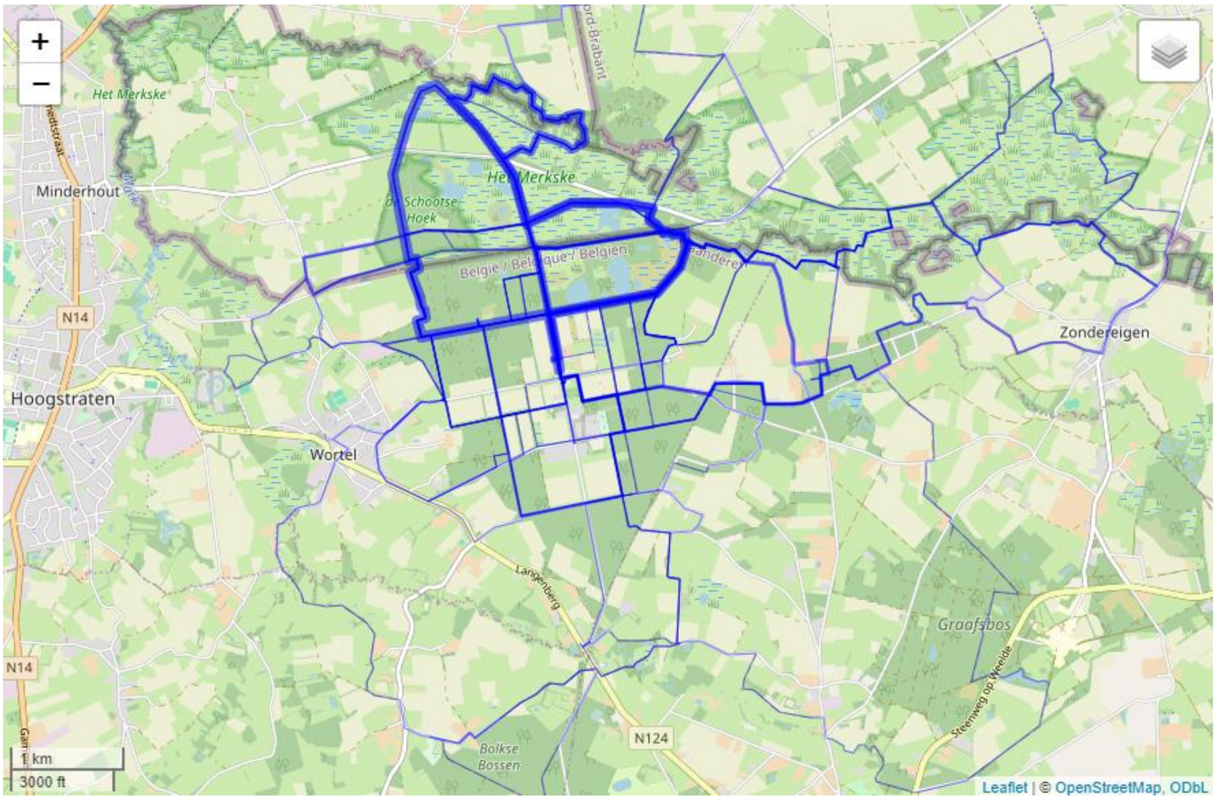


Figure 9: Visitor spread across different hikes in Wortel-Kolonie

The map indicates that a majority of visitors were registered to have taken a hike of moderate difficulty, mostly starting and ending at the Wortel-Kolonie parking (mentioned 85 times in the hiking waypoints) and visitor centre 'De Klapekster' (mentioned 23 times), and following the route along Bootjesven (mentioned 17 times) and the nature areas Het Merkske (present in 20 waypoints) and de Schootse Hoek (n = 5). The horse pasture (n = 11) and vagrant cemetery (n = 8) also appeared in a number of highlights.

6.1.2 Visitor satisfaction

Within the MONA project, visitor satisfaction is measured via two approaches: (i) as part of the visitor surveys conducted in some of the nature areas, and (ii) via scraping of Komoot (see previous paragraph).

Visitor surveys

In the visitor surveys of Activity 1.6 (see Deliverable 1.6.1 of the MONA-project) the general visitor experience is measured via a single, general question: "What was the overall experience of your visit to this nature area like?" with answer categories following a Likert-type scale between 1 to 5, ranging from not enjoyable to extremely enjoyable. Table 8 provides an overview of results from this analysis for three participating nature areas: Utrechtse Heuvelrug, Loonse and Drunense Duinen, and Scarpe-Escaut, all showing high levels of enjoyment among visitors.

