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Multiple Species Inventory and Monitoring Technical Guide

Version 1.0

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Acknowledgments

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Contents

Chapter 1. Introduction

1.1 Overview and Purpose

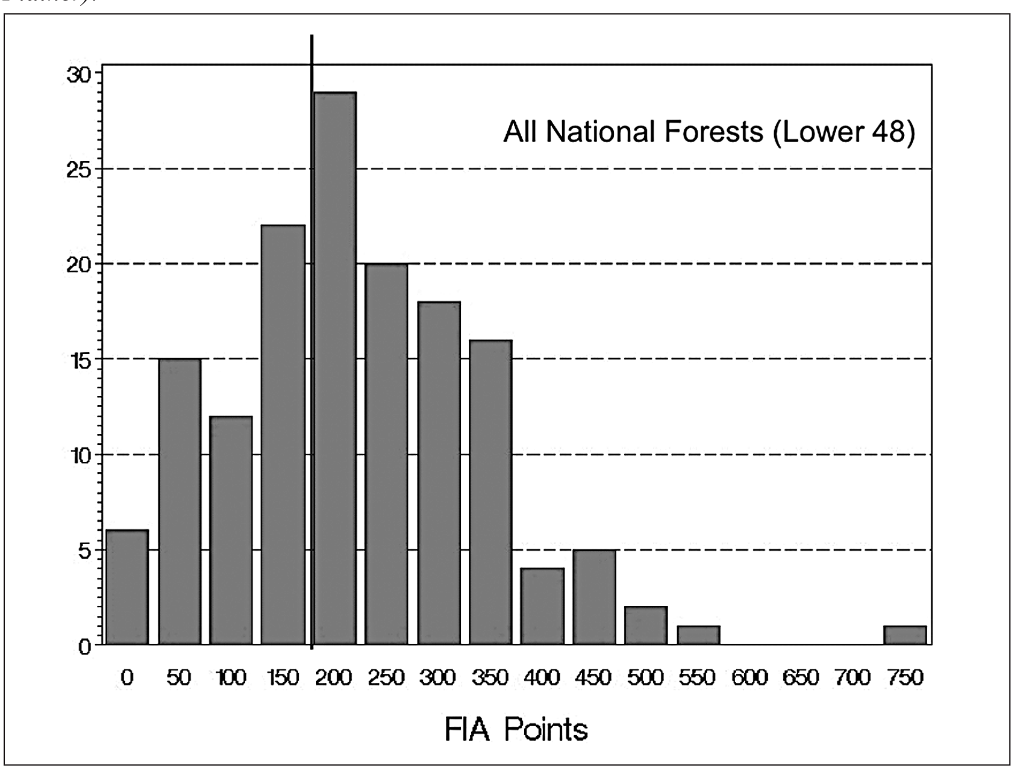
The National Forest Management Act (1976) recognizes the importance of maintaining species and community diversity on National Forest System (NFS) lands as a critical component of our ecological and cultural heritage. Monitoring is required of land management to assess the success of management activities in meeting legal, regulatory, and policy objectives, including sustaining populations of native and desired nonnative species. The Multiple Species Inventory and Monitoring (MSIM) protocol is intended to serve as a consistent and efficient method for obtaining basic presence/absence data and associated habitat condition data for a large number of individual species at sites that represent a probabilistic sample. It is designed to be implemented in association with Forest Inventory and Analysis (FIA) grid points on NFS lands. The MSIM protocol is designed as a base monitoring approach on which regions and forests can build to meet their specific National Forest Land and Resource Management Plan monitoring needs with the greatest possible efficiency (measured as the amount of useful and high-quality information gained per unit cost).

The principal purpose of the MSIM protocol is to inventory and monitor species of concern and interest, and overall biological diversity across individual and multiple forests to meet agency information needs and legal requirements for inventory and monitoring. Species of concern and interest commonly include U.S. Department of Agriculture (USDA), Forest Service Sensitive Species, State and Federal listed species, and State species of concern. To date, monitoring of wildlife populations and habitats has been lacking or poorly implemented on national forests. Indeed, the development and implementation of forest-scale monitoring in general has been challenging and progress has been slow. Two barriers appear consistent: (1) lack of clear monitoring objectives in terms that can be readily translated into sampling design specifications; and (2) lack of capacity or commitment to fund data collection, management, and analysis. The MSIM protocol targets the most basic of questions regarding change in populations and habitat conditions. It is based on a sampling design that can be used to assess trends at a range of scales, which is the most cost-effective approach to generate reliable trend data that are useful at the forest scale.

Based on evaluations conducted to date (Manley and McIntyre 2004; Manley et al. 2004, in press), the MSIM protocol can effectively detect a representative array of species at ecoregional and regional scales, including species of concern (e.g., USDA Forest Service Sensitive Species, State and Federal threatened or endangered species, State species of concern) and special interest species (e.g., harvest species, indicator species). The MSIM protocol has the potential to yield many other substantial benefits that are ancillary to its principal purpose, but meet key agency needs, such as habitat relationships modeling, indicator development, and biodiversity monitoring, which can be used to address a myriad of issues including sustainability and the status of ecosystem services.

Performance of the MSIM protocol will vary among regions and will depend largely on the number and density of monitoring points (i.e., sample size). The number of FIA points varies substantially among national forests, ranging from less than 50 points to more than 750 points in the continental United States, with the majority of forests having 200 or more FIA points (fig. 1.1). Regardless of the monitoring approach, sample size challenges will be greatest for small national forests that are not near other national forests (e.g., forests that share the same ecoregion and have many species in common), and monitoring point densities may have to be adjusted for these forests under any monitoring program. The power to detect change over time will depend on the amount of annual variability in a population, which will not be known prior to the onset of monitoring for most national forests. Implementation of MSIM throughout one or more regions would represent substantial progress in the ability of national forests to generate much needed monitoring information on species and their habitat conditions.

Figure 1.1. *Number of national forests in each FIA points density class (courtesy of Curtis H. Flather).*



Ideally, the MSIM protocol would be implemented across multiple jurisdictions (e.g., all public lands or all land ownerships) because it would yield valuable information about populations and habitats in species ranges throughout a State or ecoregion, providing valuable information for many agencies and the country.

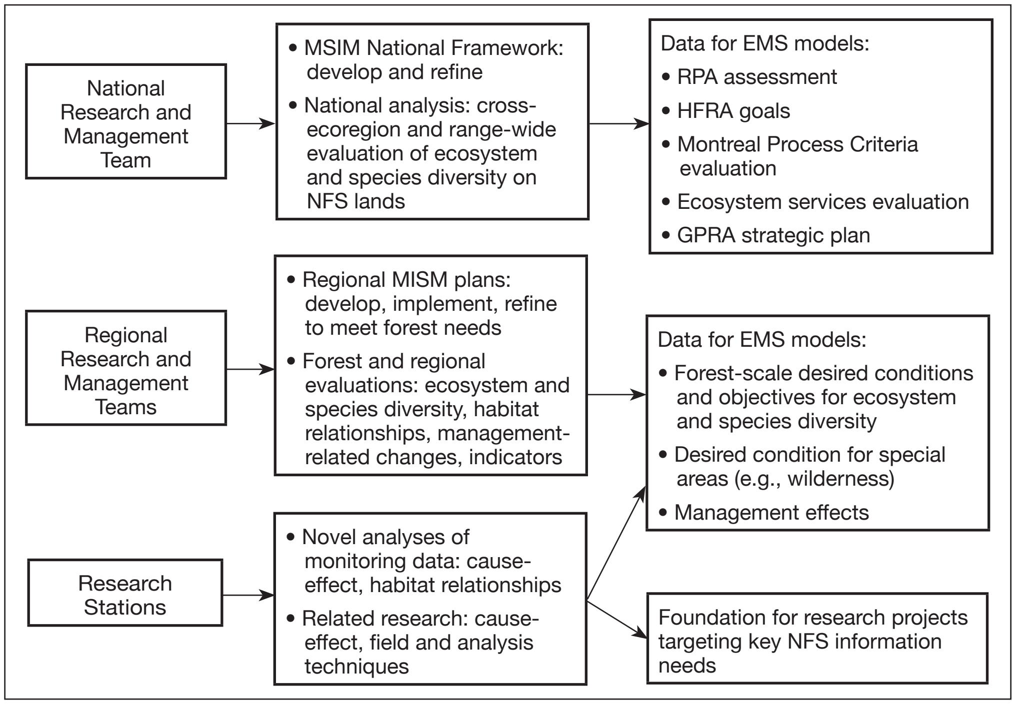
Although the MSIM protocol was developed to meet the needs of national forests, its association with FIA gives it the potential to be implemented across jurisdictions in the same way in which FIA crosses jurisdictions. If the MSIM protocol were only implemented on NFS lands, then it would provide data on the status, trends, and contribution of NFS lands to meeting agency and administration goals and objectives for sustainability at the national forest, region, and national levels.

1.2 Background and Business Needs

The MSIM protocol was developed in response to a growing need for national guidance on monitoring ecosystem and species diversity on NFS lands. The National Inventory and Monitoring Strategic Plan and associated Action Plan (April 3, 2000; http://www.fs.fed.us/emc/rig/iim) call for the development of national protocols to "ensure scientifically credible sampling, data collection, and analysis protocols are used in all inventory and monitoring activities." The MSIM protocol is designed to meet a wide range of business needs in the wildlife, fish, and rare plants resource area. The fundamental business requirements that the MSIM protocol serves include (1) Land and Resource Management Plan monitoring and revision as per the National Forest Management Act (1976); and (2) landscape, regional, and national strategic assessments and plans (fig. 1.2). National and regional teams depicted in figure 1.2 represent the recommended organizational structure to facilitate effective implementation of the MSIM protocol. Ideally, they would be created as a first step in implementation of the MSIM.

The newly revised National Forest Management Act planning rule (Federal Register 2005) calls for an adaptive management approach to land management in which monitoring for status and change plays a central role. Sustainability is the primary goal of the management of NFS lands, and it has three interrelated and interdependent elements: social, economic, and ecological. The overall goal of the ecological element of sustainability is to provide a framework to contribute to sustaining native ecological systems. This framework provides ecological conditions to support diversity of native plant and animal species in the plan area. The planning rule states that forest plans must establish a framework to provide the characteristics of ecosystem diversity and provide appropriate conditions for specific species of concern and interest in support of species diversity. Monitoring the status and change

Figure 1.2. *Roles and outputs associated with the development and implementation of the MSIM protocol.*



EMS = Environmental Management System; GPRA = Government Performance and Results Act; HFRA = Healthy Forest Restoration Act; NFS = National Forest System; RPA = Resources Planning Act.

in ecosystem and species diversity is conducted to determine if associated desired conditions and objectives are being achieved.

The new planning rule calls for the development and implementation of an environmental management system (EMS) as part of the land management framework. The EMS is to be a systematic approach to identify and manage environmental conditions and obligations to achieve improved performance and environmental protection. The EMS will identify and prioritize environmental conditions, set objectives, document procedures and practices to achieve those objectives, and monitor and measure environmental conditions to track performance and verify that objectives are being met. The MSIM protocol will contribute core data to EMS models for forest-scale desired conditions and objectives related to ecosystem and species diversity and forest health. In addition, it will contribute core data to a myriad of Forest Service information needs, such as Forest Service Manual (FSM) 2670 direction for monitoring many Forest Service Sensitive Species.

