MONITORING METHODS DECISION SUPPORT GUIDE:

Report and resource guide to aid in the evaluation of recreation impacts on forest ecosystems

FEMC Regional Project 2023-2025: Monitoring Methods Decision Support Guide: Report and resource guide to aid in the evaluation of recreation impacts on forest ecosystems

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Executive Summary

Recreational activities are increasing across the region. In forested areas, these activities include hiking, mountain biking, camping, and use of all-terrain vehicles, among others. With this increase in use, forest managers are concerned about impacts on the forest ecosystem. To aid forest managers in identifying and measuring impacts, FEMC developed a methods selection decision support tool and this resource guide. This guide provides background information about ways in which the forest may be affected, focusing on soil erosion, invasive plant introduction and expansion, and wildlife behavior and habitat disturbance. We reviewed a range of monitoring methods for each focus area, summarizing their key features and outlining the limitations of each. We also identified scenarios in which a given method would be most appropriate for addressing the questions of interest. The methods were selected based on a variety of factors including validity and history of successful implementation in Northeastern forests, ease of use, robustness of data output, and ability to compare across sites and datasets.

The accompanying online tool allows users to select the topic of interest and specify other parameters to choose an appropriate method. Links to original methods sources are provided to allow managers and researchers to access more in-depth information about their chosen method and how to implement it.

Establishing a monitoring program can provide forest managers with the information needed to evaluate how and where recreation may impact the forested ecosystem. With this information, managers can prioritize appropriate management practices to minimize soil erosion, invasive plant introduction, and wildlife disturbance.

Introduction

Each year the FEMC conducts a region-wide project, identified by members of our Steering Committee and State Partnership Committees. During 2022, FEMC conducted a literature review of common recreational activities in the Northeast and what type of impact these activities have on the forest ecosystem (FEMC, 2022). Additionally, experts in forest health and recreation were interviewed to gauge the needs of the community and identify gaps in knowledge about recreational impacts. Following these scoping activities, an expanded project plan was developed for 2023. The project had two elements of interest that were divided into two distinct work plans. The first was a spatial analysis of recreation trails and factors that may lead to increased disturbance as a result of recreation. The results of this project can be found here (Donisvitch et al., 2024). The second element, and focus of this report, was the identification of monitoring methods to be used for tracking on-the-ground trends in forest health in recreation areas. A working group was formed to identify ecological impacts of interest. The group recommended exploring monitoring methods to provide guidance in selecting a method that fits within the needs and resources of the organization conducting monitoring.

Researchers and land managers employ ecological monitoring to observe trends, conduct experiments, and discover the effectiveness of management practices (IVUMC, 2019). Carefully designed monitoring employing consistent and repeatable protocols is more likely to provide information that can be used in making management decisions and improves the ability to compare data across sites over time (McComb et al., 2018).

However, monitoring can also be costly and time-consuming to conduct and maintain. Implementing a long-term monitoring plan requires funding and personnel to conduct the monitoring and interpret the data. To aid in designing a monitoring program, FEMC created a decision tree that guides users through the process of selecting a monitoring protocol based on the user goals and resources available. A collection of protocols were identified for inclusion based on their widespread use and ability to be modified for different scenarios, with a focus on methods that are applicable to Northeastern forest types. A collection of monitoring protocols was selected based on their widespread use and adaptability to various scenarios, with an emphasis on methods suited to northeastern forest types. Selection was guided by the type of data the protocols generate and their capacity to support comparisons across different sites, rather than by the specific types of recreation occurring at each site. The forest health conditions of interest include monitoring wildlife, invasive plants, and soils. These categories were selected as of greatest interest to FEMC partners.

Protocol selection and monitoring plan development

Protocol selection should be guided by the goals of the monitoring program and the resources available. This guide suggests several factors that may be considered when selecting a monitoring program protocol. Protocols are available for each of the three categories (invasive plants, wildlife, and soil) with guiding questions designed to help narrow the recommended options to one or a few protocols. Some protocols are species-specific. While the selection process is primarily driven by the intended monitoring objectives or desired outputs, it also takes into account practical considerations such as required skills, time commitment, and cost.

As a monitoring program is planned, a research design should also be developed. The design of a program incorporates planning decisions that will determine how the monitoring data can be used in management decisions. Several factors are considered in the monitoring design, including whether it will be a long-term program or a one-time assessment, the number of plots to be established, and the independence (or correlation) of those plots. Return frequency should be determined by the minimum detectable change expected (Herrick et al., 2005), which describes the least amount of change that can be observed for your conditions. Sites that are highly variable will require a larger sample or take a longer period of time to detect change. By understanding the rate of change and the minimum detection you are able to determine how frequently to return to a site. If it will take several years for change to be detected, it is not worthwhile to return to a site before change is possible, thereby saving time and costs associated with establishing a monitoring program. These decisions will determine the appropriate approach to data analysis and how to use the information in management decisions. For example, selection of appropriate statistical analysis will be necessary based on the number of plots established or the independence of the plots from each other. The design may also incorporate a before and after approach to monitor changes following an event such as the creation of a new trail network.

Several resources are available to help guide managers in their monitoring plan development and implementation. Two that we found helpful are *Monitoring Animal Populations and their Habitats: A Practitioner's Guide* (Mccomb et al., 2018) and *Monitoring Guidebook, Evaluating Effectiveness of Visitor Use Management, Edition One* (IVUMC, 2019). Each of these resources provides guidelines that take many factors into consideration to help managers create an effective monitoring program that produces information to use in decision-making. Broad-scale, strategic monitoring and inventory can be used to generate hypotheses, whereas small-scale, tactical monitoring guides the specific tests to be used in a science program (Oswalt et al., 2021). The guidance provided in this report and decision-tool will focus on the small-scale tactical perspective that can be implemented as part of local management programs.

SOIL

Soil erosion due to recreation activities leads to sedimentation in aquatic systems, trail-widening and incision, muddy trails, opportunity for invasive plant establishment, and—sometimes—creation of new trails (Jewell & Hammitt, 2000; Marion, 2016). Loss of soil due to erosion is an irreversible impact, so it is critical to identify where erosion is happening in order to employ management practices to minimize losses (Marion et al., 2011). The discussion presented here does not provide recommendations for management practices, which are provided in other trail-planning and recreation management resources.