Table 8: Overall experience of the visit

	Utrechtse Heuvelrug	Loonse and Drunense Duinen	Scarpe-Escaut
Not enjoyable at all	0.0%	0.7%	0.0%
Not enjoyable	0.0%	2.0%	0.6%
Neutral	1.0%	4.3%	9.9%
Enjoyable	64.7%	53.2%	46.8%
Extremely enjoyable	34.3%	39.9%	42.7%

Source: MONA D1.6.1

User-generated content

As discussed under 6.1.1, the user-generated hiking paths presented on www.komoot.com were analysed in terms of their characteristics and popularity. Part of the information provided on the website relates to customer review scores and specifically the user reviews for each of the suggested hikes, measured on a scale from 0 to 5. The analysis here is conducted once more for Wortel-kolonie in the Province of Antwerp. The minimum score given to a hike was 3.5, with a maximum score of 5 and a mean of 4.79, indicating a large degree of satisfaction, as can also clearly be seen from the histogram in Figure 10.

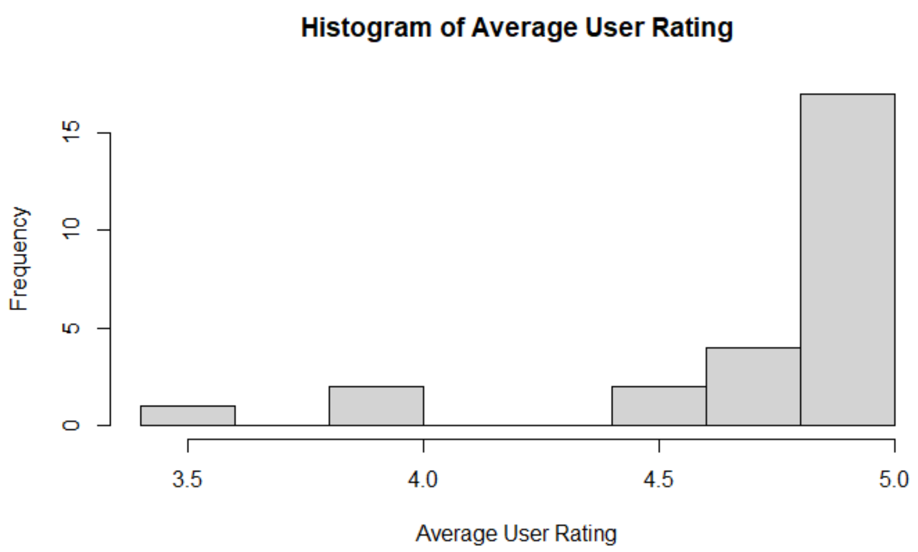


Figure 10: Average satisfaction of hiking routes in Wortel-Kolonie

6.1.3 Visitor behaviour

Visitor behaviour is assessed via surveys. In this case, both visitor surveys conducted as part of Activity 1.6 in the MONA-project, and resident surveys, part of Activity 1.7, are used to inform the perception of negative behaviours. Due to the issues of potential social-desirability bias in responding to questions about negative behaviour, visitors and residents were not queried about their own pro-environmental behaviour, but rather on their perception of behaviours of other visitors. Table 9 provides an overview for three queried nature areas: Utrechtse Heuvelrug, Loonse and Drunense Duinen, and Scarpe-Escaut.

As a general reflection, also discussed in D1.6.1 and D1.7.1, it is noticeable that residents were, as a whole, somewhat more negative in their perceptions of problematic behaviour. The results of these questions are particularly useful in terms of their potential changes after repeat measurements, particularly in light of MONA-interventions aimed towards more pro-environmental behaviour.

Table 9: Perceptions on pro-environmental behaviour of others

	Utrechtse Heuvelrug		Loonse and Drunense Duinen		Scarpe-Escaut	
	Visitors	Resid-ents	Visitors	Resid-ents	Visitors	Resid-ents
Most people properly disposed of the garbage generated while being here	79.7%	69.6%	85.7%	72.2%	70.2%	52.7%
Most people followed the environmental guidelines here	88.6%	78.4%	89.0%	66.6%	76.6%	56.8%
Most people stayed on the designated tracks and trails	86.9%	78.4%	85.4%	65.6%	82.5%	60.8%
Most dog owners put their dogs on a leash in areas where this is required	51.0%	41.2%	65.8%	39.3%	70.2%	43.2%
Most people do not disturb wildlife	81.0%	61.8%	89.7%	57.2%	80.1%	52.7%
Most people leave rocks, stones, plants and trees untouched	84.6%	81.4%	86.7%	74.5%	83.6%	71.6%
Most people make sure not to disturb ruins or historic sites	89.5%	85.3%	88.0%	77.4%	87.7%	71.6%
Most people respect the peace-and-quiet of the nature area	80.7%	65.7%	83.1%	59.8%	83.0%	67.6%