In addition to monitoring specified in the National Forest Management Act and the FSM, the Forest Service responds to larger scale information needs, and the MSIM protocol contributes core data to meet the following business needs:

- National Resource Planning Act (RPA) assessments.
- Healthy Forest Restoration Act (HFRA) assessments.

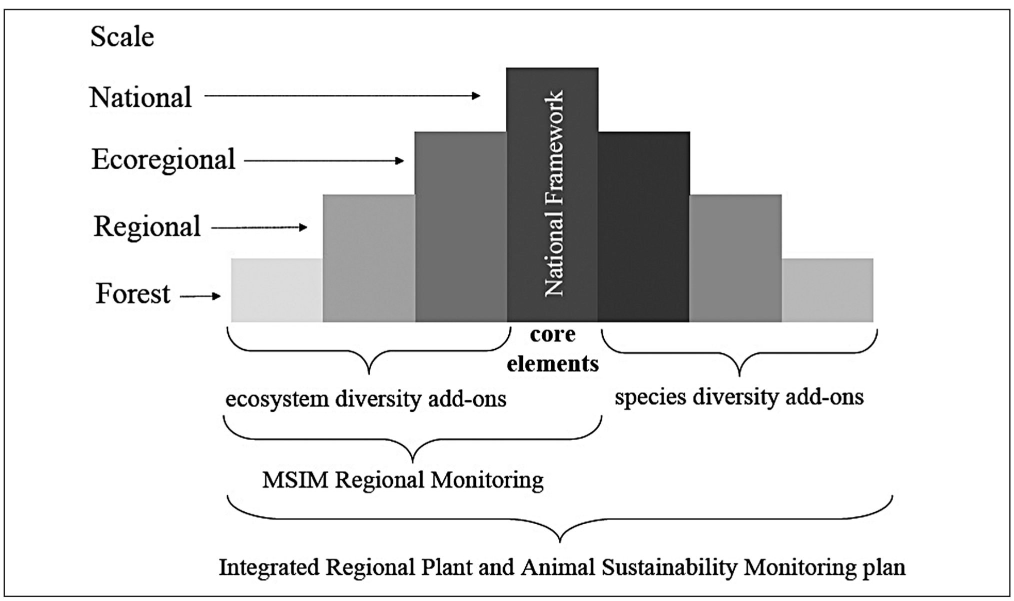
- Montreal Criteria and Indicators assessment of sustainable forest management—Criteria #1 (biological diversity) and #3 (forest health and vitality) (Anonymous 1995.
- Wilderness character evaluation of compliance with the Wilderness Act (1964).
- Government Performance and Results Act (GPRA) strategic plan assessments.
- Regional and ecoregional assessments, including assessments of ecosystem services, as needed.

1.3 Key Concepts

1.3.1 Components of the MSIM Protocol

The MSIM protocol consists of two components: the National Framework and regional plans. The National Framework identifies the core elements of the protocol, and regional plans summarize how, where, and when MSIM survey methods will be implemented on national forests in the region as partial fulfillment of meet forest, regional, and national monitoring program needs. The concept of core elements originated with the FIA and Forest Health Monitoring programs, the push for nationally consistent Geographic Information System (GIS) layers, and the need to support RPA reporting. As per the Forest Service Framework for Inventory and Monitoring (Powell 2000), core elements are collected using standard protocols, and they are designed to be flexible enough to allow for the collection of additional data beyond the core set to meet regional and local business needs for monitoring (fig. 1.3).

Figure 1.3. *Conceptual model of role of the MSIM protocol at each of four spatial scales.*



The National Framework for the MSIM protocol serves as the foundation on which regional plans are built to meet forest, regional, and national information needs. The National Framework consists of the following elements: (1) the MSIM sampling design, (2) regional plan development guidance, (3) evaluation and response guidance, and (4) “core” survey methods for species groups and habitat conditions, including recommended data management and analysis procedures. Core survey methods target the minimum information to be collected on every national forest across the country. The MSIM protocol specifies additional survey methods (primary and supplemental) to consider for inclusion into regional plans to fill out forest and regional monitoring needs. Although this version of the MSIM protocol targets vertebrate and vascular plant species and their habitats, additional methods could be added in future versions to address additional taxonomic groups (e.g., invertebrate pests) or specific information needs for species (e.g., invasives), areas (e.g., wilderness), or uses (e.g., off-highway vehicle use).

Regional monitoring plans are the working documents that implement monitoring programs, including accomplishing monitoring associated with the MSIM protocol. They accomplish the following objectives: (1) document the design options and survey methods selected; and (2) describe how the plan meets forest, regional, and national monitoring needs. Ideally, a regional monitoring plan is an integrated tool that reflects all the coordinated biological, physical, and socioeconomic monitoring to be accomplished throughout the region and by each forest, with MSIM being just one component. Regional monitoring plans are intended to serve as tools that specify and guide activities to meet the objectives of regional and forest monitoring programs. Each regional plan should recapitulate the technical guide outline, providing all the detail necessary for any reader to implement the plan consistently. Field guides may be developed by forests or regions to address logistical considerations, cost/time saving measures, and other field-oriented matters.

1.3.2 FIA Program Linkage

The MSIM protocol is designed to link to the systematic grid sample design of the FIA program. The FIA program of the Forest Service has been in continuous operation since 1930 with a mission to “make and keep current a comprehensive inventory and analysis of the present and prospective conditions of and requirements for the renewable resources of the forest and rangelands of the United States.” FIA consists of a nationally consistent core program that covers forests on all forest lands within the United States, and the program can be enhanced at the local, State, or regional level to address special interests.

Throughout this technical guide, the term “monitoring point” is used to describe the center point around which the MSIM survey methods are conducted, and is the corollary to the FIA point. Linkage to the FIA grid system creates an efficient ecosystem approach to gathering and evaluating information about the environmental conditions at each monitoring site that can be used to inform interpretations of observed changes in ecosystem and species diversity. It also creates the opportunity to expand ecosystem and species monitoring efforts beyond NFS lands, facilitating the assessment of conditions and trends across contiguous landscapes. Currently, the FIA program does not collect vegetation data at grid points that occur in nonforested habitat types. The MSIM protocol, however, is conducted at monitoring points established in association with a systematic subset of all FIA points that fall on NFS lands, regardless of the vegetation type in which they occur.

1.3.3 Parameter Estimation, Prediction, and Hypothesis Testing

The MSIM protocol is designed to estimate population and habitat parameters: basic parameters of detectability, proportion of points occupied, and habitat parameters. “Status” is a static description of population parameters (e.g., proportion of monitoring points occupied) or habitat parameters for a species (i.e., average and variance estimates for various measures) for a given sample period. “Change” is a comparison of values for population and habitat parameters between two or more sample periods. “Trend” is an evaluation of temporal patterns of change over multiple sample periods.

The MSIM protocol also generates data that can be used to estimate the ancillary parameters of species richness and spatial patterns of change in site occupancy. In addition, the data can be used to test hypotheses about expected linkages and relationships that are articulated prior to the onset of monitoring, and updated as results are obtained. Models developed from the monitoring data can provide the basis for developing hypotheses regarding cause-and-effect relationships, and building models that predict the effect of management on habitat conditions and species. The MSIM protocol targets presence/absence data, but a variety of data result from the core and primary survey methods that can be used to estimate parameters other than the proportion of points occupied. Some of the main data yields are described below.

Information on status and change in species diversity. MSIM enables national forests and regions to monitor populations and habitats of hundreds of species on NFS lands, including many species of concern and species of interest and their surrogates. In addition, many of the primary survey methods generate data other than predictions of presence, such as estimates of abundance for several species of land birds, small mammals, and plants, and reproductive status, age ratios, and sex ratios for small mammals.

Information on status and change in ecosystem diversity. The large number of species detected by the MSIM protocol results in data on the status and change of characteristics of ecosystem diversity, such as species richness, species diversity, species distribution, ecologically significant species, and nondesirable invasives. Monitoring data can be analyzed in terms of species composition and co-ocurrences that will provide insights into the strength and validity of species groups and surrogates, so that monitoring results and interpretations will gain in credibility and reliability in the course of implementation. In addition, effects of changes in populations and habitats of individual species can be evaluated in terms of overall community structure and dynamics.

Locally specific environmental relationships data. Patterned relationships between species occurrence or abundance and environmental conditions can be used to build predictive models of population status and change based on environmental variables, including habitat condition. In cases where species-habitat relationships are so strong that models explain most of the variation in species occurrence or abundance, MSIM will yield the ability to (1) improve habitat-based predictive models for species, facilitating credible habitat monitoring; (2) evaluate changes in habitat status compared to changes in the status of populations and ecosystem diversity characteristics; (3) make reliable inferences about species, species groups, and characteristics of ecosystem diversity using habitat-based predictive models; (4) evaluate and test existing or proposed surrogate species or species groups; and (5) empirically derive robust attributes of ecosystem characteristics, species groups, and surrogate species.

A foundation for comprehensive monitoring strategies. The MSIM protocol can meet an expanded suite of monitoring objectives at several spatial scales (fig. 1.3). It can be used as a foundation for regional monitoring strategies, expanding beyond multiple-species survey methods to include targeted single-species survey methods and human-use survey methods. It also builds a reliable empirical data set that can be used to identify and evaluate specific conditions of concern and interest, such as habitat thresholds beyond which species are predicted to experience precipitous declines (e.g., Fahrig 2002, Flather and Bevers 2002). Ecological, social, and economic objectives can be charted and identified as “checkpoints” that inform management as monitoring data are collected and evaluated. In addition, data on spatially explicit change in species occurrence and composition can yield insights on the effect of management activities and natural disturbances on plant and animal populations and communities. Finally, monitoring data can be used to improve the design and efficiency of monitoring programs over the course of their implementation.

A context for research. Where management actions or natural disturbances intersect monitoring points, MSIM data can be used retrospectively to identify potential effects of management actions or natural disturbances on populations and habitat conditions. Research can then be used to test hypotheses about potential cause-and-effect relationships and ecological thresholds that are of particular interest or concern. For example, MSIM data may show a positive relationship between fire and the abundance of a ground squirrel of concern. Further research may be required to establish the boundaries of this relationship—how intense and how large the fire needs to be over what period to have a desired effect. The results of research then further inform management as to how to accomplish objectives (maintain or reverse observed trends) by increasing certainty and perhaps identifying thresholds associated with cause-and-effect relationships. Thus, the MSIM protocol provides the broad-scale context for making informed decisions about when this intensive work is really necessary. It can also provide a backdrop of data collection that could make research studies less expensive and speed the delivery of results.

1.4 Roles and Responsibilities

1.4.1 Overview

Design and implementation of the MSIM protocol requires the involvement of management and research at all levels of the organization, with primary nodes of responsibility at regional and national scales (fig. 1.2). Successful implementation of any nationally consistent monitoring approach requires a partnership between management and research. This technical guide provides the specific steps necessary to monitoring multiple species to meet NFS monitoring information needs, but its success will ultimately depend on regional and national leadership in developing a regional and national program to conduct and support monitoring activities and products. Specific responsibilities for a program to implement the MSIM protocol as part of a regional and national monitoring program for NFS lands at the forest, regional, and national levels are described below.