When establishing a monitoring program to evaluate soil erosion on trail networks, several pieces of information are important to understand prior to selecting a method. These are described below.

Soil type

Understanding which types of soil are present in the area of interest is important to understanding the susceptibility of soils to erode. Soil type information is available from NRCS. These data were used to assess soil suitability for trail and path recreation [in the spatial analysis portion of this FEMC project] (Donisvitch et al., 2024). Suitability ratings were developed based on soil characteristics such as erosion potential, drainage, stone content, and load-bearing capacity. However, this analysis does not provide site-specific information or analysis of soil erosion. On-the-ground sampling is needed to confirm conclusions based on suitability ratings. Establishment of monitoring programs will improve analysis of soil erosion at the local scale, and can contribute to further spatial analyses with the addition of new data. Implementing a monitoring program and analyzing soil erosion will provide information for trail planning and management decisions.

Trail attributes

Trail attributes include various features of the trail network such as vistas and points of interest, bridges, and stairs. Additionally, on-the-ground mapping of trail grade and slope ratio can provide useful detail to lower resolution maps. By documenting these characteristics, the trail manager is able to identify locations where traffic may be higher, soil erosion may be more likely, or impacts of erosion may be greater. Tracking these locations with GPS and an online form such as Arc Collector or KOBO provides an easy to use and access source information for trail managers. Marion et al (2011) provide an overview of this process.

Trail conditions

During the trail attribute data collection process, the trail condition can also be assessed to identify locations where soil erosion is occurring. Assessing soils includes the identification of soil erosion risk, compaction, and infiltration. A variety of methods can be used to conduct these assessments. These methods are outlined here, with details about how to select among the methods. The decision tree tool provides the ability to walk through the process of selecting a method appropriate for the trail of interest. Design options for establishing a monitoring program will also be described. The design of the program largely entails conducting a full census of the trail network or determining a point-location approach to selecting where to conduct monitoring. Frequency of return to sites also needs to be incorporated into the monitoring plan to be able to assess changes over time or following specific events.

The FEMC reviewed several methods to develop recommendations and guidance for utility by trail managers. Details of the methods are available in several publications, including Jewell & Hammitt (2000), Herrick et al. (2005), and Marion et al. (2006). The decision support tool guides users through the selection process based on user objectives. The outputs provide information about the method, suggestions for how to adapt to recreational settings, data output, and any limitations to consider when implementing the method.

Rapid assessment methods

Condition class assessment

In condition class assessment, the person conducting the assessment assigns a descriptive classification to a trail or segment of trail. These descriptive classifications are pre-defined, ranging on a scale of 0 – 5 from “trail barely distinguishable; no or minimal disturbance of vegetation” to “soil erosion obvious, as indicated by exposes roots and rocks or gullying.” The sampling is done at pre-determined intervals along the trail. This assessment allows for the trails to be systematically sampled and classified. Training requirements are minimal, and the process can be rapid and efficient. The process is subjective, which may result in different classification assignments depending on the person conducting the assessment—calibration and validation between team members is thus essential. Application of this type of assessment should be limited to cases where a qualitative measure will be appropriate. This approach is easy to implement over a large trail network and can provide a baseline for use in other monitoring methods (Jewell & Hammitt, 2000).

Census of active erosion and Census of erosional events

The census of active erosion and census of erosional events methods are similar (Jewell & Hammitt, 2000). The census of active erosion only identifies locations that appear to be consistently losing soil with a substantial loss over a year. A census of erosional events includes a tally of locations of inactive events where erosion has reached bedrock and soil loss is no longer occurring. Before conducting this method, the manager must define what constitutes an erosional event, including its length and depth. Using these predefined criteria, a census can be conducted by tallying events along the trail. This method can be performed quickly, but it requires training and cross-calibration among observers due to the subjectivity involved. It can help identify priority areas for allocating management resources.

Inventory or monitoring

Cross-sectional area method

The cross-sectional area method consists of measuring changes in the cross-sectional area of the trail at a fixed location. This measurement is taken at intervals along the trail. At each designated location, fixed points are established with permanent markers on both sides of the trail. A rope is stretched taught across the trail, attached to each point. The area below the rope is measured by taking several vertical distances measurements from the rope to the trail tread, allowing for the direct comparison of changes in the trail over time at specified point locations with high levels of accuracy. Note that it requires a high level of training and is time-intensive, which can make it challenging to apply across large trail networks. Still, it may be a suitable approach for monitoring change over time at a small number of priority sites.

Soil Compaction Test

Compacted soils limit water infiltration, which in turn contributes to reductions in root growth and microorganism activity. Herrick et al. (2005) outline the steps and considerations in conducting the soil compaction test using an impact penetrometer. The penetrometer is dropped from a standard height, typically 40cm. Multiple drops are made along a transect, with multiple transects randomly established along the trail network. There are several considerations to be aware of when determining if this test will be used. Specifically, the penetrometer is sensitive to soil moisture, so moisture must be the same to make comparisons at different locations or over time. As a result, assessing soil moisture independently at each site is recommended. The test cannot be conducted on either surface rocks or plants, including areas with leaf litter or duff. While conducting the test, ear protection and thick gloves should be worn to protect the person conducting the tests. Some training is recommended, but the method generally does not require advanced skills.

Infiltration test

Infiltration tests are used to determine how quickly water enters the soil, providing a relative estimation of infiltration capacity. When water does not drain properly, puddles form on level surfaces and erosion occurs on sloped areas. The single-ring infiltrometer (Herrick et al., 2005) is recommended to measure how long it takes water to infiltrate at a sample location. This test may be used to determine if infiltration capacity is causing puddles to form or erosion to occur in specific locations. This information may be used in management decisions to reduce puddling or erosion, and to track changes over time.