Source: MONA 1.6.1; MONA 1.7.1

6.1.4 Availability of facilities

Since the MONA-project aims to improve accessibility and multi-modal transport options, while also being inclusive towards all potential visitor segments, monitoring of available facilities around the nature area entrances could help to identify gaps in the offer, bottlenecks for service delivery and potential issues in supporting a qualitative visitor experience. Furthermore, the analysis of comparative differences between access area can help to identify proper strategies for zoning according to a Recreational Opportunity Spectrum Strategy.

To underline such monitoring possibilities, we use the case of Loonse and Drunense Duinen, the nature area being evaluated by Visit Brabant. The entrance gates to the park were identified from the visitor website and a 1 km buffer around these entrances was mapped in R. Next, the OpenStreetMap resource was used to identify facilities along within a few different recreational categories, namely:

- Food and drinks: bar, biergarten, café, pub, fast food, food court, ice cream, restaurant;
- Shops: bakery, beverages, coffee, convenience;
- Rest areas: bench, bbq, toilets, picnic table;
- Hotels: hotel;
- Cycling: bicycle parking, bicycle rental;
- Car: parking;
- Public transport: bus station, public transport stops, station, tram stop

Figure 14 visualizes the result of this mapping exercise. For Loonse and Drunense Duinen, Natuurpoort Herberg Manege van Loon offers most recreational opportunities, with 36 identified food and drink locations, one shop, a bicycle parking, and 330 car parkings. Secondly, Loonse en Drunense Duinen, Café Roestelberg includes 15 food and drink locations in its vicinity, as well as one cycling parking, and 31 car parkings. The other three entrances all include either one or two food and drink locations but still offer a relatively large amount of car parking (32, 11, and 54 identified places). On the other hand, none of the five entrances was within a kilometre distance from a public transport stop and there seems to be a general lack of resting places and public toilets.