1.4.2 Forest Responsibilities

Data Acquisition

- Participate in regional monitoring plan development; forest-specific needs for augmentation for MSIM should be integrated into the regional plan.
- Participate in multiforest and regionally coordinated implementation by providing leadership and support to train field crews and collect field data, ideally at the multiforest scale.
- Ensure that any funding provided to forests for the MSIM protocol are allocated directly and efficiently to accomplishing the MSIM program of work.

Data Management and Analysis

- Participate in forest and regional data management and analysis tasks.
- Ensure that data entered at the forest level meet quality control and assurance standards.
- Maintain confidentiality of monitoring point locations as per agreements with FIA.
- Address questions unique to the forest, in coordination with regional analyses and evaluations.
- Assess the utility of existing management indicator species based on forest and multiforest scale monitoring results.

Evaluation and Response

- Participate in processes to evaluate monitoring results and determine appropriate management and monitoring responses at both the forest and regional scales.
- Use results in forest planning and assessments.
- Participate and assist in the implementation of research to address key research questions complementary to or posed by monitoring results.

1.4.3 Regional Responsibilities

Data Acquisition

- Design and implement the MSIM protocol consistent with the MSIM National Framework through coordination among forests, regional offices, and research stations.
- Develop, coordinate, and conduct training for field data collection and protocol oversight, in collaboration with other regions and the Washington Office, to ensure consistency and quality control.
- Oversee and direct implementation of monitoring plans that include the MSIM protocol as part of the agency's Inventory and Monitoring Framework, including direct responsibility for appropriate expenditures of funds allocated to the MSIM protocol and faithfully implementing the regional plans.
- Coordinate data collection at the regional level, with direct involvement of the

forests, to maximize efficiency, consistency, and data quality.
- Work with FIA to generate monitoring point locations and abide by the associated memorandum of understanding (MOU).

Data Management and Analysis

- Oversee data entry and management, including input into the appropriate National Resource Information System (NRIS) modules and quality assurance and control activities.
- Coordinate with adjacent regions on data collection and data management related to shared species or ecosystems of particular interest to enable rangewide analyses and inferences.
- Analyze and report on forest and regional (and ecoregional where of interest) status and change in populations and habitat conditions, and their implications for biological diversity and sustainability.
- Summarize and analyze the status and change of species and habitats of interest and biological diversity for each forest and the region, relating forest and regional results.
- Coordinate with FIA to protect the integrity of monitoring points and obtain FIA data for habitat analysis.
- Evaluate sampling efficiency and statistical power, propose and coordinate changes to plans as needed.
- Coordinate with local agencies and organizations to maximize collaboration in data collection and implementation across administrative boundaries.

Evaluation and Response

- Design an inclusive process to evaluate monitoring results.
- Conduct annual and 5-year review of reports of MSIM-related activities and findings to determine the relationship between desired conditions and the status and change of conditions reflected in monitoring results at the scale of each national forest and the region.
- Evaluate habitat relationships, identify potential indicators and surrogates, and validate the utility of existing indicators, surrogates, and other direct and indirect measures of desired condition.
- Test hypotheses pertaining to potential cause and effect relationships of immediate significance to management.
- Make adjustments in management and monitoring activities and plans as indicated by monitoring results.
- Apply data and results as needed to inform forest, regional, and ecoregional assessments.

1.4.4 National Responsibilities

Data Acquisition

- Provide and manage funding for implementation of the MSIM protocol in each region.
- Oversee implementation of the MSIM protocol as part of the agency's Inventory and Monitoring Framework.
- Develop and maintain a MOU among NFS, Research and Development, and FIA regarding access to and confidentiality of monitoring point locations and facilitate access to FIA habitat data for NFS lands.
- Provide guidance in the development of regional plans, including review and revision as needed for finalization.
- Support, monitor, and evaluate implementation of regional MSIM plans.
- Assist regions in providing training for field data collection and protocol oversight.
- Develop collaborative relationships with other agencies and States at the national level to facilitate implementation of MSIM across land ownerships and integration of MSIM with other inventory and monitoring programs.

Data Management and Analysis

- Support development and update of NRIS modules and servicewide GIS data standards to accommodate MSIM data.
- Assist regions in providing training for data management and analysis.
- Develop basic EMS models for forest, regional, and national evaluations.
- Analyze and report on national status and trends in populations and habitat conditions in compliance with national commitments, such as RPA, GPRA, Sustainability Criteria and Indicators, and HFRA.

Evaluation and Response

- Update the MSIM protocol based on experiences and results obtained at forest, regional, and national scales, including the development of additional elements which may include invasive species, pests, and human use.
- Review annual and 5-year reports for each region to determine that they are compliant with the National Framework, and provide guidance to the forests and regions regarding significance of results, research needs and priorities, and opportunities to improve the efficiency and effectiveness of the plans.

1.5 Relationship to Other Federal Inventory and Monitoring Programs

Many national and regional inventory and monitoring programs exist in the Forest Service and other Federal agencies. The MSIM protocol is integrated with FIA, one of the most substantial and significant inventory and monitoring programs in the Forest Service. The MSIM protocol makes a unique and complementary contribution to information provided by FIA and a host of other monitoring efforts described below.

- The U.S. Geologic Survey (USGS) is working on behalf of the Department of Interior to develop standardized monitoring protocols for wildlife refuges and National Parks (e.g., Partners in Amphibian and Reptile Conservation). These efforts are still early in their development; however, effective collaboration between the Forest Service and USGS has resulted in primary detection protocols that reflect a general consensus about the most effective survey methods to meet broad-scale monitoring objectives. The USGS monitoring programs target lands managed by the Department of the Interior, and no nationwide multiple species program has been proposed by USGS to date. The MSIM protocol, however, incorporates many of the statistical and sampling innovations developed by USGS, and MSIM is likely to be an effective tool for monitoring populations and habitats in large refuges.
- The National Park Service (NPS) Inventory and Monitoring Program is identifying ecosystem vital signs and developing monitoring programs for the 270 Park Units with significant natural resources. The goal of the program is to integrate and communicate scientific information on status and trends of the Parks' natural resources to support Park management. Park monitoring programs are as comprehensive in scope as possible, and an explicit programmatic goal is to use shared monitoring protocols, where possible, to facilitate collaboration and data sharing with other State, Federal, and nongovernmental organizations. Information from other agency monitoring programs, including FIA, is incorporated in monitoring databases and analyses as part of a strategy to leverage existing activities. Monitoring plans are being developed for each network of National Parks, typically consisting of three or four National Parks within an ecoregional area, with each network developing its own approach to monitoring populations and habitats. Collaboration between NPS and the Forest Service (e.g., between a National Park and a national forest, or between National Parks and national forests throughout an ecoregion) in the design and implementation of multiple species inventory and monitoring is likely to result

in a fruitful cross-pollination that will increase the robustness of the data and strengthen inferences for both agencies.

- The National Resources Inventory (NRI) is a statistical survey of land use and natural resource conditions and trends on U.S. non-Federal lands. Non-Federal land includes privately owned land, tribal and trust land, and lands controlled by State and local governments. The NRI is conducted by the Natural Resources Conservation Service in cooperation with Iowa State University's Center for Survey Statistics and Methodology. The primary objective of the NRI is to provide natural resource managers, policymakers, and the public with periodic information on land use and land cover dynamics, soil erosion rates, and conservation practices implemented (Nusser and Goebel 1997). The NRI was conducted every 5 years during the period 1977 through 1997, but currently is in transition to a continuous or annual inventory process. This shift helps align the NRI with the need for timely information to support development and assessment of agricultural and conservation policies and programs (http://www.nrcs.usda.gov/technical/NRI/).

- The GAP Analysis Program (GAP) meets a fundamentally different objective of predicting wildlife occupancy using existing data, and evaluating threats to areas key to species conservation (Scott et al. 1993). GAP is a scientific means for assessing to what extent native animal and plant species are being protected. The goal of GAP is to keep common species common by identifying those species and plant communities that are not adequately represented in existing conservation lands. By identifying their habitats, GAP gives land managers, planners, scientists, and policymakers the information they need to make better-informed decisions when identifying priority areas for conservation. GAP classifies landscapes in areas that are multiple kilometers across and then attributes these landscape areas by various parameters, including species composition, threats, and protection status. (See http://www.gap.uidaho.edu for more details.) The MSIM protocol could provide high-quality species composition data for GAP.

- The Breeding Bird Survey is a standardized, road-based survey of breeding birds (Droege 1990). It is conducted by volunteers, and it is an effective national and rangewide monitoring approach for breeding birds. Because it is road-based, however, it is incompatible with monitoring most other species and poses some difficulties in providing unbiased information on habitat relationships and habitat trends. The MSIM protocol could provide a validation data set for BBS data in terms of evaluating the potential bias associated with the road-based BBS data.

- U.S. Army Land Condition Trend Analysis has developed detailed vegetation and soils monitoring protocols, but they are tailored to inventory and monitor the condition of individual military training sites. The MSIM protocol is intended for implementation across broader landscapes, thus requiring a consistent, systematic grid approach, and targeting of presence/absence data.
- NatureServe has a well-developed vegetation classification system and gathers heterogeneous data on species occurrences. The MSIM protocol is designed to link to the NFS vegetation classification system (Society of American Forester types) and data management system (NRIS), and the NatureServe vegetation classification and data management systems.
- The Nature Conservancy (TNC) has a strategic, science-based planning process, called Conservation by Design, which helps identify the highest priority landscapes and seascapes that, if conserved, promise to ensure biodiversity over the long term. Within each TNC ecoregion, the following steps are taken to conserve nature: (1) identify conservation targets, (2) gather information, (3) set goals, (4) assess viability of at-risk elements, and (5) develop a conservation portfolio. The MSIM protocol could provide valuable information to TNC for their conservation planning efforts, and TNC could potentially contribute monitoring data on other public and private lands to build a more comprehensive picture of the status and trends of plants and vertebrates in the ecoregion and the contribution of NFS lands to sustaining populations in the ecoregion. Information at http://nature.org/aboutus/howwework/about/art5721.html.

1.6 Quality Control and Assurance

Quality control and assurance procedures vary among taxonomic groups addressed by the MSIM protocol. Quality control and assurance procedures for survey methods associated with the MSIM protocol are discussed in each chapter. Considerations and recommendations for quality control and assurance for sampling design and analysis are discussed in the planning and design (section 2.3) and data analysis (section 2.5) sections of chapter 2.

1.7 Change Management

The *MSIM Technical Guide* will be updated as needed based on the results of implementation. During the first 3 years, the protocol will be evaluated in terms of its efficiency, utility, sample-size requirements, and cost of target variables. These method-based evaluations will inform expectations about species likely to be detected adequately enough to detect change in the proportion of sites occupied, and help determine if sampling intensities specified in the National Framework are sufficient or need to be increased to meet basic objectives for the precision of estimates of status and change. The first 3 years will also be used to hone analytic techniques for exploring population, community, and habitat change and relationships to one another. During the first 3 years, EMS models should also be developed for forest and region evaluations of ecosystem and species diversity and management effects. EMS models need to explicitly specify the evaluation questions and the analytic processes that will be used to refine the monitoring plan. After the first 5 years, it is likely that plans can move to a 5-year cycle of evaluation and update.

Chapter 2. National Framework

2.1 Purpose and Objectives

The National Framework for the Multiple Species Inventory and Monitoring (MSIM) protocol is intended to provide consistency in data collection and analysis within and among regions to fully realize the potential benefits of an investment in broad-scale change monitoring. The National Framework, as reflected in regional plans, has the following primary components: (1) sampling design, (2) preparation and planning, (3) data collection and analysis, and (4) evaluation and reporting. The core elements of the National Framework are the recommended minimum elements for inclusion in regional plans, and are summarized in table 2.1. Descriptions of all of the National Framework are provided in this chapter.