INVASIVE PLANTS

Invasive plants grow rapidly and readily, especially in disturbed soils (Poland et al., 2021), and often have high dispersal ability and short generation times. These traits increase the ability of invasive plants to become established and spread rapidly, overtaking native plants and disrupting forest ecosystem understories. Trailheads represent a high-risk area for invasive plant introduction and establishment due to disturbed soils and regular use (Rew & Pokorny, 2006). Plant seeds can be inadvertently carried on and spread by boots, tires, and dog fur.

Early detection is the most cost-effective management tool because isolated introductions can be treated and removed before a population becomes established (Poland et al., 2021). Awareness of invasive plants near the recreation area is the first step to early detection. High-risk areas near existing populations need regular monitoring for invasive plants. Online tools, such as EDDMaps, hosted by the University of Georgia, and InHabit, developed by the USGS, are available to help determine which plants are of the highest concern based on their proximity to the land of interest. Selecting a few plants to focus efforts on makes early detection easier.

Once invasive plants become established, monitoring programs that detect the expansion of the population provide land managers with valuable information to prioritize locations for the implementation of treatment and removal practices. Monitoring the effectiveness of the treatments is also necessary to determine if the population is under control or needs additional treatment.

Effective monitoring requires training and careful planning, but there are various protocols to choose from. When selecting a specific protocol, it is important to consider the goals of monitoring, the skills and resources available, and the time needed for implementation. The choices made in the monitoring plan will guide this selection process. Once a protocol is selected, plots should be established and a return visit plan determined to capture change over time.

Several inventory and survey methods are widely used across ecosystems to detect and observe changes in invasive plant populations. These methods are briefly described here, with references to more in-depth resources also available. The decision support tool that was created as part of this project provides details about each protocol, as well as any limitations to using it.

Invasive plant monitoring approaches

Several approaches are available for consideration when conducting inventory and survey methods as part of a monitoring program. These approaches include both the establishment of plots for return visit sampling or single-point-in-time rapid assessments when the opportunity arises. Monitoring of defined plots and transects by trained staff allows for observation and analysis of changing plant populations as well as early detection. By establishing plots, land managers can regularly return to assess any changes over the growing season. Alternatively, trained staff who are conducting other field activities may conduct rapid assessments as part of an opportunistic protocol, monitoring a location they are visiting for other field activities. The technicians should have some training in plant monitoring and a list of targeted species to look for when doing rapid assessments. Field crews can conduct these rapid scans at any location where the crew stops, including when they are parking vehicles or starting a sampling plot. Having trained eyes on the lookout for invasive plants at locations where managers are already visiting improves the potential for early detection (Wheeler & Miller, 2014).

Valuable data can also be collected by volunteers and citizen scientists using the recreation area. The volunteers may conduct an assessment at defined locations or may submit observations through apps such as iNaturalist and iMapInvasives (available in NY and ME). Messaging and outreach are needed for these programs to be successful, along with training materials to help volunteers know what to be on the lookout for, but this is a valuable resource to consider when monitoring invasive plants. Information signs can be set up at trailheads and parking lots to alert people to be aware of invasive plants, and citizen scientists can submit sightings through iMapInvasives, iNaturalist, or another app that land management staff can have set to alert them of any sightings. Volunteers should be able to report any sightings, including location, to be verified by an expert, such as with a project in iNaturalist. Volunteer efforts can be used in a variety of approaches, from opportunistic sightings to volunteer days to actively conducting systematic monitoring.

The decision support tool helps users identify the most appropriate design and method for your monitoring project based on questions of interest. The methods included in the tool are suggested from publications by Herrick et al. (2005), Rew and Pokorny (2006), Huebner (2007), and Keefer et al. (2014). As the user makes selections based on their objectives, methods are filtered to create a list of recommendations. Options to select among include rapid assessment approaches, methods to conduct an inventory, methods that detect change over time, and approaches that are dynamic or allow for multi-tier monitoring. The output includes a brief description of the method, how to adapt the method for recreation, the data output provided by the method, and any limitations that should be considered.

Systematic monitoring

Systematic plots are typically 1 m^2 plots arranged on a central transect. Four plots are placed at each cardinal direction, arrayed 1 m from a point 15 m on either side of the transect at 50 m intervals along the transect. This method provides an estimate of percent cover of herbs, shrubs, and vines within plots. While this is a valid method for monitoring vegetation, it is not highly recommended for early detection or monitoring of invasive plants. The method requires more time per plot than some other methods. Caution should be used in selecting systematic sampling because the plots will not be independent from each other. There is the possibility that a periodic pattern in the environment will result in an artificial standard error (Elzinga et al., 1998). Systematic monitoring can also result in missing rare plants, such as non-native plants that have not yet been detected (Elzinga et al., 1998).

Stratified Random Sampling

Stratified random sampling divides a study area into strata, or layers. These layers should be based on environmental or topographical features such as elevation, aspect, vegetation type, or soil type. Plots or transects are then established randomly within each identified strata. By using a random sampling approach, statistical analysis is robust for detecting trends. By selectively representing different habitats, the method better allows for distinguishing between habitats or features that may be more conducive to invasive plant spread. Using a stratified transect approach may be particularly useful when studying the spread of invasive species along a linear feature such as a trail, road, or waterway.

While stratified random sampling is an efficient method, there are limitations, including time and expertise. Developing the initial stratification can take time. Selecting plots or transects can also be complicated, with the need to randomly select locations, but also ensuring the plots or transects can effectively be sampled and are not over- or underrepresenting a habitat type. Analyzing the data can be complex, requiring additional statistical analysis skills. Additional resources and descriptions of this approach can be found in Huebner (2007) and Pew and Pokorny (2006).

Modified Whittaker

The Modified Whittaker nested design provides plant species richness of an area as a measure of biodiversity. The method was modified from previous approaches that were very time-intensive (Herrick et al., 2005). While the method is intended to estimate species richness, it can also be used to detect invasive plants.

The method nests rectangular and circular plots within a larger plot. Presence or absence is collected in all subplots. Additionally, the percent cover of each species is estimated in a subset of subplots. By collecting both presence/absence data and percent cover, species-area relationships are able to be determined. This method is suitable for detecting rare species, or newly arrived invasive species, as well as species that are already established.