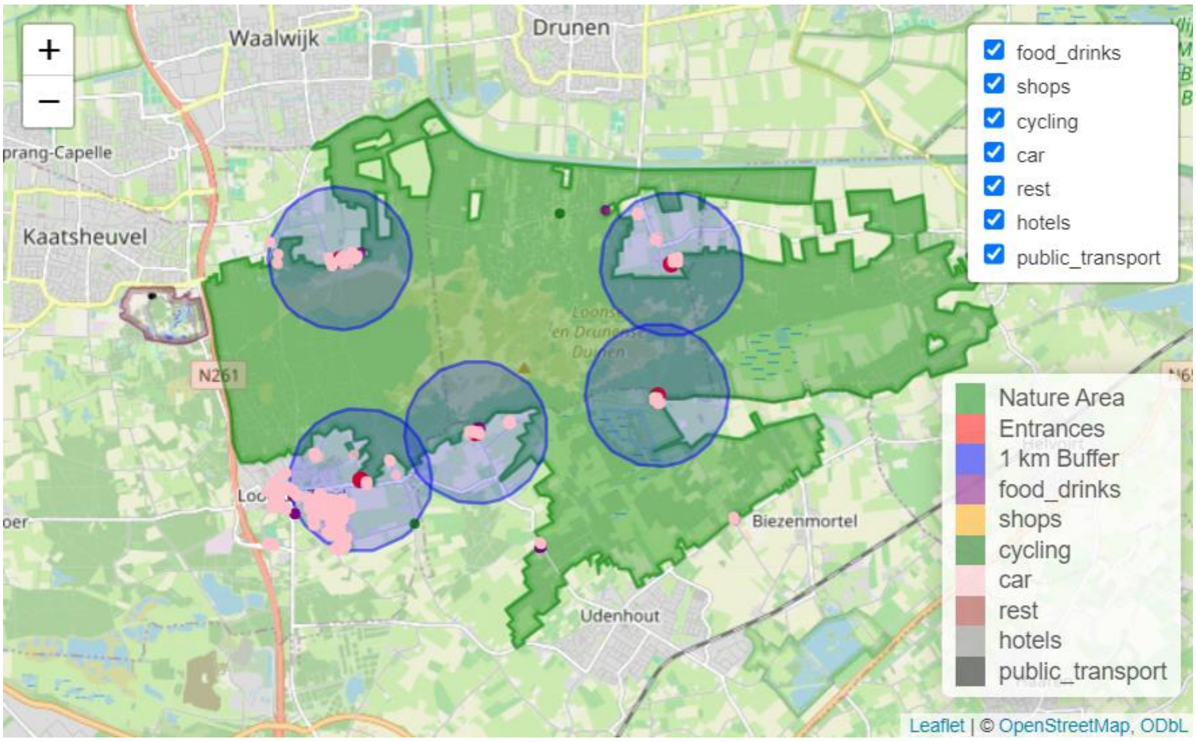


Figure 11: Availability of facilities near nature entrance areas at Loonse and Drunense Duinen

6.2 Indicators related to ecological conditions

6.2.1 Normalized Difference Vegetation Index (NDVI)

Calculation of the NDVI assists a longitudinal, high-level analysis of vegetation cover and health across large areas. In the MONA project, the rsi-package, developed by Michael Mahoney and aimed at efficiently retrieving and processing satellite imagery, was used in R. Satellite data was extracted from the Copernicus Sentinel-2 programme of the European Space Agency, providing high-resolution images in the visible and infrared wavelengths to monitor vegetation, soil and water cover. For optimal performance, only images were considered with a cloud coverage of maximum 10%.

Underlying analysis shows the results for one of the participating MONA nature areas: Grenspark Kalmthoutse Heide. Images were extracted for 2023 – period June-July – and 2024 – period August-September, in order to calculate both yearly indicators, and differences across time. Figure 11 shows the mapped NDVI values for the park, with lighter values being indicative of denser vegetation. In 2023 the minimum NDVI value equalled -0.134, with a maximum value of 0.736, mean of 0.433 and median of 0.448. In 2024 the minimum was -0.141, with a maximum of 0.725, a mean of 0.431 and median of 0.447. The negative values relate to the bodies of water such as Stappersven and Groote Meer.

The NDVI values should be interpreted in light of the type of vegetation cover in the nature area, with moderate values – ranging from 0.2 to 0.3 – representing shrubs and meadows and large values – ranging from 0.6 to 0.8 – representing temperate and tropical forests. Given that Grenspark Kalmthoutse Heide has a varied nature with forests, heaths, drifting dunes, and a large number of fens, it is logical that the NDVI values are lower than the values for dense forest areas.

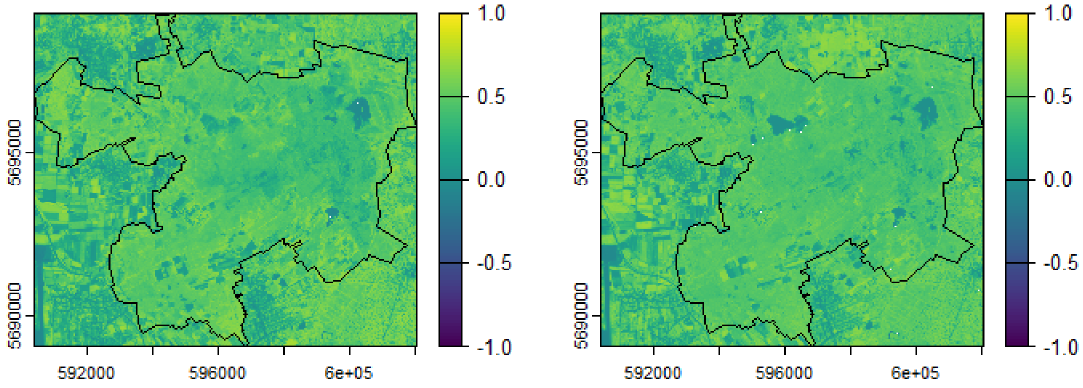


Figure 12: NDVI values for Grenspark Kalmthoutse Heide on July 2023 (left) and September 2024 (right)

Figure 12 presents situational changes between 2023 and 2024. Since the figure and histogram is built by extracting 2024 from 2023 values, positive numbers indicate that NDVI values were higher in 2023.