2.1.1 Objectives

The MSIM protocol provides reliable, standardized data on status and change in the distribution and site occupancy for a large number of plant and animal species that occur on national forests and grasslands at the forest, regional, and national scales. These data are expected to serve as the primary source of population and habitat monitoring data to address the status and change of ecosystem and species diversity to inform land management and comply with the National Forest Management Act (1976).

The MSIM protocol is designed to answer the following inventory or status questions:

- What is the status of populations of a variety of individual species (1) within a forest or region, (2) on National Forest System (NFS) lands within an ecoregion or biome, and (3) throughout their range?
  - Proportion of monitoring points occupied.
  - Spatial distribution of occupancy.
- What environmental factors are associated with individual species or groups of species (1) within a forest or region, (2) on NFS lands within an ecoregion or biome, and (3) throughout their range?
  - Vegetation structure and composition at monitoring points.

The MSIM protocol is designed to answer the following monitoring questions:

- What is the direction and magnitude of change of proportion of monitoring points occupied by a variety of individual species (1) within a forest or region, (2) on NFS lands within an ecoregion or biome, and (3) throughout their range?

- Change in the proportion of monitoring points occupied.
- Change in the spatial distribution of probability of occupancy.
- Change in site occupancy rates and patterns (i.e., sequence of occupancy for individual sites summarized over all sites).

- What is the direction and magnitude of change of habitat for a species or species group for which predictable habitat relationships have been determined (1) within a Forest or region, (2) on NFS lands within an ecoregion or biome, and (3) throughout their range?
  - Change in vegetation structure and composition at monitoring points.

Table 2.1. *Summary of core elements of the National Framework for the MSIM protocol.*

Element	Specifications
FIA grid base	MSIM monitoring points are established in association with FIA grid points.
Sampling design	At least 50% of the FIA grid points are used to establish monitoring points in regional monitoring plans, and the process by which monitoring points are randomly selected.
Resample frequency	A 3-year sample period and no more than a 5-year resample cycle are specified.
Core methods	Landbird point count, small mammal live trapping, trackplate and camera survey, nocturnal broadcast survey, visual encounter survey—each with multiple visits—and habitat monitoring.
Data acquisition	Regional plans coordinate design and data collection at the regional scale, with forests working collaboratively in data acquisition to enhance consistency and reduce costs.
Data storage	Core data (species detections and habitat conditions) stored in the Fauna module of the NRIS. A national framework for an Access database is provided for use and customization by regions, and then relevant data copied to a variety of destinations, including NRIS Fauna, The Nature Conservancy, and State heritage programs (via NatureServe).
Data analysis	Data analysis follows minimum standards, such as estimates of proportion of monitoring points occupied, probability of detection, and a quantitative description of habitat condition for each species detected. A regional-scale analysis guide developed by regions will provide consistency and reliability to results from regional analyses.
Reporting	Annual reports are produced by each region, and they comply with reporting standards established as part of the National Framework to ensure a minimum quality and detail, and to facilitate the examination of change across regions. Annual reports contain a description of sampling effort and descriptive statistics and estimates for the data collected each year since the last 5-year summary. At 5-year intervals, a more detailed analysis will be conducted that analyzes population change, habitat change, habitat relationships, and any desired ancillary analyses.
Evaluation and revision	Annual and 5-year reports are reviewed by (1) the Wildlife, Fish, and Rare Plants and the Ecosystem Management Coordination staffs; and (2) the region and station leadership teams in each region and station for compliance with the National Framework and significance of results to management.

FIA = Forest Inventory and Analysis; NRIS = National Resource Information System.

2.2 Sampling Design

2.2.1 Status and Change Parameters

Status, change, and trends were defined in chapter 1, but their definitions are repeated here for clarity. "Status" is a static description of population parameters (e.g., proportion of monitoring points occupied) or habitat parameters for a species (i.e., average and variance estimates for various measures) for a given sample period. "Change" is a comparison of values for population and habitat parameters between two or more sample periods. "Trend" is an evaluation of temporal patterns of change over multiple sample periods.

The MSIM protocol is designed to estimate species' presence at monitoring points distributed across NFS lands. Surveys that intend to document species presence are commonly referred to as "presence/absence" surveys. Given that absence can result from either absence or nondetection, the survey data are actually detection/nondetection data that are then interpreted as in terms of presence or absence. Thus, the MSIM protocol refers to the target data as detection/nondetection and the target population parameter as presence/absence.

Data analysis consists of creating species lists for each monitoring point across all visits (surveys) in a sampling period, and estimating the proportion of all monitoring points occupied within the entire area of inference, using the probability of presence and detection probabilities as parameters in a maximum likelihood model (section 2.6.2). The freeware program PRESENCE is available for this analysis (http://www.mbr-pwrc.usgs.gov/software.html). The species detection data from each station or site are compiled to create detection histories for each visit to each monitoring point for each species. Detection histories consist of either a "1" for the entire sample unit (regardless of the number of detections) or a "0" if no detections were made. For example for two visits, the detection history for a given species will be 00, 01, 10, 11, 1x, or x1, 0x, or x0, where x represents that either the first or second visit was not made. Status for populations and habitats is determined at the conclusion of the initial 3-year sample period. Change is determined at the end of the second (and subsequent) sample period(s), which takes place within 5 years of completing the initial sample period.

2.2.2 Standards of Precision

The ability to detect population and habitat change depends on the magnitude of change that is of interest and the precision of estimates of change. Given that MSIM targets multiple species, change and precision standards can not be strictly set. Minimum standards can be established, however, that apply to the conservation of any species, and then monitoring data can be evaluated at various scales to determine (1) which species are sufficiently detected to meet minimum standards, and (2) species for which sampling is inadequate to meet minimum standards or to meet higher standards that may be desired for species of special interest or concern.

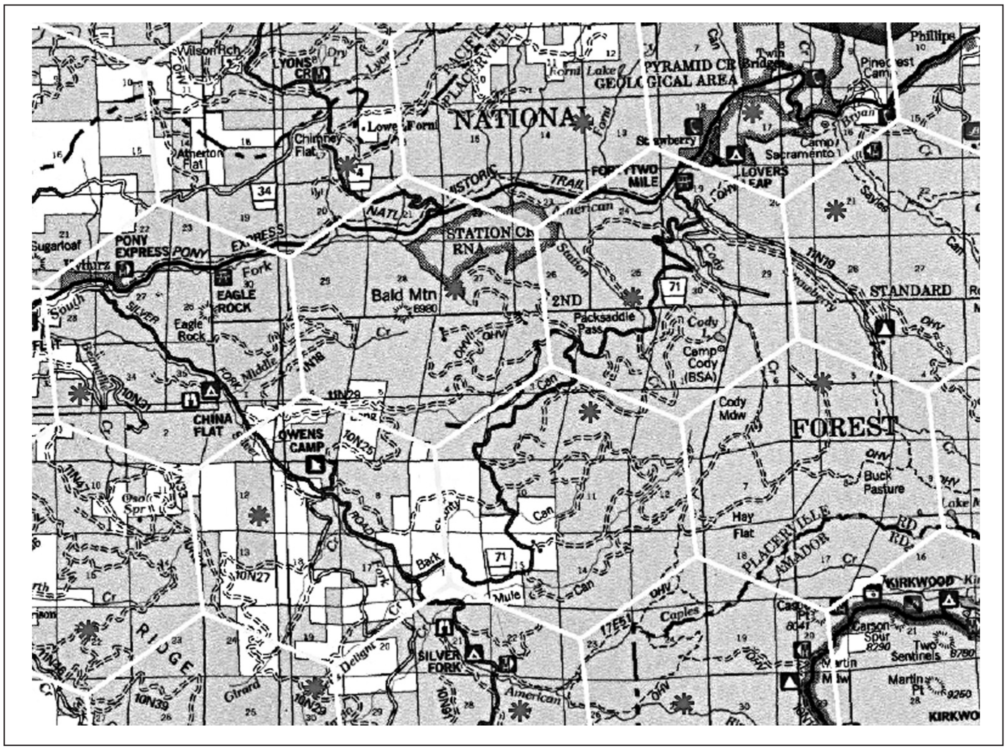
Minimum standards of the National Framework are a relative change of less than or equal to 20 percent (i.e., 20 percent relative change in the proportion of monitoring points occupied) between two sample periods with statistical confidence and power of 80 percent. If estimates were any less precise, they would be unreliable, and if they were any less able to detect change, they would risk species extirpation. These sensitivity standards are deemed adequate to provide an early warning for species for which no concerns for population persistence currently exist. Of course, statistical confidence and power will vary among species, with some not detected well enough to meet the minimum standards and others detected so well that monitoring will provide a highly sensitive measure of change. Higher sensitivity standards and/or smaller areas of inference may be appropriate for individual species of interest and concern, and these standards should be specified and accommodated in regional monitoring plans.

2.2.3 FIA Grid

The MSIM protocol is designed to link to the systematic grid sample design of the Forest Inventory and Analysis (FIA) program. The current FIA grid design consists of a systematic hexagonal grid across all ownerships in the United States, with each hexagon containing approximately 6,000 ac (2360 ha). One FIA point is randomly located within each hexagon (fig. 2.1), and at each point vegetation structure and composition are scheduled to be described once every 5 to 10 years (Roesch and Reams 1999).

The national FIA program consists of three levels of detail in data collection called “phases.” Phase 1 is a remote sensing phase aimed at classifying the land into forest and nonforest and taking spatial measurements such as fragmentation, urbanization, and distance variables. Phase 2 provides the bulk of information, and consists of field data collection at each FIA grid point to describe vegetation structure and composition. Phase 3 data collection is conducted at a relatively small subset of the grid points (approximately 6 percent of the points) and consists of an extended suite of ecological data including full vegetation inventory, tree and crown condition, soil data, lichen diversity, coarse woody debris, and ozone damage. At the present time, nonforest locations are only visited as necessary to quantify rates of land use change. FIA generates reports on the status and change in forest conditions, and area and location, but on NFS lands the raw data are available to NFS for site-specific

Figure 2.1. *Example FIA grid on a national forest. FIA points are indicated by asterisks.*



FIA = Forest Inventory and Analysis.

analysis and interpretation. Many regions rely on FIA data for generating vegetation maps for forest and project planning, and they also conduct FIA Phase 2 protocols at nonforest sites to complete their vegetation databases. The program is implemented in cooperation with a variety of partners including State forestry agencies and private landowners who grant access to non-Federal lands for data collection purposes.

The MSIM protocol link to the FIA grid system is intended to provide an efficient source of information about the environmental conditions at each monitoring point that can be used to inform interpretations of change in populations and habitat conditions. Linkage to a nationwide sampling grid also creates the opportunity to expand population and habitat monitoring efforts beyond NFS lands to other public lands, which would confer the ability to assess conditions and change across contiguous landscapes. Careful consideration of site integrity and anonymity is warranted, and these issues are addressed in detail in a memorandum of understanding between the FIA program and the NFS to ensure that investments in the FIA program are secure (for more information visit www.fs.fed.us/fia). In brief, MSIM monitoring points are not the same as FIA grid points, but rather they are located 100 to150 m away in a random direction. The FIA program derives the location of the MSIM monitoring points and provides them to the regions. The spatial offset of MSIM monitoring points from FIA points sampling serves to maintain the anonymity and integrity of the FIA points for the purposes of vegetation and soils monitoring. Most survey methods for terrestrial environments occur within a 200-m radius area around the monitoring point, so FIA data collected at the FIA point remain spatially coincident with animal sampling.