The modified Whittaker method requires considerable time to establish the nested plots and collect accurate data (Huebner, 2007). The single plot design of this may not represent landscape heterogeneity; as such, multiple plots may need to be sampled to adequately capture diverse landscapes. The analysis of the data can also be limited if there are not sufficient plots established due to the effort required.

Timed meander

The timed meander method, as described by Goff et al., (1982) involves slowly walking through a site for a pre-specified time period, typically 30 minutes to 1 hour, and noting any new species sighted. If no new species are noted after a ten-minute block, the process can stop. Because this method covers an entire site of interest, rare species such as newly introduced invasive plants are captured in the census.

Huebner (2007) compared the method to other plot and transect methods to identify benefits and weaknesses of each method in monitoring for invasive plants. The timed meander method has several benefits to consider, including that it has no setup requirements, it can be faster to complete than other methods, and it can be done as a rapid assessment. The method is a good tool to use for early detection of invasive species. However, the person conducting the assessment does need to be skilled in identifying plants and it is helpful if they are already familiar with the sites being assessed. The method can also be difficult to replicate, and the results can be biased due to observer subjectivity. Plots are not used in this method, so analysis is not directly comparable to other methods that use plot designs.

Adaptive monitoring methods

Adaptive monitoring methods allow for modifications to be made as needed based on circumstances and management needs. Rew and Pokorny (2006) provide a thorough description of using adaptive monitoring methods. Additionally, Maxwell et al., (2012) evaluated several methods, both adaptive and non-adaptive, to test for effectiveness, accuracy of estimates, and efficiency of detecting invasive plants. The method maps patches of invasive plants. As the size and shape of a patch changes over time, the method is modified to account for the new boundary. The method can be done relatively quickly because each plant does not need to be counted, but the area of the infestation and an estimate of percent cover is documented. These estimations can result in detection error, in which an invasive plant is not detected when it is actually present. Mapping large areas is possible using an adaptive monitoring method, but if multiple invasive plants are present, mapping can become difficult.

Tiered Sampling Method

The tiered sampling method consists of three tiers of the survey. Tier 1 creates a detailed inventory of locations of all target species. Disturbed areas are targeted due to the increased likelihood of invasive plant presence. Tier 2 uses a stratified random survey design to sample areas that are not associated with disturbance to sample in areas where invasive plants may have spread unknowingly. Locations are selected for sampling using randomization, which allows for extrapolation. The area should be stratified by community type or another environmental variable such as elevation. Tier 3 is used to randomly check sites in which surveying was conducted using Tier 1 and Tier 2 methods.

Opportunistic Assessment for Indicator Species

The Northeast Temperate Network of the National Park Service (Wheeler & Miller, 2014) uses an opportunistic approach for early detection of invasive species. This was designed to be a rapid assessment conducted by field crews as part of their other work activities. Species of interest are determined based on several risk factors such as known proximity to the land, habitat types conducive to the pre-determined species, and disturbed areas that are more likely for invasive species to be introduced. The approach requires minimal effort, relying on people to be familiar with plants of concern and spending a short amount of time looking at locations across the property. If an invasive species is detected, additional monitoring can be established to positively identify and confirm the presence, determine how widespread it is, and be prepared to look for it in other locations. This approach can also be used by recreationists using the property and community scientists who can be made aware to be on the lookout for the species of concern. This method is not likely an ending point of monitoring, but rather a rapid response approach to early detection.

Other trail impacts not included here focus on the creation of informal trails. Resources are available to create a monitoring plan for this area of interest, such as (Visitor Use and Impacts Monitoring Program, Yosemite National Park, n.d.)

WILDLIFE MONITORING

Recreation impacts wildlife in many ways, from habitat to behavior (Miller et al., 2020). In this report we cover mammals, birds, and amphibians and reptiles. Each of these categories of animals responds differently to the abundance of trail users, types of trail use (motorized or non-motorized), or changes to habitat that result from recreation trails. Additionally, not all monitoring methods or monitoring designs are appropriate for all types of animals. To collect data that will best inform management decisions, careful selection of methods is necessary.

The impacts of recreation on wildlife vary depending on the type of wildlife being considered (Larson et al., 2016). Some animals are more sensitive to human activity, resulting in avoiding interaction and reducing activity in high-use recreation areas. Other animals, such as squirrels, raccoons, or bears, may be attracted to human activity, in particular when food sources become available. In addition to behavior change, habitat can also be impacted by human activity (Miller et al., 2020). Changes in habitat may include disruptions to delicate habitat such as ephemeral ponds or alpine vegetation. Introduction and expansion of invasive plants changes understory habitat, which may not provide suitable cover or food sources when compared with native vegetation (Bierker et al., 2023). As a result of the variability of types of impact, there are a wide range of monitoring methods that can be used, dependent on the class of animals of interest. The recommendations provided for monitoring wildlife include guidance for selecting and establishing monitoring programs that use direct approaches such as live-traps, camera-traps, and acoustic recordings as well as indirect monitoring such as fecal counts and track pads. The outputs of these methods will provide different types of information, with some methods capturing information about the population of an area and other methods only providing presence/absence data.

The decision tree created by FEMC can guide managers in selecting a method. The interests and goals of the organization/agency/research project, type of land cover, and other considerations such as skills and resources available will help guide users to a set of methods to consider implementing. As with invasive plants, one-time monitoring data can provide a snapshot of information that can be used to determine additional monitoring needs and establish baseline conditions. However, to understand long-term impacts caused by recreation, a monitoring program should be designed to continue to collect data into the future.

When designing a monitoring plan, several considerations need to be made about the data output of interest and how the data will be analyzed. A valuable resource for designing a monitoring plan is available in the book "Monitoring Animal Populations and their Habitat: A Practitioner's Guide" (McComb et al., 2018). This book provides details about how to set up and conduct monitoring to collect data that can be effectively analyzed. Monitoring plots that are set up with no plan for how the data will be used can lead to effort and resources being used to collect data that cannot answer the desired question. Some specific considerations that should be made when designing a monitoring plan include:

- selecting an appropriate time of year and day for the animal of interest in which sampling will occur; sampling done at times when a species is not active or not present will result in low data quality;
- confirming the habitat suitability for the animal of interest;
- considering comparisons before and after a trail is established to analyze the data for recreation impact;
- and ensuring population independence when selecting plot locations to minimize sampling bias.