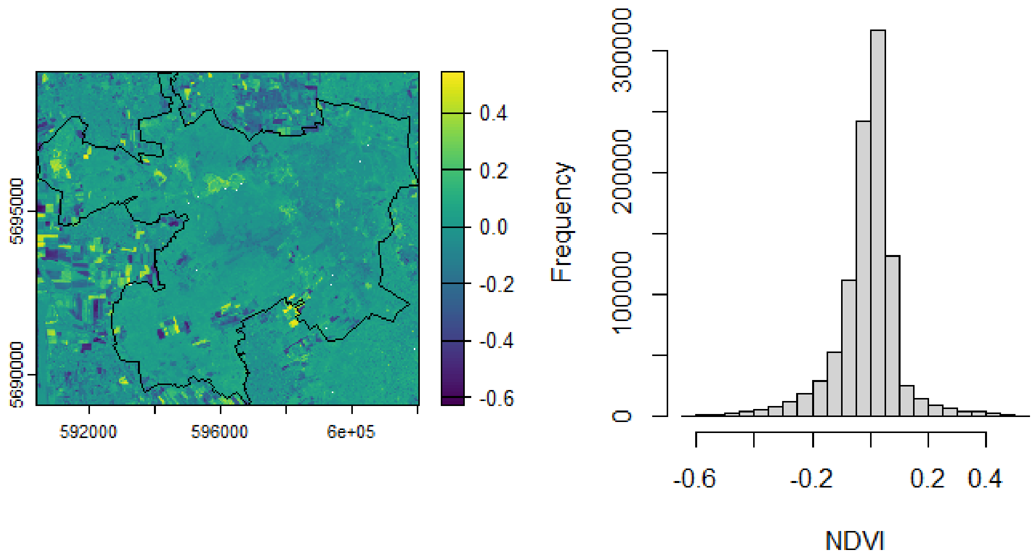


Figure 13: Changes in NDVI values for Grenspark Kalmthoutse Heide between July 2023 and September 2024

As can be seen from the histogram there were very limited differences between both years, with nature values and vegetation quality remaining stable across the two years.

6.2.2 Landscape fragmentation

As noted by Jaeger et al. (2007), landscape fragmentation can be an important indicator for human and environmental well-being and is particularly important for the assessment of undisturbed wildlife corridors. By calculating the effective mesh size (m_{eff}), as the probability of two randomly chosen points in a region being connected without separation by roads, we can formulate a simple indicator of undisturbed landscape quality.

As a monitoring example, these values are calculated for National Park Utrechtse Heuvelrug, which is located in a quite densely populated area of the Netherlands. In order to create segmentation barriers, roads were identified from OpenStreetMap. All road categories were included, ranging from highways, to primary, secondary and tertiary roads, agricultural or forestry tracks, and paths for walkers and cyclists. Figure 13 provides a visualization of the road network crossing Utrechtse Heuvelrug. Given the relatively dense road network, it is not surprising that the connection probability is relatively low at 0.289, with an effective mesh size of 32.70 km².