2.2.4 Monitoring Point Selection

The number of FIA grid points in NFS lands varies from approximately 2,000 to 3,500 points within a region. The National Framework calls for a minimum of 50 percent of the FIA grid points to be selected for MSIM monitoring points. This core set of monitoring points is established by randomly selecting half of the 10 FIA grid panels that have been created to identify annual sampling activities of the regional FIA programs. The remaining panels are randomly placed in rank order, as are the points within each panel based on serial random selection of 10 percent of the FIA points on each national forest. If desired, regions can identify the primary vegetation series in which remaining monitoring points (i.e., the remaining 50 percent of the grid) occur and use this information in selecting additional monitoring points as needed to meet specific regional and individual forest monitoring needs for specific vegetation types or species. Any additional points selected to meet specific local or regional needs may not be included in region or rangewide distribution and change estimates, or may only be included with appropriate statistical adjustments.

Sample size adequacy to meet monitoring objectives at region or forest levels can be evaluated through a few simple steps. First, one can calculate the number of monitoring points falling within the ranges of all species, highlighting those species of current interest (e.g., U.S. Department of Agriculture Forest Service Sensitive [FSS] or Federal threatened and endangered [FTE] species). Then, one can evaluate sample size adequacy to meet various population objectives (e.g., proportion of monitoring points occupied or abundance of species of interest, representation of all species) based on best available estimates of probability of detection for the survey methods to be employed (e.g., Manley et al. 2004). Sample size adequacy may be enhanced by (1) an increase in the probability of detection per point by increasing sample effort (e.g., more sample stations, increased sampling duration, additional sample sessions, additional sampling methods) at monitoring points in the species range; or (2) an increase in the number of monitoring points within suitable habitat within the range of species.

2.2.5 Sampling Frequency

The FIA sampling design is based on a serial alternating panel approach (Lesser and Overton 1994, Roesch and Reams 1999, Thornton et al. 1994). A systematic subset of points (a panel) is identified for sampling in each State each year. The alternating panel design generally consists of *n* sampling units partitioned into *m* panels, with each panel containing *np* sample units (np = n/m) and having the same temporal pattern of remeasurement. The remeasurement schedule determines the number of panels; if all sites are visited every 5 years, then there are 5 panels, one for every year. The goal of FIA is to sample 20 percent of all field plots sampled in every State every year. As a step toward this goal, the program is currently sampling 15 percent of plots in the Eastern United States, and 10 percent of the plots in the Western United States every year as a base Federal program. Alaska, Hawaii, and other island areas receive treatment as special cases not necessarily conforming to the general model.

Sampling monitoring points associated with every FIA grid point every year clearly would yield the greatest statistical confidence and power. In the interest of cost savings, efficiency, and logistical feasibility, however, serially alternating panel designs such as those used by FIA are more feasible to implement and appear to provide a high degree of statistical precision to describe status and statistical power to detect change over time per unit effort. For resources that fluctuate from year to year (such as animal populations), panel designs are best augmented with a panel that is visited every year (i.e., augmented serial alternating panel design) to characterize annual variation (Fuller 1999, Urquhart et al. 1993). Simple detection/nondetection data, however, should exhibit lower annual fluctuations compared to abundance data. Based on these factors, the National Framework is a serial alternating panel design with no annual panel with the following characteristics:

- All monitoring points are sampled within a 3-year sample period, which is long enough to integrate any annual variation that may exist, short enough to make it feasible to devote the required funding to finish the sampling, and short enough to schedule two or three sample periods within a 10-year planning period if desired.
- Core monitoring points (used to make inferences at the forest, multiforest and regional scales) are divided into three panels and one panel is sampled per year for 3 years.
- Panels are sampled in the same order in the next sample period so they all have the same number of intervening years between samples.
- Panels are resampled a minimum of once every 5 years, resulting in a minimum of two sample periods within a 10-year planning period; however, the time period between resamples does not need to be consistent to calculate change.

2.2.6 Survey Methods

Core survey methods are defined as the one or two most effective survey methods for detecting the greatest number and most representative suite of species per unit effort for species groups of primary interest to most national forests. Bats, plants, and aquatic ecosystems do not have ubiquitous emphasis across the regions, and so they have primary survey methods as opposed to core survey methods. Primary survey methods similarly represent the most effective survey methods for these species groups, but they are not considered part of the National Framework. In the case of habitat monitoring, core methods are designed to be the most efficient measures of environmental condition pertinent to the majority of species detected by core detection protocols and consistent with FIA protocols (table 2.2). The foremost

Table 2.2. *Core and primary survey methods for each of several taxonomic groups as identified for the MSIM National Framework. Methods considered core to the MSIM protocol (i.e., applied everywhere) are indicated.*

Taxonomic group	Species	Survey method	Core or primary	Chapter
Landbirds	All diurnal and crepuscular bird species that regularly vocalize	Point counts	Core	3
Raptors and other nocturnal bird species	Hawks, owls, nighthawks, poorwills	Nocturnal broadcast surveys and visual encounter surveys	Core	4
Small mammals	Rodents, carnivores (small weasels)	Live traps	Core	5
Medium and large mammals	Carnivores (larger weasels, skunks, cats), omnivores (bears), lagomorphs, ungulates (deer, moose, elk)	Trackplates with cameras	Core	6
Bats	Bats	Mist nets with acoustic survey	Primary	7
Terrestrial amphibians and reptiles	Salamanders, snakes, lizards	Visual encounter surveys	Core	8
Aquatic-associated vertebrates	Frogs, toads, newts, snakes, tutles, beaver, water shrew, river otter, mountain beaver, water birds	Visual encounter surveys and point counts at aquatic sites	Primary	9
Vascular plants	All vascular plant species	Quadrats, fixed plots, line transects	Primary	10
Habitat	Physical and biological conditions associated with species presence	Multiple methods at monitoring point and distal sample locations	Core	11

objective of core (and primary) methods is to obtain detection data that can be attributed to the monitoring point. The methods prescribe multiple visits per season (i.e., temporal replication), thereby enabling statistical estimates of probability of detection, proportion of monitoring points occupied, and species richness.

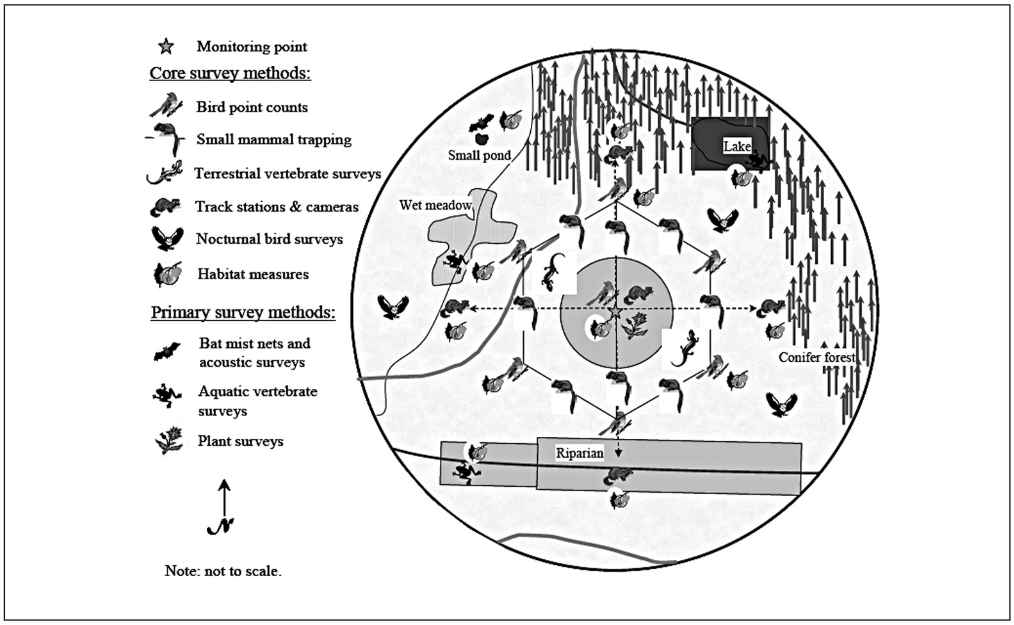
Supplemental survey methods are those that best complement the core survey methods, such as efficiently targeting sets of species missed by the core protocol. Supplemental survey methods can also include recommendations for improving the precision of detections or measurements obtained using the core survey methods (e.g., increased sample effort to obtain more precise measurements). Core and supplemental survey methods are the result of consultation with taxonomic experts for each species group and for habitat conditions. Experts were asked to review existing information on available methods and their performance in similar applications and provide a recommended method for detecting species at a series of monitoring points. Effectiveness of the survey methods was judged based on their ability to consistently detect a broad array of species in a spectrum of environments. All methods were designed to minimize costs, bias of estimators, and conflicts among methods. The methods maximize efficiency, representation, and acquisition of ancillary data.

2.2.7 Sample Units

Sampling associated with most of the survey methods is contained within a 200-m radius hexagonal area occupying approximately 10 ha (i.e., "10-ha sampling hexagon") centered on the monitoring point (fig. 2.2). Coordinated design of the survey methods reduces the time required to flag sites and find sample sites, increases the efficiency of data collection (observers can collect multiple types of data during a single visit), and reduces the amount of flagging at each point, making the points less conspicuous. The relatively large area occupied by the sampling hexagon reflects the desire for surveys to encounter the variety of vegetation types and conditions that occur in proximity to the monitoring point, thus increasing the number of species available for detection. Exceptions to the standard configuration of the 10-ha sampling hexagon will occur where dangerous conditions or large water bodies occur within 200 m of the monitoring point.

All the survey methods are designed to make inferences about areas associated with the monitoring point, but survey methods differ in two important features: (1) the area that they effectively sample for their target taxa, and (2) how sample sites are selected. Some survey methods consist of a fixed sampling array that is configured in some consistent manner around the monitoring point. These survey methods are common for species that are broadly distributed or can be readily

Figure 2.2. *Graphic representation of coordinated sampling configuration for survey methods in the MSIM protocol.*



detected from a fixed location. For example landbird point counts and Sherman live traps are arrayed in a hexagonal pattern around the monitoring point, and visual encounter surveys search 100 percent of the area within the 200-m radius sampling hexagon. Some taxonomic groups require a search area that is larger than the primary sampling hexagon, such as raptors. Other survey methods entail first seeking suitable substrates or environments for survey, namely aquatic habitats. In these cases, suitable substrates are located throughout a primary sample unit of a given size, and then one or more of the substrates are surveyed.

A nested set of sample units of various sizes would be an ideal tool for spatially integrating sample units among survey methods. Although not currently part of the National Framework, one option would be to use FIA hexagon boundaries as an organizing feature on which to build nested sample units. The locations of these hexagons, however, are confidential to protect the integrity of FIA points. In lieu of hexagon boundaries as an organizing feature, a consistent grid of nested sample units could be developed for the country, perhaps based on FIA hexagons. Until a contiguous grid is developed, data collected in association with MSIM monitoring points will be analyzed as point data.