To determine the impact of recreation on wildlife, it is important to consider how far from recreational trails or areas impacts will be measured, depending on the behaviors and life histories of the wildlife of interest and the type(s) of recreation of concern. Wildlife flight initiation distance can be used to determine if a plot is located beyond the trail impact area. Two resources that are available include the U.S. Forest Service resource: "Conservation Buffers – Design guidelines for buffers, corridors, and greenways" (Bentrup, 2008) and the "Trails for People and Wildlife" publication created by the New Hampshire Fish and Game Department (Stevens & Oehler, 2019).

Another approach to understanding how recreation is impacting wildlife is to monitor the habitat. Plots can be established both along the trail and away from the trail to assess differences in habitat impact at varying distances from the trail. The habitat impacts can include the introduction and establishment of invasive plants, trampling of vegetation, degraded water quality due to soil erosion, barriers for movement between habitats (for example, road crossings), and water impoundments.

Mammal Monitoring Methods

Methods for monitoring mammals may vary between large, meso, and small mammals, which may have different habitat requirements, behaviors, and appropriate methods for monitoring. Large mammals in the northeast U.S. region include ungulates (deer and moose) and black bear. Medium, or meso mammals include beavers, bobcats, and possum, among others. Small mammals include squirrels, rabbits, mice, shrews, and other small rodents. Bats are also small mammals, but require monitoring that is more similar to bird monitoring such as acoustic monitoring, mist netting and harp netting.

Monitoring methods include both active monitoring such as trapping and tagging, as well as observational methods such as camera traps, scat or dung counts, and direct observation (Hoffmann et al., 2010).

Small-Mammal Monitoring Methods

Many small mammal species are nocturnal, making them less likely to be disturbed by recreational activities. Small mammals tend to have a higher threshold for human presence than large mammals (Dertien et al., 2021), and thus may be more tolerant of closer contact.

Small mammals are regularly monitored by establishing monitoring arrays that use appropriate traps or track pads for the species of interest (Hoffmann et al., 2010). Array designs can vary depending on the question of interest, estimation method being used, as well as species of interest and habitat. Pearson and Ruggerio (2003) conducted comparisons of transects and grid arrays to improve data collection based on the question being asked. Transect lines are recommended for studies focused on estimating small mammal species richness and diversity, as well as relative abundance indices, rather than grid arrays. Grid arrays are more appropriate to answer questions focused on estimating population density, home ranges, and small-mammal dispersion. The Forest Service Multiple Species Inventory & Monitoring Protocol recommends using transects within a hexagonal array (Manley et al., 2005). The array should be established in an area with appropriate habitat for the species of interest. Traps that include bait and a safe place for an animal to shelter overnight is one approach that can be used.

An alternative method to the use of traps is to use a track tube which does not trap, but uses bait to bring the animal to the tube where they walk across an ink pad and leave tracks in the tube (Glennon & Porter, 2007). This method does not allow for individual identification, but species can be identified, allowing calculation of some measures of diversity. Camera traps are not typically used for small mammals because they are too small to accurately detect.

With either of these methods, a minimum number of track-/tube nights are recommended. Approximately ~400-500 trap-nights are needed to have a large enough sample size (Hoffmann et al., 2010), whereas ~100 tube-nights may be sufficient. Trapping typically occurs over several consecutive nights with multiple traps/tubes set each night.

To understand the impacts of recreation on small mammals, a study design may include establishing a trapping array both near the recreation activity, such as near a parking lot and trailhead or along a transect that follows a trail as well as a plot that is in similar habitat, but removed from the recreation activity. The plots should be established to allow for independence of samples, so the population of animals is not the same in both locations. Vegetation sampling should also be conducted within the plot to provide habitat information and confirm the similarity of plots. Use of FIA or other standard vegetation monitoring protocols is recommended.

Bats

Bat monitoring methods include acoustic monitoring arrays and use of bat boxes. Bat Conservation International provides tools and resources for establishing a robust monitoring program and managing acoustic data. Trapping bats is also an option, using mist nets and harp traps. However, this approach requires technicians to be trained in appropriately handling bats and also being up to date on rabies vaccines. Acoustic monitoring likely provides sufficient information to assess if recreation is impacting bat populations (Hoggatt et al., 2024). Recreational activities that may disrupt bats are those located near bat roosts. Acoustic monitoring can be established in these locations to monitor over time, detecting change if there is a change in recreational activity, or comparing bat activity at another roost location that is not near a recreation site.

Medium-sized mammal monitoring methods

Medium-sized mammals are a broad group that include mustelids, lagomorphs, larger rodents, skunks, opossums and canids, among others. Medium-sized mammals have unique monitoring challenges owing to their body size, cryptic lifestyles, and susceptibility to stress when trapped (Hoffmann et al., 2010). Many medium-sized mammals in the Northeast region are carnivores, and evidence suggests that mammalian carnivores may change their activity patterns towards increasingly nocturnal lifestyles in response to human activity (Lewis et al., 2021). In addition, some medium-sized mammals may evade emplacements such as traps and game cameras due to their size, movement speed, and arboreality (Gompper et al., 2006; Hoffmann et al., 2010). Considerations for array design and research questions may resemble those for small mammals, but with the addition of increased spatial scale to account for the broader ranges medium-sized mammals may inhabit. Observers will need to weigh the benefits of trapping, cameras, or surveying activity indicators in relation to their research questions.

Trapping is arguably the most comprehensive sampling of live individuals along trails. Medium-sized mammals will typically require Tomahawk traps, which are available in sizes from small rodents to coyotes. Species-appropriate bait must be considered. Trapping enables observers to identify and mark individuals, collect metabolic and genetic data, and survey community composition. However, small sample sizes will bias abundance estimates and other population-level trends, so establishing a sufficient number of trap sites is key. Trapping medium-sized mammals is also labor-intensive in that traps will require frequent checks, and observers may need to be proficient with animal handling. Manley et al. (2005), Hoffmann et al. (2010) and Chapter 8 of Kinkead (2016) offer guidelines for trapping medium-sized mammals.