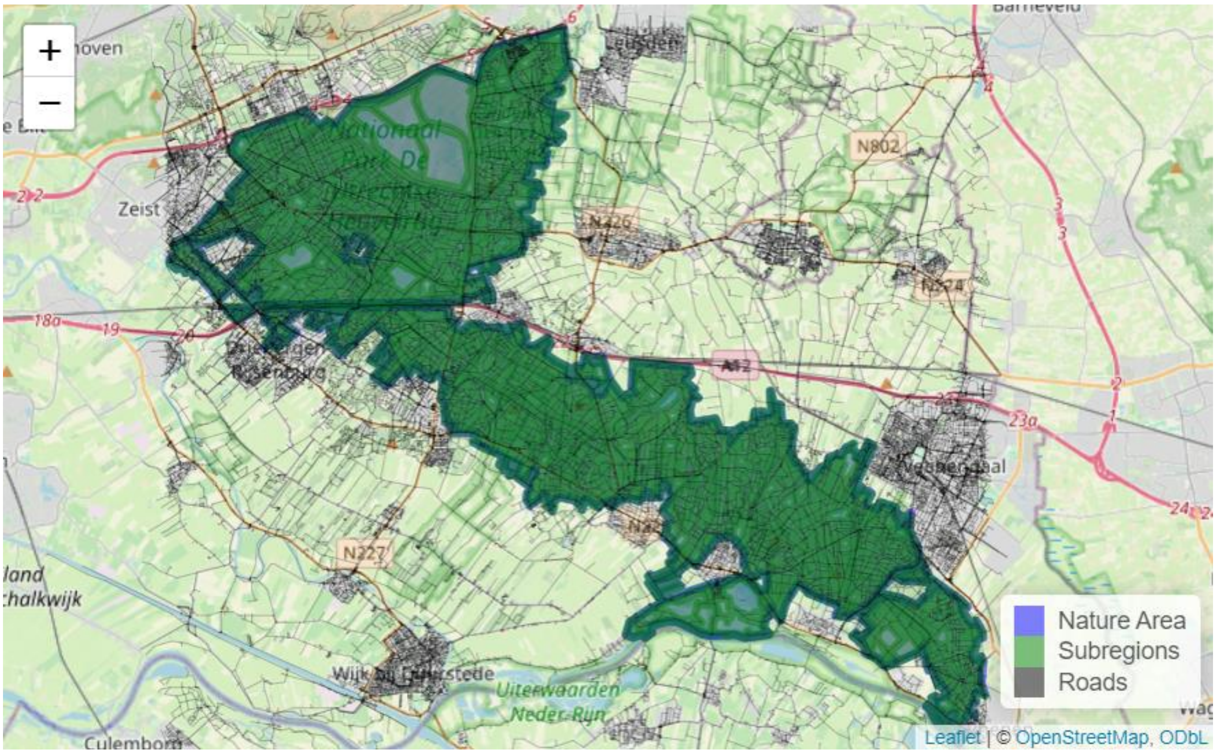


Figure 14: Landscape fragmentation for National Park Utrechtse Heuvelrug

6.2.3 Informal trails

As referred to in Figure 7, even though measuring social trails – their length and ubiquitousness, and the effects on fragmentation of the landscape – can be important, such analysis is complex and requires field observations and mapping. Therefore a proxy was used from the visitor and resident surveys. As already discussed in Table 9, one of the potentially disruptive behaviours that was assessed was people straying off official paths. It could be noted that in most cases, people answered positively to the question whether "Most people stayed on the designated tracks and trails", with consistently around 85% of visitors agreeing on that across Utrechtse Heuvelrug, Loonse and Drunense Duinen and Scarpe-Escaut. Resident perception on this issue was somewhat more negative (78.4%, 65.6%, and 60.8% respectively agreeing on the statement). By comparing the baseline results with repeat measurement results, we could infer an evolution in the presence of informal trails.

Table 10: Perceptions on informal trails

	Utrechtse Heuvelrug		Loonse and Drunense Duinen		Scarpe-Escaut	
	Visitors	Resid-ents	Visitors	Resid-ents	Visitors	Resid-ents
Most people stayed on the designated tracks and trails	86.9%	78.4%	85.4%	65.6%	82.5%	60.8%

Source: MONA 1.6.1; MONA 1.7.1

6.3 Indicators related to transportation

6.3.1 Modal shift

Particularly for MONA-partners within pilot A, indications of a positive modal shift towards public and soft means of transportation are relevant to collect. To accomplish this type of analysis, the baseline and repeat visitor surveys of D1.6.1 can again provide the necessary foundations. As Visitors were asked about their selected means of transportation, indicating a large dominance of car use, with only Utrechtse Heuvelrug having a somewhat significant amount of visitors using the train. These percentages can be compared to the repeat survey at the end of the project in order to assess whether a modal shift took place.

Table 11: Modal choice

	Utrechtse Heuvelrug	Loonse and Drunense Duinen	Scarpe-Escaut
On foot	14.7%	13.3%	7.0%
By car	79.1%	74.4%	87.7%
By camper van	1.0%	2.3%	1.2%
By bicycle	25.2%	19.6%	12.9%
By train	10.1%	6.0%	0.0%
By regular bus	1.6%	2.7%	2.3%
By shuttle bus	0.3%	2.0%	0.6%
By motorbike	1.6%	1.3%	0.0%
Other	1.3%	0.7%	1.2%

Source: MONA 1.6.1

6.3.2 Modal shift potential

Another indicator that can be usefully developed for the nature areas that have relevant actions around the use of train stations as entrance areas, is the development of isochrone maps. An isochrone map depicts the boundaries of accessibility to an area within a certain time threshold. Isochrones can be developed for different types of mobility, ranging from pedestrians, to cyclists, cars, and also public transportation. The latter is of particular interest for the MONA-interventions, because it can give insights into the visitor catchment areas for public transport use – thereby potentially guiding information efforts. So while it cannot be expected that the MONA project could significantly alter travel times – and we would therefore see a change in isochrones – the exercise can help to identify which markets have a higher potential for a modal shift.