2.3 Preparation and Planning

2.3.1 Regional Plans

The MSIM protocol provides population and habitat information on a large number of species that are likely to include a substantial number of species of concern or interest that are specifically targeted for monitoring. The scale of implementation is the national forest, but the primary planning scale is the region to ensure consistency in monitoring approaches for species and ecosystems shared among forests. The suite of species sampled adequately by the MSIM protocol to detect a change will depend on the geographic area in which it is implemented (forest, multiforest, regionwide) and the survey methods used. The core survey methods are designed to provide a representative sample of species in various taxonomic groups and at various trophic levels. Supplemental survey methods identify additional sampling options that are complementary to the core methods to detect a greater number or representation of species, or to target species of concern or interest at forest or regional levels (chapter 1, fig. 1.3). Single-species methods are not specified, but could be integrated into a comprehensive regional monitoring plan including a combination of MSIM, additional effort targeting one or more species, and any additional habitat measurements that might be needed. Substantial efficiencies are gained by colocating additional single-species monitoring efforts, including the availability of habitat, prey, and environmental data.

The structure and content of each regional monitoring plan should follow the organization of the technical guide. Regional monitoring plans should include, at a minimum, all elements in the MSIM National Framework, and serve to synthesize and coordinate population and habitat monitoring on NFS lands across the region. The full suite of benefits associated with the MSIM protocol is contingent on consistent implementation of protocols among forests that share ecotypes and associated species. Regional monitoring plans should be developed through a collaborative effort between research and management teams composed of research scientists and managers.

2.3.2 Integrated Monitoring

Table 2.3 provides an example of integrated regional monitoring plans that are designed to meet forest, regional, and national information needs. The National Framework states that the six core protocols will be conducted within every region. Region A decides to augment the core protocols with a survey effort directed at accipiters and plants. They choose to conduct the multiple-species accipiter broadcast surveys (a supplemental survey method for raptors covered in chapter 4) at MSIM monitoring points, and augment the MSIM monitoring points with a few additional sample units in suitable habitat to meet the sample design requirements of the National Goshawk Survey Protocol. Region A is also interested in a strong ecological monitoring program for its wilderness areas, so it decides to sample every FIA point in wilderness areas and add MSIM plant surveys in wilderness areas, as well as regional invasive plant survey methods. Region A determines that, in addition to the core survey methods, they will implement the primary survey methods for bats and aquatic ecosystems. Forest A is located within Region A, and it has a very active fisheries and amphibian management program. Forest A adds all primary and supplemental aquatic surveys to their monitoring program, plus fish surveys using electrofishing, such that they are fully implementing MSIM and Aquatic Ecological Unit Inventory (AEUI) protocols for monitoring aquatic ecosystems on their forest.

Region B has many bat species of concern and interest and chooses to implement

Table 2.3. *Example components of a spatially and programmatically integrated regional monitoring strategy.*

Scale	MSIM surveys	Other surveys
National Framework	Bird point count Small mammal live trap Trackplate and camera Nocturnal broadcast survey Vertebrate area search	
Region A	Accipiter surveys at monitoring points and additional sample units within suitable habitat Additional monitoring points in wilderness for all core and primary survey methods Bat and aquatic vertebrate surveys at core sites	Invasive plant surveys at wilderness monitoring points
Region B	Bat surveys at core sites Additional monitoring points in aspen for bird point count surveys	Spotted owl nest surveys
Forest A	Aquatic vertebrate surveys and habitat monitoring (primary and supplemental = full AEUI)	Fish surveys as per AEUI
Forest B	Bat surveys at supplemental survey sites	Roost monitoring

AEUI = Aquatic Ecological Unit Inventory.

the primary survey methods for bats on every forest. Region B is also interested in monitoring neotropical migratory birds within each of their major vegetation types. Their calculations reveal that MSIM monitoring points provide an adequate sample in every vegetation type except aspen. Therefore, the region selects all additional FIA points occurring in aspen plus 10 additional randomly selected locations in aspen (not associated with FIA) to establish monitoring points at which they will conduct bird point counts. Region B is also interested in determining the nesting status of spotted owls, so they include a followup protocol to determine the nesting status of all spotted owls detected during nocturnal broadcast surveys. The followup protocol consists of locating the individual owl the morning after its first detection and providing it prey in an attempt to get it to take the prey to its nest site. Implementation of the nocturnal broadcast survey and followup to determine nest status enables the forests to forego preproject spotted owl surveys. Forest B is in Region B, and it is the only forest within the range of a bat species that is on a Federal list of threatened species. Forest B surveys for bats at supplemental sites throughout the 100-km^2 sample units as per the MSIM supplemental survey methods for bats, and also surveys known and suspected roost sites (e.g., bridges, caves, mines) as per regional protocols.

2.4 Data Collection

2.4.1 Staffing Requirements

Staffing requirements will vary depending on a number of factors: number of points per forest; distribution of NFS lands (isolated or clustered forests); accessibility (e.g., many or few roads, topography); and the survey methods implemented (i.e., core, primary, supplemental). If the modal number of monitoring points per national forest is 200, then the MSIM National Framework calls for 100 monitoring points, with an annual sampling effort of 33 monitoring points. Based on this generic scenario, staffing to accomplish implementation of core and primary survey methods would look something like the field schedule in table 2.4. Although the actual month that sampling will begin will vary depending on the geographic location, sampling will generally span 6 to 6.5 months with methods implemented in the appropriate seasons and associated months. The total number of field crewmembers can be reduced by minimizing the amount of overlap between survey methods. Reducing overlap allows for a smaller, core group of individuals to conduct multiple survey methods, which confers substantial savings in basic training, such as driver safety, first aid,

Table 2.4. *Generic schedule of field crew activities to accomplish core and primary survey methods on a national forest with 100 monitoring points (200 FIA points) that are sampled over a 3-year period (33 per year).*

Taxa	Survey Method	Apr week				May week				Jun week				Jul week			
	Core :	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Landbirds	Point counts						2	2	2	2	2	2	2				
Raptors and other verts	Nocturnal broadcast and TVES	4	4	4	4	4											
Small mammals	Sherman live trapping													4	4	4	4
Large mammals	Trackplate/camera stations							3	3	3	3	3	3	3	3	3	3
Terrestrial amph and reptile	ARVES		4	4	4	4	4										
Plants and habitat	Plant and habitat measures					2	2	2	2	2	2	2	2	2	2	2	2
	Total field crew	**4**	**8**	**8**	**8**	**8**	**8**	**7**	**7**	**7**	**7**	**7**	**7**	**9**	**9**	**9**	**9**
	Primary:																
Bats	Mistnet and acoustic									2	2	2	2	2	2	2	2
Aquatic-associated verts	AQVES and AQPC							2	2	2	2	2	2	2			
	Total additional field crew							**2**	**2**	**4**	**4**	**4**	**4**	**4**	**2**	**2**	**2**

Taxa	Survey Method	Aug week				Sep week				Oct week			
	Core:	1	2	3	4	1	2	3	4	1	2	3	4
Landbirds	Point counts												
Raptors and other verts	Nocturnal broadcast and TVES	4	4	4	4	4							
Small mammals	Sherman live trapping	4	4	4	4	4							
Large mammals	Trackplate/camera stations												
Terrestrial amph and reptile	ARVES						4	4	4	4	4		
Plants and habitat	Plant and habitat measures	2	2										
	Total field crew	**10**	**10**	**10**	**10**	**8**	**4**	**4**	**4**	**4**	**4**		
	Primary:												
Bats	Mistnet and acoustic	2	2	2	2	2	2						
Aquatic-associated verts	AQVES and AQPC												
	Total additional field crew	**2**	**2**	**2**	**2**	**2**	**2**						

AQPC = Aquatic Point Counts; AQVES = Aquatic Visual Encounter Survey; ARVES = Amphibian and Reptile Visual Encounter Survey; TVES = Terrestrial Visual Encounter Survey.

orienteering, and site locations. It also enables field crewmembers to assist one another when staffing bottlenecks occur as a result of any number of factors (e.g., sickness, weather). Based on the generic example, core survey methods require a field crew size of around four individuals in the spring and fall, increasing to 7 to 10 individuals for the majority of the summer. Primary survey methods (bats and aquatic site surveys) require two to four additional individuals, for a maximum of 12 individuals.

2.4.2 Quality Control and Assurance

Methods for ensuring quality control are provided for all core, primary, and some supplemental survey methods. Regardless of the survey method, the greatest sources of error are usually observer error and sloppy data management. Observer training and consistency are critical to maintaining data quality, and regions can best reduce observer error and increase consistency by training and testing all observers for each survey method together as a group. Ideally, observers should be trained and tested in one or two groups—they will learn faster and be more consistent because the training is consistent and they are learning as a group. In addition, the valuable contribution of local experts can usually be garnered for one or two training sessions, such as field demonstrations or trips to university museums to talk with curators and study museum skins. In addition to being trained in survey methods and species identification, observers also need to be taught consistent data management procedures. The greatest loss of data (quantity and quality) typically occurs between the observer and the data sheet. Careful training and reinforcement of critical data recording and data checking procedures during group training sessions are the most efficient and effective means of ensuring high-quality field data management.

2.4.3 Safety

A job hazard analysis (JHA) should be prepared for each data collection protocol, outlining all potential hazards field workers might encounter. All crewmembers must review the JHA and must understand how to avoid hazards, how to handle a hazardous situation, and how to respond after an accident. JHAs may be amended as new hazards are realized. Typical field hazards include, but are not limited to, vehicle/traffic hazards, inclement weather, poisonous plants (poison ivy, nettle), wild and domestic animals and insects (bears, dogs, bees), diseases (West Nile virus, plague), physical conditions (hypothermia, heat stroke), falling debris (pine cones, branches), stream crossings, cultivation/manufacture/transport of illegal substances, and toxic wastes (unidentified barrels, disposed oil). In addition to the generic field hazards are those associated with each protocol, such as those that require individuals to work alone, at night, odd hours, or with dangerous equipment (e.g., acetylene torches for sooting trackplates). The JHA for each protocol should identify all hazards associated with a protocol and provide guidance on maintaining a safe work environment and ensuring safe conduct.

Bimonthly or weekly safety meetings or "tailgate sessions" are recommended to review safety topics among crewmembers. Each crewmember should wear good hiking boots, appropriate clothing (long pants, long sleeves, hat, and rain wear), and sunscreen to protect them from the elements. In cases in which individuals work alone, each should carry a reliable radio and/or cell phone, a Global Positioning System unit and appropriate maps. All crewmembers must be certified in basic first aid. The crew leader should be responsible for knowing and tracking the whereabouts of each crewmember at all times during the work day. A daily sign-in/sign-out sheet is recommended.

2.5 Data Management and Storage

Standard data forms should be used for data collection throughout a region, and standard data forms will be available at regional or national levels. All regions should understand and abide by the suggested format. Most data will be recorded on paper at first, although computerized systems are likely to be developed and used in the future. In the case of paper data sheets, each crewmember is responsible for turning in legible data and crew leaders are responsible for quality control. Data sheets are printed on water-resistant paper (e.g., Rite in the Rain). Pencil (mechanical, with 7-mm or larger lead) works best on this type of paper and allows for erasures. Pen may run under moisture or may fail to write, and promotes illegible scratchouts and writeovers. Each crewmember should review their data sheets each day for legibility and missing information. Crewmembers should also swap, review, and sign each others' data sheets each day. Any corrections needed should be addressed as soon as possible. This type of data quality assurance promotes responsible data collection. The crew leader should give a final review to all collected data sheets each day. Data sheets should be photocopied each week and copies stored in separate locations in case of fire, flood, or loss. Data should be organized by site, then by date/visit to facilitate data review and data entry.