Observers without animal handling expertise that aim to survey greater spatial scales with less labor intensity may prefer surveying activity indicators and camera data over live specimens. The decision matrix between cameras or activity indicators, and within activity indicators themselves, will focus on whether observers are interested in assessing behaviors, abundance, demographic and metabolic data, and sampling scale (individuals, one or a few species, or entire communities).

Cameras and track pads offer continuous passive data collection across broad spatial scales. Both are regularly employed to identify species presence and assess relative abundance, spatial use, and community composition. However, cameras come with the added benefit of being able to record behaviors and distinguish individuals. Because some medium-sized mammals can evade cameras due to their size and movement speeds, observers should refer to publications for suggestions relating to camera model, placement, and detection settings for their target sample (Burton et al., 2015). Camera setups for medium-sized mammals are described in Manley et al. (Manley et al., 2005), Gompper et al. (2006), and Lewis et al. (2021). While conventional open-air track pad designs can be used for medium-sized mammals, observers should also contemplate enclosed designs. While enclosed designs are limited to sampling species that can fit in the device, they are far more weather and element resistant. Refer to Manley et al. (2005) and Gompper et al. (2006) for simple enclosed track pad designs appropriate for medium-sized mammals. If possible, cameras and track pads are best used simultaneously to complement one another's shortcomings – cameras provide more comprehensive context and identification while track pads may catch individuals that avoid cameras.

Advances in genetic testing enable observers to utilize hair and scat when monitoring medium-sized mammals. While hair and scat cannot elucidate behavior, they are useful in determining community composition, population estimates, identifying individuals, and collecting demographic data such as diet and stress. Scat sampling is preferable for observers who have the time to actively collect samples in the field and are interested in metabolic data. For instance, Rehnus, Werle, and Palme (2014) used scat samples collected at recreation sites to detect presence of glucocorticoids, a hormone group associated with stress. Scat sampling may be useful for monitoring species that are known to frequent trails, such as coyotes (Gompper et al., 2006).

Hair collection is passive and achieved through devices called hair snares. While most hair snare setups are cumbersome and cater towards larger mammals, Zielinski et al. (2008) describe a simple device that can use either barbed wire or glue to retrieve hair samples from medium-sized mammals. Ultimately, sampling scope may be the deciding factor in the decision matrix between the two: Scat sampling can be conducted across a flexible range of species along randomized or even opportunistic temporal scales, while hair snares best provide data for one or a few target species at regularly maintained intervals. See Gompper et al. (2006) and Rehnus, Werle, and Palme (2014) for scat sampling procedures, and Zielinski et al. (2008) for a convenient hair snare procedure for medium-sized mammals.

Large mammal monitoring methods

Large mammals may be elusive, exhibit wariness around humans, and span vast home ranges. As with medium-sized mammals, evidence suggests that large mammals may change their activity patterns along recreational routes based on human presence – some species and individuals may be attracted to trails while others are averse to them (Erb et al., 2012; Lewis et al., 2021). Therefore, observers monitoring large mammals in recreational areas should prioritize passive, noninvasive means capable of surveying broad spatial ranges over as much time as possible. Considering these factors, it is best to enact monitoring strategies that are static, opportunistic, or sample indicators of mammal activity. Methods should be tailored based on whether the observer is interested in broader-scale measures, such as species richness, movement, or relative abundance, or finer scales that include recording behavior and tracking individuals.

In general, methods for observing large mammals in recreation areas will likely consist of static emplacements, surveying activity indicators, or opportunistic live observations. Observers should choose methods based on critical research questions, time allocated for training, maintenance level, and cost. Due to the challenges of observing large mammals, it is best to combine several methods simultaneously if time and budget permit.

When monitoring large mammals, game cameras and track pads permit the greatest versatility with respect to study scale and research goals. Cameras can quantify abundance, distribution, behavior, community diversity, and even track individuals that have been marked, all while providing time and location. Track pads can be used to ask similar questions but cannot show behaviors, distinguish individuals, or activity times. However, track pads do not encounter the detection distance issues of cameras. Technical expertise and setup time may be the deciding factors between the two methods. When reviewing game camera protocols, observers must consider finer details that include camera model specifications, detection distance, emplacement height and spacing between units, all while tailoring these specifications to track target species or communities to enable repeatability (Burton et al., 2015). Observers might therefore benefit from track pads as a low-tech option that may not require as much trial-and-error testing with technical specifications, and for quicker assessments mostly concerned with species presence. Track pads are also well-suited for recreational sites that include corridors and road crossings. Cost and maintenance estimates will differ: While cameras have been reported to have higher startup costs than trackpads and can remain in the field for longer, track pads may require more time from the manager or researcher and typically need to be reset at more regular intervals. See Gompper et al. (Gompper et al., 2006) and Ford et al. (Ford et al., 2009) for comparisons in application, maintenance and efficacy between game cameras and track pads. Consult Manley et al. (Manley et al., 2005), Ford et al.(Ford et al., 2009) and Kinkead (Kinkead, 2016, Chapter 8) for detailed specification outlines for track pad and game camera setups tailored towards large mammals.

If cost, time, and staff availability are of concern, observers should consider recruiting civilian volunteers to assist with large mammal observations. Civilian volunteer recruitment and surveys can be made far more convenient via smart technology, such as mobile apps. For example, moose populations have been catalogued via a survey app designed for hunters (Boyce & Corrigan, 2017). A mobile app for recreation trails may ask for species seen, demographic information, recreational activity, and timestamps with geolocation. Civilians with game camera experience may also be recruited to assist with volunteering their own cameras for use or with analyzing camera data (Erb et al., 2012). Volunteers may be recruited online via parks websites and social media, or in-person by canvassing trail clubs and posting advertisements at trailheads. If using an app, include a QR code download link online or at trailheads.