In order to be able to accurately calculate travel times by public transportation, up-to-date timetables are required. Such timetables are available as General Transit Feed Specification (GTFS) files, which contain transit information such as stops, routes, trips, and other schedule data. Public transport companies such as the French SNCF, the Belgian NMBS, GTFS.de in Germany, etc. Combined with OpenStreetMap cartography (as, for instance, found at www.geofabric.de), a routeplanner can then be programmed to calculate possible travel routes, distances, and travel time.

As an example, isochrones were drafted for Montagne de Reims Regional Park, specifically for the train station of Germaine, that is located in the heart of the nature area. The analysis was done in R, using the packages tidytransit for reading the GTFS files, and r5r for calculating isochrones. The mode of transport was selected as 'transit'. This combines the travel time of public transport, with the additional transfer time on foot. Isochrones were calculated for travel times of 10, 20, 30, and 60 minutes.

As a standard, isochrones are calculated for a specific date (to take differences between weekends and weekdays into account) and departure time. Particularly the latter can lead to an underestimation of the relevant catchment area due to the scheduling of public transport – e.g. when the departure time is set at 9:00 and a scheduled train leaves at 8:58, this train is not taking into account as a potential route, therefore potentially missing relevant connections. In order to avoid this, a loop was written to calculate isochrones every hour, for a complete day, after which all isochrones were combined for a final analysis. Figure 15 provides an overview of all areas around Montagne de Reims Regional Park that are within 10, 20, 30, or 60 minutes from Germaine station. The red area delineates the 60-minute buffer and indicates that most people living in Reims or in Épernay could reach the heart of the nature area within an hour by public transport. When the suggested travel time decreases to 30 minutes, only people living very close to the stations of Épernay or Reims, or near any of the other stations on route, could reach Germaine in that timeframe. This is demarcated by the orange isochrone. The green area

– which is not so visible due to the multiple layers – denotes the catchment area for people only having to travel 20 minutes. In such case, only communities already living within the borders of the park could reach the destination in that timespan. Finally, only local people can make the trip in 10 minutes.