Data generated by the MSIM protocol will link with National Resource Information System (NRIS), specifically the NRIS Fauna and TERRA modules. Data will initially be entered into ACCESS or Oracle databases by a coordinated regional team. Data tables to support primary protocols will be designed and maintained at a national level, including all species code tables. Tables associated with each monitoring point should include annual monitoring efforts and results (species detected and descriptive statistics for habitat conditions). Change analyses also have the potential to be displayed in NRIS Fauna. Specific locations of detections of species of concern (e.g., FSS, FTE) will remain confidential as forest and regional records. Migration of data from ACCESS databases to NRIS Fauna for storage will require the development and application of computer software to convert the data (in many cases involving simplification of data) to the appropriate format for NRIS. Data sharing with TNC, State heritage programs, and other interested partners will be developed as quickly as possible. One ACCESS/Oracle database will be established for each region, including the development of specialized data tables to accommodate unique data collection efforts. The database and associated data tables will be located on a Web site such that every data entry port (e.g., a national forest) can access the same database for data entry. Access to one database is critical in terms of the assignment of unique identifiers to data records.

2.6 Data Analysis

2.6.1 Area of Inference

Implementation of MSIM across NFS lands requires a system for organizing, synthesizing, and evaluating population and habitat data at multiple scales (i.e., the forest scale and larger). Above the forest scale, data points may be variously combined to make inferences about NFS lands within particular geographic areas (e.g., administrative zones, ecoregions, regions) or ecosystem types (e.g., bottomland hardwood forests, subalpine ecosystems). Primary areas of interest and inference should be identified in the sampling design phase so that core sampling may be augmented as needed to meet primary information needs.

Multiple national forests or larger contextual scales serve an important function in monitoring programs by providing an ecologically meaningful basis for forest-scale evaluations. At the scale of an individual forest, fewer species will be sampled adequately to determine change with the desired statistical confidence and power. Status and change, however, will be more precisely described at larger scales for many species because of the larger number of sample points, lending context to less precise estimates of status and change generated at the forest scale. In particular, the ecoregional scale can serve as a valuable context for interpreting forest-scale patterns of status and change in populations. In addition, species habitat associations are commonly consistent at the scale of ecoregions, so species detections can be used to quantify geographically specific habitat associations and evaluate indicators of environmental conditions. Although not a primary MSIM objective, the ability to build or refine habitat relationship models is a valuable application of monitoring data.

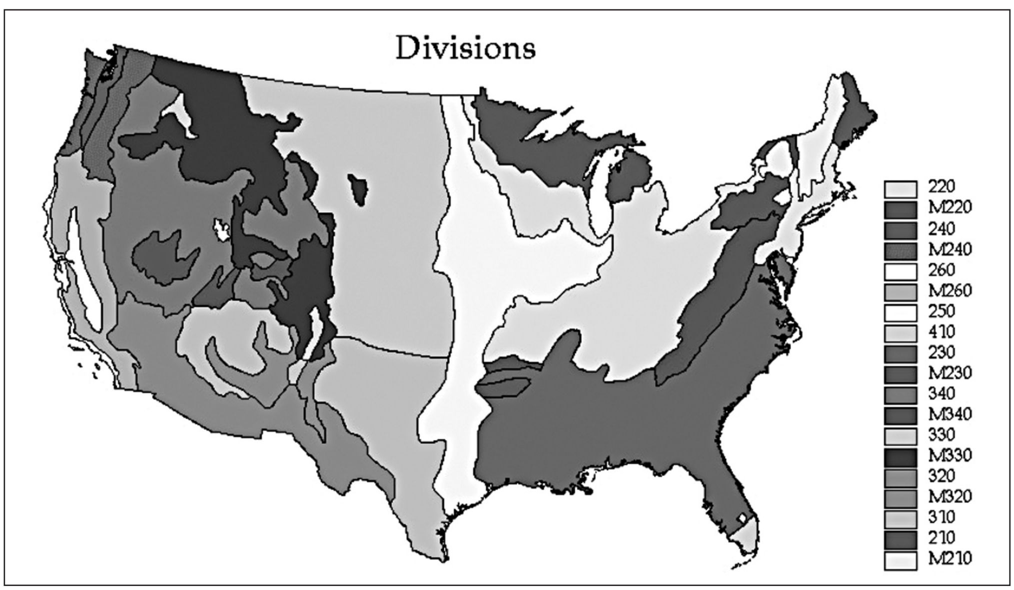
Many ecoregion classification schemes currently exist, including schemes that pertain to terrestrial or aquatic ecosystems (e.g., Bailey and Hogg 1986, ECOMAP 1993, Maxwell et al. 1995, Omernik 1987, Ricketts et al. 1999, Udvardy 1975). Few classification schemes are based on wildlife species distributions where the biogeography of wildlife species shaped the boundaries of the ecoregions resulting in greater consistency in species composition within than among ecoregions. For the purposes of monitoring populations, ecoregional boundaries should encompass entire distributional ranges of many species and ecologically meaningful subsets (e.g., ecosystem types) of more widely distributed species ranges (e.g., black bear, mule deer, American robin).

Several classification schemes delineate ecoregional boundaries at various scales, based on a variety of ecological variables: climate, physiography, soils, land use, vegetation and flora/faunal species assemblages (Bailey 1995, Fenneman 1928, Herbertson 1905, Holdridge 1947, Olsen et al. 2001, Omernik 1987, Udvardy 1975).

Indeed, monitoring points and sites can be grouped based on any variety of strata, including multiple ecoregional schemes (terrestrial or aquatic), depending on which confers the greatest advantage to the questions being answered.

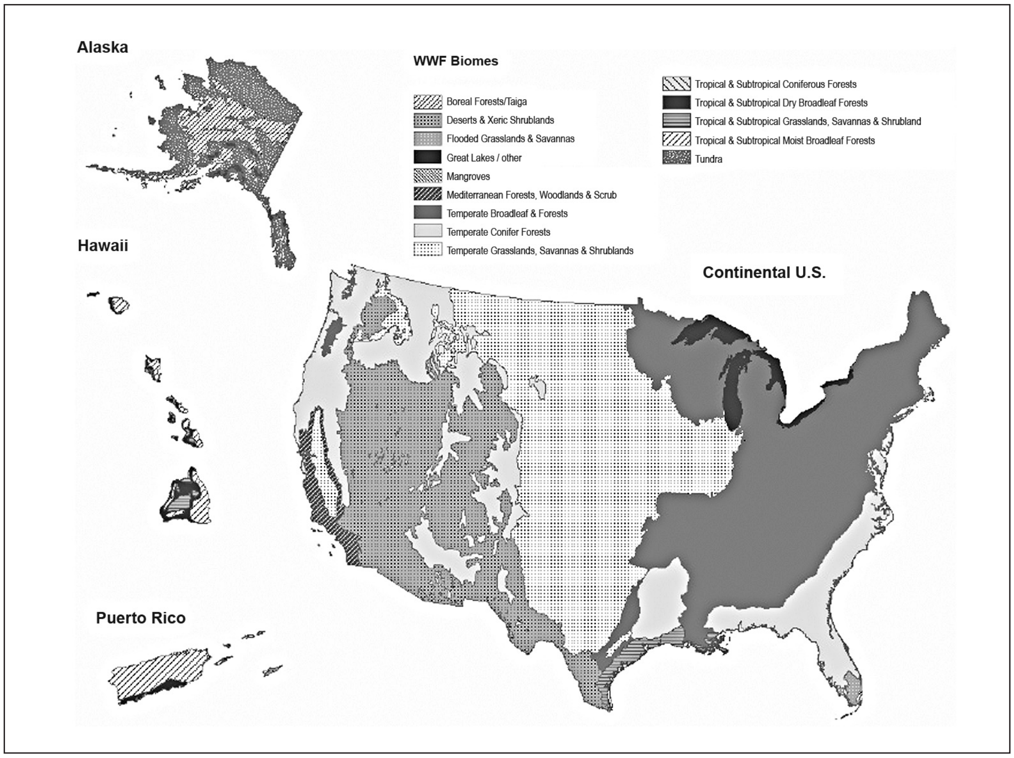
Three recently developed ecoregional classification systems—Bailey (1995), Maxwell et al. (1995), and Ricketts et al. (1999)—stand out as most useful for evaluating population and habitat status and change at the ecoregional scale. Bailey's hierarchical ecoregions have been adopted for many applications within the Forest Service (e.g., FIA, Terrestrial Ecological Unit Inventory) (fig. 2.3). Bailey used primarily single variables to delineate boundaries at each of several ecoregional scales. The classification is based primarily on climatic variables to derive large-scale boundaries, and vegetation and soil patterns to derive finer scale boundaries. Bailey's classification scheme does not take into consideration the biogeography of wildlife species, and the more dissected patterns of the smaller-scale ecoregions may limit their utility for clustering forests to strengthen forest-scale inferences. Bailey's classification includes 19 divisions (fig. 2.3) and 35 provinces in the United States. Divisions are likely to be the most feasible scale in Bailey's classification for evaluating population and habitat status and change across NFS lands within an ecologically defined region.

Figure 2.3. *Bailey's ecoregions (Bailey 1995).*



An additional classification scheme that reflects vertebrate biogeography is the ecoregion classification developed by the World Wildlife Fund (WWF) and National Geographic (fig. 2.4). The WWF ecoregions developed by Ricketts et al. (1999) are intended to represent distinct biotic communities across the globe and to aid in identifying areas of high priority for conservation (Olsen et al. 2001). Ricketts et al.

Figure 2.4. *Map of World Wildlife Fund (WWF) biomes of the United States (Ricketts et al. 1999).*



combined boundaries of multiple variables per scale. They considered faunal and floral species assemblage patterns, as well as geologic history, to establish large-scale boundaries. They also used a combination of land form, land use, vegetation, and soil types for delineating finer scale boundaries. A total of 96 ecoregions are identified in the United States, including Hawaii and Puerto Rico, which reside within 10 biomes: tropical moist broadleaf forests, tropical dry broadleaf forests, temperate broadleaf and mixed forests, temperate coniferous forests, temperate grasslands/savanna/shrub, flooded grasslands, Mediterranean shrub and savanna, xeric shrublands/deserts, boreal forest/taiga, and tundra.

The evaluation of monitoring data for aquatic species is most appropriately assessed using Maxwell et al. (1995) aquatic ecosystem hierarchy. The aquatic hierarchy consists of three levels (subzones, regions, and subregions) within the continental United States that are based primarily on the distribution of fish species. For some groups of aquatic amphibian and reptile species, the ecoregions identified in the aquatic hierarchy may be useful for summarizing population and habitat status and change.

2.6.2 Analysis Techniques

Data analysis is accomplished by a combination of Access, Excel, and SAS software programs. Computer code to perform routine data manipulations and conduct basic data summaries for data associated with core and primary protocols will be developed and supported at the national level.