Medium and large mammal array design

Due to their range of body sizes, activity patterns and capacity for dispersal, scale is of utmost importance when monitoring medium and large mammals. When determining geographic scope, recreational trails and roads are convenient in that they can be considered “mega transects” that effectively outline possible areas of interest to place devices and observers, with transect distance set by the observer (Erb et al., 2012). To establish comparative datasets, observers should consider device placement or observation routes both along trails and set distances off-trail. When designing protocols to suit various mammal species and size classes, emplacements, and transects may need to be upscaled to account for body size and movement capacity. Camera height and placement distance will change for each species or community being monitored with respect to movement speed, range of motion, and body size (Burton et al., 2015). Likewise, track pads and hair snares will need to be of sufficient size to capture data from the focal species (Ford et al., 2009; Gompper et al., 2006). Transect-trail distance is vital for scat surveys, as scat will generally be more visible along maintained trails.

If designing a transect out of an existing trail, consider a setup with monitoring emplacements stationed within 1 km of one another, spanning varied distances off-trail to maximize coverage (Erb et al., 2012). Alternatively, a grid approach can be used wherein the geographic area of the trail is converted to cells spanning the kilometer range, and devices are stationed at differential densities based on recreation activity (Lewis et al., 2021). Refer to McComb et al. (Mccomb et al., 2018) for detailed guidelines and suggestions when designing monitoring plans, scales, and arrays.

Birds

The effects of outdoor recreation on birds remain a subject of debate. While some studies have proposed that bird abundance, species richness, and reproductive success are reduced by trail activity (Bötsch et al., 2018), others have suggested that trails do not negatively affect bird communities (Deluca & King, 2014). Conflicting results may occur due to differences in survey times relative to peak trail activity, regional effects, and species' resilience to human presence. Bird monitoring programs at recreational sites are encouraged to track trends in bird abundance, richness, distribution, and demographics over time to clarify whether trail activity influences bird communities and elucidate management priorities.

Birds are a taxonomic group that remains a popular monitoring subject for both professional researchers and amateur hobbyists. Therefore, a bevy of monitoring techniques for birds exist that can operate on scales ranging from informal abundance assessments to comprehensive demographic surveys. While these methods vary greatly in their level of investment and expertise, observers are encouraged to take advantage of interested parties in hobbyist settings to increase their personnel and resource pool. Along with state and federal agencies, community science groups such as the North American Banding Council (NABC) and Cornell University's NestWatch program offer accessible resources to support bird monitoring initiatives.

Methods included in our decision tree account for temporal scale, research questions, and personnel availability. When monitoring birds, it is crucial to establish whether observers are interested in abundance trends, behavior, demographics, and life stage. While some methods may overlap in their capacity to answer these questions, others are more specific. Ultimately, time and resources may be a deciding factor in a chosen methodology.

Bird monitoring methods

Methods in our decision matrix are broadly delineated by whether they are best suited to answer research questions pertaining to abundance or demographics while accounting for scale and resource intensity. While some methods may overlap in their capacity to answer specific questions, they may also differ in the amount of personnel and training required.

Popular techniques for monitoring bird abundance and distribution include area searches, point counts, transect counts, and spot mapping. Area searches are an informal method that simply requires tallying every individual and species seen while surveying a given area. Point counts involve one or more observers remaining stationary at points for a set amount of time cataloguing every bird they visually observe within a predetermined radius. By contrast, transect counts allow for observers to count while mobile, albeit along a fixed constructed path. Spot mapping is an intensive method wherein observers follow singular birds to assess territory span, population density, and behavioral interactions during the breeding season. Refer to Siegel (2009) for detailed explanations and applications of these methods, and for suggested publications that include protocols. Furthermore, Chapter 3 of Manley et al. (2005) and Chapter 11 of Kinkead (2016) provide technical guidance for designing point count protocols.

It is critical to note that bird abundance and distribution surveys are inherently limited by detectability factors such as visibility, environmental noise, and observer skill. There exist several variations of point and transect counts that allow for detectability estimates, mathematical equations that account for observer limitations to improve survey accuracy. Detectability estimate techniques are varied and include distance sampling, wherein observers estimate distance to each bird observed, and the double observer method, whereby one observer exclusively spots birds while another documents what the former sees (McCallum, 2005; Siegel, 2009). See McCallum (2005) for an in-depth exposition of the reasoning behind detection probability estimates and common applications for bird monitoring.

Observers interested in demographic data such as breeding productivity, recruitment, and survivorship should consider constant effort mist netting and nest monitoring. Mist nets are large fine-meshed nets hung from trees or other heights that capture passing birds. Nest monitoring is a technique by which observers search known bird habitat for nests, documenting habitat and egg/fledgling characteristics through repeated visits to each nest throughout the course of development. While these techniques are fundamentally optimized to assess different life stage contexts, they both permit mark-recapture surveys via color banding individual birds. Those who aim to incorporate banding or physical sample collection must become acquainted with ethical bird handling safety techniques, manuals for which can be conveniently accessed via the North American Banding Council (NABC) website. However, even without banding, both techniques are considered rather labor intensive due to the amount of training, personnel, and repeated site visits required for quality data. Consult Siegel (2009) for further explanations and protocols pertaining to mist netting and nest monitoring, and Dunn and Ralph (2004) for a guide on the applications of mist netting versus abundance surveying techniques. Refer to the Monitoring Avian Productivity and Survivorship (MAPS) manual (DeSante et al., 2024) for a standardized mist netting protocol, and the Cornell Lab of Ornithology's NestWatch manual (Bailey et al., 2019) for accessible nest monitoring procedures.

The FEMC decision matrix conveniently suggests monitoring methods based on applicability, resource requirements, and limitations. As with monitoring other wildlife, it is best to choose a method that is most efficient within your organization's means and suited for your questions of interest. When monitoring birds, reach out to birdwatching hobbyist groups and community science initiatives to expand your resource pool and technical support network.

Amphibians and Reptiles

Disruptions to amphibians and reptiles as a result of recreation are not well-studied. Trail networks that include streams, ponds, wetlands, and other water features have the potential to be disruptive to amphibians (Larson et al., 2016), but of larger concern is habitat loss or degradation that may occur as a result of recreational activities. Such examples include the creation of roads and parking lots near water bodies that result in sedimentation (Welsh & Ollivier, 1998).