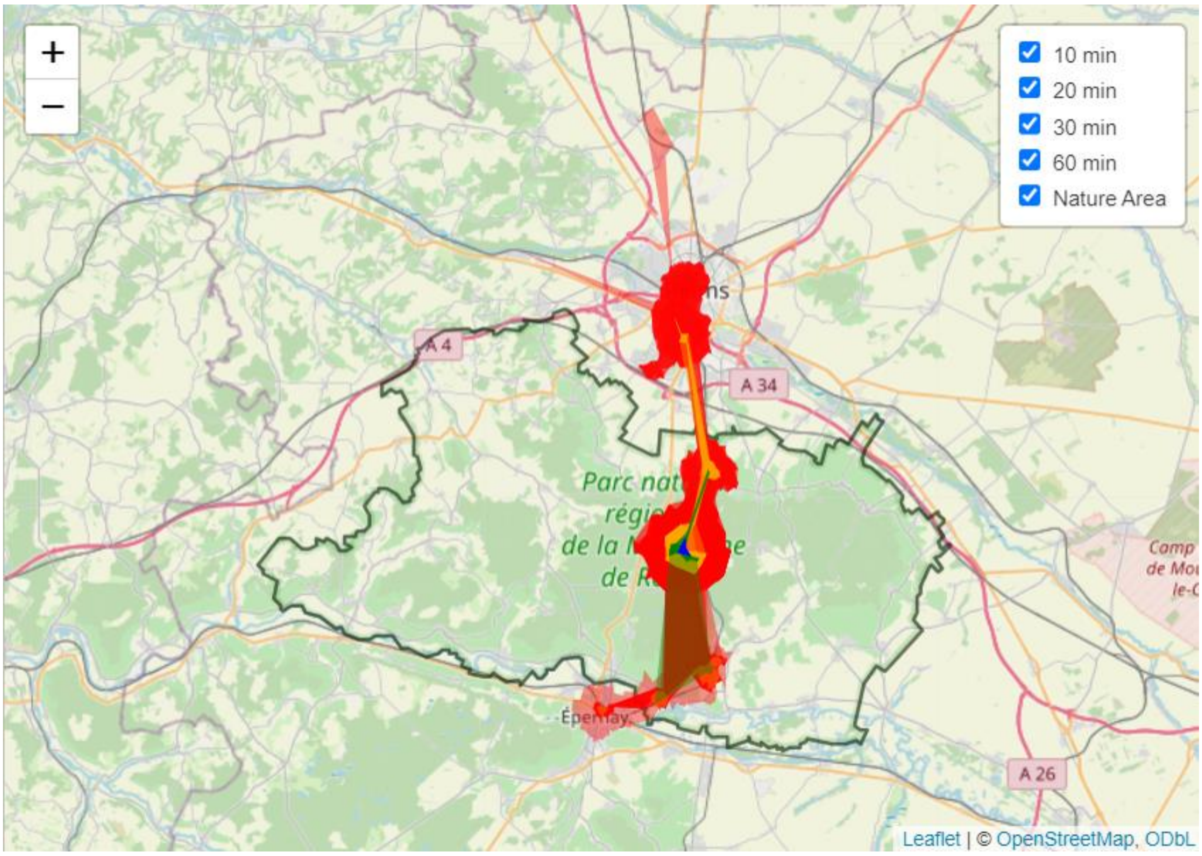


Figure 15: Public transport isochrones for Montagne de Reims Regional Park

6.3.3 Decreased parking disturbance

Interventions aimed at decreasing parking disturbance for local residents was specifically mentioned as an objective at Grenspark Kalmthoutse Heide. The MONA resident surveys of D1.7.1 could help to provide an indication of intervention success by comparing baseline results with repeat measurements. In particular, within the perceived impacts of nature area visitation, people were asked whether or not they agreed with the statement that visitation leads to "Increased parking issues for locals", which was agreed on by around one-third of respondents in Utrechtse Heuvelrug, Loonse and Drunense Duinen, and Scarpe-Escaut. A relevant decrease in this percentage by the end of the MONA project could therefore offer some indication of success on this topic.

6.4 Indicators related to information provision

Specifically for National Park Utrechtse Heuvelrug, one of the objectives mentioned was to improve information provision in order to better inform and guide users towards the use of public (or alternative) transformation. One aspect within the D1.6.1 visitor questionnaire that could provide a proxy measurement is the follow-up question to people who did not use public transport. As one of the reasons for non-selection, 1.3% of visitors to Utrechtse Heuvelrug mentioned not selecting public transportation because there was too little information on the route taken. Logically, an improvement in information provision might see this percentage decrease – albeit the percentage is already very small at baseline.

7. Conclusions

When developing projects focused on sustainable development of tourism and recreation in and around nature areas, it is important to identify relevant indicators to both monitor the current state of (tourism in) the nature area, and define strategic KPIs linked to actions and interventions, in order to ensure that best practices can be generated and results can be tracked.

Nature areas have a historic dual purpose of providing recreation and education to visitors – thus supporting open access – while also requiring stewardship of sensitive and valuable ecological resources. It is therefore unsurprising that the monitoring frameworks that have been developed in the past have included both needs. Furthermore, these instruments highlight the need for multidisciplinarity, stakeholder involvement, strategic thinking about visitor experiences and resource conditions, and zoning, as discussed in the nine proposed steps of the VERP assessment (Manning, 2002):

1. Assemble an interdisciplinary project team;
2. Develop a public involvement strategy;
3. Develop statements of park purpose, significance, and primary interpretative themes;
4. Analyse park resources and existing visitor use;
5. Describe a potential range of visitor experiences and resource conditions (potential prescriptive zones);
6. Allocate the potential zones to specific locations in the park (prescriptive management zoning);
7. Select indicators and specify standards for each zone; Develop a monitoring plan;
8. Monitor resource and social indicators;
9. Take management action.

These steps therefore seemingly highlight a need for contextualization and an individual approach to monitoring and indicator selection. At the same time, there are aspects to the visitor experience and ecological impact monitoring which are near-universally relevant, providing a generalized basis for comparative monitoring. Such base indicators can then be expanded on by strategically relevant KPIs. This was proposed in the document by analysing the individual nature area strategies of the three MONA pilots, identifying their respective objectives, distilling KPIs, and proposing monitoring indicators/measurement approaches.

The final part of the deliverable set out to operationalize the identified indicators in order to provide a proof-of-concept for holistic measurement. The approach combined dedicated data collection (via surveys), with user-generated content, remote sensing data, open data GIS, and webscraping, highlighting the opportunities that are available for widescale data collection.

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