Limited data is available for how recreation may affect amphibian and reptile populations. Developing a monitoring program specifically to study these impacts will provide valuable information to researchers and managers to aid in decision-making and management practices. Many methods and designs have been developed and tested. We recommend following the methods outlined by the Partners in Amphibian and Reptile Conservation (Graeter et al., 2013).

The decision tree allows users to select a species of interest, which then narrows down the appropriate methods to use. Monitoring methods are dependent on the species of interest because not all methods are appropriate for the life histories, habits, and habitats of all species (Faccio, 2001). The methods include approaches such as visual encounter surveys, auditory surveys, and various trapping methods. Additional selections can be made to refine protocols that provide outputs of interest, such as population demographics or presence/absence information.

When designing a monitoring program to determine if amphibians and reptiles are impacted by recreation, transects and plots should be established in a way that comparisons and considerations can be made for the recreation activities, such as along a trail, at stream crossings and other known habitat for the species of interest. Time of year, number of return visits, and habitat are important considerations when monitoring amphibians and reptiles. Amphibian movement during spring rains provides a commonly used period for monitoring, while monitoring for reptiles will more likely occur during warm summer months.

Surveys

Visual encounter surveys involve searching for amphibians and reptiles over a wide area without a set path or time limit. Visual encounter surveys can be conducted in a variety of ways, depending on the setting and species of interest. This method can be used to measure the general presence and visibility of species in relation to human use of the area. Limitations of this method include high variability in species detection. Observer bias is also a consideration, as this can result in poor reproducibility of the data. It is easy to implement and create a baseline to use when creating a more robust monitoring program. The general approach involves an area search. However, other approaches can focus on roadways or along trails as a form of a transect. To detect species in streams and rivers a viewbox can be used.

Cover objects

Monitoring reptiles and amphibians can also be done using cover objects arranged in a standardized pattern. Objects can be either natural objects such as rocks and wood, or artificial cover objects such as plywood, corrugated metal, or wood boards. These cover objects serve as shelter sites for a variety of reptiles and amphibians, providing insulation and retaining moisture. The array is set up and left for a specified period of time before returning to check under the objects. When considering how recreation may disrupt herpetofauna, plots can be established in suitable habitat locations both near the trail or recreation site and further away to detect differences in species presence, abundance, and diversity. This method does allow for quantitative analysis, but extensive coverage may be required in order to have a representative sample size across habitats.

Traps and nets

Handling herpetofauna provides additional information that detection surveys do not provide. Using traps and nets provides the opportunity to mark animals for recapture, more thoroughly assess individuals, and better quantify population metrics. Land-based methods include drift fences with pitfall or funnel traps. Aquatic methods include a variety of trapping and netting approaches that can be tailored depending on the species of interest.

Drift fences require building an impassable fence to intercept amphibians and reptiles moving across the landscape. Aluminum flashing or plastic silt fencing is used to build the barrier, which guides the animals into buried containers at intervals along the fence. This approach can be adapted for assessing recreational areas by comparing areas of human activity to areas that have lower levels of human presence. This method provides insight into habitat use and migration patterns. The data provided from this method include species identification, abundance, movement patterns, and habitat use. Limitations of the method include the set-up time and effort, which can be considerable. Additionally, the traps must be checked daily to prevent stress or mortality. Biases may arise due to species' differential ability to avoid traps.

Dip netting involves using a long-handled net to sweep through aquatic habitats to capture amphibians and reptiles. This technique is particularly effective in shallow water bodies like ponds, streams, and wetlands. Surveyors methodically sweep the net through various microhabitats within the water body to capture species for study before releasing them back into their environment. This approach is especially well-suited to capturing species active or resting in shallow waters and for sampling amphibian larvae. There is potential to disturb the habitat using this method. Skill and experience are important to maximize capture efficiency and minimize stress to the animals and habitat. The effectiveness of dip netting declines with the size and depth of aquatic habitats, potentially skewing species inventories or estimates of abundance. Animals may not be equally catchable, which can introduce bias in study results.

Various types of traps can be used for aquatic species. If soil erosion along trails into vernal pools or streams is of concern, monitoring these locations can provide information about how the animals are impacted. Some of the trapping methods require additional training and skills, as well as additional people available to deploy and retrieve the traps. Traps need to be checked daily to minimize stress and mortality.

Auditory

Amphibian calls can be used to detect species as well as estimate abundance. This method requires the use of auditory recorders suitable for outdoor use. The recorders are deployed near potential breeding habitats and retrieved following breeding season or a pre-determined amount of time. The data requires further analysis to identify species and estimate abundance. Software is available to analyze the data, which requires training by the technician. This method can be adapted for recreation settings by deploying recorders near high recreation areas and in more remote settings to compare the effects of human activity on species presence and behavior. Limitations of the method include the cost of recorders and data analysis software, as well as skills of the technician in setting up the recorders and using the software. This method is limited to those species with auditory calls.

While auditory monitoring is specifically mentioned for amphibians, it should also be noted that auditory methods are commonly used to monitor birds and bats, as well.

Conclusions

Many of these monitoring and design recommendations cannot explain cause and effect; instead, they are intended to help a land manager assess trends over time and space and provide insight into the ways recreation may be affecting a range of environmental variables. The purpose of the monitoring program and the information desired should guide the study design, including frequency of visits, plot location, and sampling methods.

Additional information that will contribute to the analysis and interpretation of data outputs from these monitoring methods includes type of recreation and level of use. The methods themselves will not change with this consideration, but some elements of the research design may be adjusted to better understand how recreation is contributing to a change. For example, analyses may be conducted to compare if the number of users on a trail has an impact on wildlife behavior, perhaps by monitoring recreational areas on both weekdays and weekends within a short period of time.

The information in this report, along with the FEMC decision support tool and GIS analyses and layers, provide users with several resources to improve their understanding of how recreation may impact soil erosion and compaction, the introduction and spread of invasive plants, and wildlife habitat and behavior. Land management decisions can be made using the information gained from implementing a monitoring program. These may include decisions about creating new trails or limiting the number of users in locations where trail use is resulting in negative impacts to the forest ecosystem.

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