Population Data

Basic data analysis procedures will be developed for each protocol and associated species. The target population parameter for each species is the proportion of monitoring points occupied. Detection probabilities directly affect the values used to represent population parameters for inventory and monitoring. The National Framework for the MSIM protocol provides guidance on how to derive estimates of the primary population parameters that account for spatial and temporal variation in probability of detection that is likely to result from a number of sources (e.g., climatic influences, observer variability, variation in sampling effort). Parameter estimation also allows for the consideration of environmental covariates that can mask and confound temporal change.

Proportion of points occupied (*P*) and probability of detection (*1-q*) estimates will be generated using maximum likelihood estimators for all species with adequate detections (MacKenzie et al. 2002, 2003, 2004). Not all monitoring points within a region need to be included in estimates of the proportion of points occupied. The statistical power to detect change declines as the proportion of sites unoccupied increases. Therefore, it is advantageous to eliminate sites from the analysis that have no probability of occupancy. It is not recommended, however, to eliminate points based on highly specific habitat requirements. The population of points included in each sample period should remain constant, and habitat conditions are subject to change. Geographic ranges can change also, but they are more likely to change slowly, which can be more easily accommodated in data analysis over time.

For all but aquatic sample sites, detections obtained by conducting the survey methods for MSIM are considered associated with the monitoring point for the purposes of change analysis, and therefore are used to determine presence associated with the point regardless of whether they were conducted in close proximity to the monitoring point. Aquatic sites selected in association with a given monitoring point (chapter 9) can occur anywhere within a large sample unit (e.g., 1500 to 6500 ha subwatersheds as per Maxwell et al. 1995) that will encompass multiple monitoring points. For the purposes of describing the status and change of individual species, sites may be treated as independent sample sites. Multiple sites, however, may also be used to describe the status and change of species composition at the subwatershed scale as well. The software program PRESENCE, developed by the U.S. Geological

Survey Patuxent Wildlife Research Center and available on their Web site (www.mbr-pwrc.usgs.gov/software.html), can be used to generate estimates of *P* and *1-q* in which data are collected from one sample site over several visits, are collected across several sample sites during one visit, or both.

Population change estimates will be determined using paired comparison techniques, such as McNemar's test (Zar 1984). Once several sample periods have been completed, trends may be evaluated using linear and nonlinear regression techniques. For trends, the slope, intercept, and confidence intervals of trend lines for the duration of the monitoring program can be calculated and used to describe change over time. In addition, sample size analysis may be conducted to evaluate the confidence and power that the existing monitoring program offers for estimating status, change, and trend of various measures (occupancy, abundance, richness), particularly for species of interest or concern.

Habitat Data

Ideally, status and change in habitat conditions are derived from the FIA program and data collected at FIA points. A number of factors, however, pose short-term barriers to relying on FIA data for habitat change. The 10- to 15-year remeasurement cycle and the limitation of most programs to Phase 2 protocols, which target primarily woody vegetation, present significant challenges. Phase 3 protocols target some additional, more detailed measurements of herbaceous vegetation and woody debris that are important habitat variables for many species. As the FIA program is fully implemented, it can serve an increasingly central role in providing habitat data. In the short term, habitat measurements are taken at the MSIM monitoring points that can be used as covariates to improve initial estimates of proportion of points occupied, and can then be used to evaluate the proportion of FIA points potentially occupied as they are sampled each year over time. The need to remeasure habitat conditions in the subsequent sample periods can be evaluated based on the strength of habitat covariates and the ability of FIA data to adequately describe key habitat variables for priority species.

Data summaries of habitat conditions will consist of simple summary statistics that describe plant species composition and vegetation structure (e.g., tree density by size class, canopy closure, etc). Basic metrics to describe habitat conditions and their derivation will follow FIA procedures. Species-specific habitat parameters may be developed individually or jointly by regions, and their measurement and description should be described in regional plans.

Ancillary Data

The MSIM protocol yields ancillary data on population parameters, community ecology, and habitat relationships that have great utility to forests and regions.

For example, detection data can be used to estimate species richness for each site within or among taxonomic groups (Boulinier et al. 1998, Burnham and Overton 1979). Shifts in species composition within and among sites can provide insights into potential causal factors for observed changes in individual species or groups of species. In addition, abundance estimates and indices may be generated with data from some survey methods. Guidelines for generating and interpreting these additional population and community metrics from detection/nondetection and abundance data (where applicable) need to be developed.

Many approaches are available for exploring habitat relationships, and it is recommended that regions work with research stations to develop analysis plans that will address key questions, conduct associated analyses, and interpret management implications. Habitat data collected at MSIM monitoring points rather than FIA point data should be used to build initial habitat relationship models because such data are spatially and temporally coincident with plant and animal population data.

Finally, the effects of natural and anthropogenic disturbances can be explored through retrospective analysis of point data. Once a set of sites has been sampled two or more times, points that have experienced disturbances of a given type, such as prescribed burns or thinning, can be analyzed retrospectively to evaluate changes in plant and animal populations. Sites that did not experience any disturbances and that match disturbed sites for key environmental variables can be used as a baseline against which to evaluate changes associated with the disturbance. This exploratory analysis will generally only be possible at multiforest and larger scales.

2.7 Reporting

Periodic evaluation of monitoring data is a cornerstone of any effective monitoring program, and it is essential to adaptive management. For each year of sampling, a report should be produced that describes the monitoring activity, including the number of points sampled and their identity, survey methods conducted and any aberrancies in implementation, and a list of species detected at each point. At the end of the sample period, the data should be analyzed and results reported and evaluated within 1 year of completing field data collection. During evaluation, the results of monitoring should be reviewed with respect to checkpoints to provide a context for evaluating institutional performance and management direction. In the second (and subsequent) sample periods, status and change are both reported.

Monitoring points within the geographic range of each species should be determined before data analysis. The precision of all estimates will depend on the number of detections and the proportion of monitoring points with detections.

For each forest and region, the MSIM protocol will then produce an observed and estimated proportion of monitoring points occupied and estimated probability of detection for each vertebrate and plant species detected based on the monitoring points within their geographic range. Data can also be compiled across forests within the same ecoregion (i.e., with the same vegetation series) and then used to generate estimates of proportion of points occupied on NFS lands for the ecoregion. The MSIM protocol will also provide change data on environmental variables (including natural and anthropogenic disturbance) that can be used to make inferences about habitat conditions for a range of species. Habitat relationships can be inferred by exploring patterns of co-occurrence of species and environmental conditions.

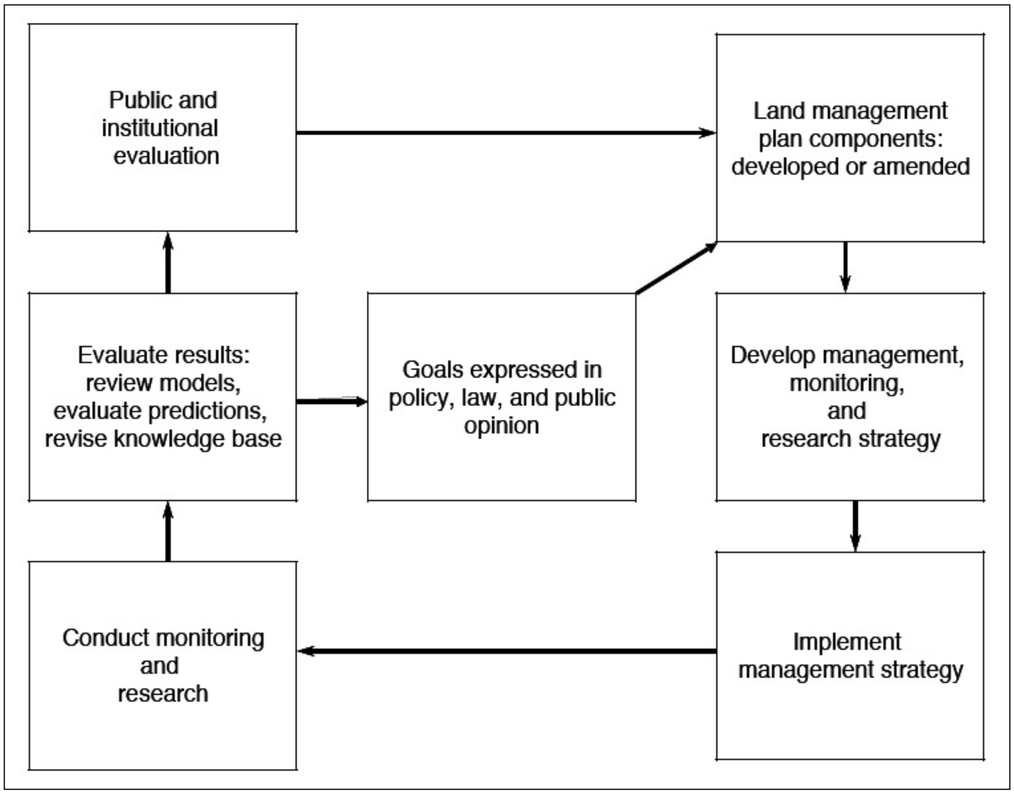
2.8 Evaluation and Response

2.8.1 Adaptive Management

The 2005 planning regulations for National Forest Management Act (NFMA) define adaptive management as, "an approach to natural resource management where actions are designed and executed and effects are monitored for the purpose of learning and adjusting future management actions, which improves the efficiency and responsiveness of management." Adaptive management requires organizational learning; an active pursuit of the best available scientific information through monitoring, evaluation, and research; the evaluation and disclosure of uncertainties and risks about scientific information; and a response to change. Adaptive management acknowledges that unknowns and uncertainty exist in the course of achieving any natural resource management goals, and that a strategic approach to management, research, and monitoring can reduce uncertainties and risks in an abbreviated time frame (Gunderson et al. 1995, Johnson 1999, Lee 1993, Walter and Box 1976).

Adaptive management starts with the land management plan components, which are informed by congressional, agency, and public goals (fig. 2.5). Managers develop and document strategies to achieve desired conditions and objectives described in the plan, along with monitoring and research strategies to track progress and address risks and uncertainties associated with the management strategy. As the management strategy is implemented, so is the monitoring and research strategy. Monitoring and research results are summarized and evaluated annually to determine how conditions compare to those expected or desired. These results will be evaluated by the agency, public, and partners to determine if any changes in the land management plan are warranted.

Figure 2.5. *Cycle of adaptation proposed for the generation, evaluation, and integration of inventory and monitoring information.*



Role of Research

Given the limited nature of resources available to support Forest Service research, it is important that it be very efficient. Research can be directed at key uncertainties that are most limiting to management, and it can be designed in a manner that builds on existing management activities such that projects are more efficient, sample sizes are larger, and results are more widely applicable than would be possible based on research funding alone. MSIM can contribute to research effectiveness by (1) detecting population and habitat change of concern that warrants further investigation; (2) identifying the possible causes for those changes; (3) providing a suite of sample sites that could serve as a comparative data set (e.g., used to describe population across the landscape compared to selected treatment sites); and (4) providing a context for interpreting research results by placing them in the larger context of population and habitat status and change over a broad area.

The statistical power of research studies can be enhanced when MSIM monitoring points are used as a backbone for research designs, providing long-term, pretreatment information that can be supplemented by additional sampling between MSIM monitoring points. For example, more intensive sampling of burned or riparian ecosystems may be warranted to gather more intensive information on species that are of concern as a result of habitat change or decline in numbers. MSIM monitoring points can also serve as controls in the investigation of treatment effects.

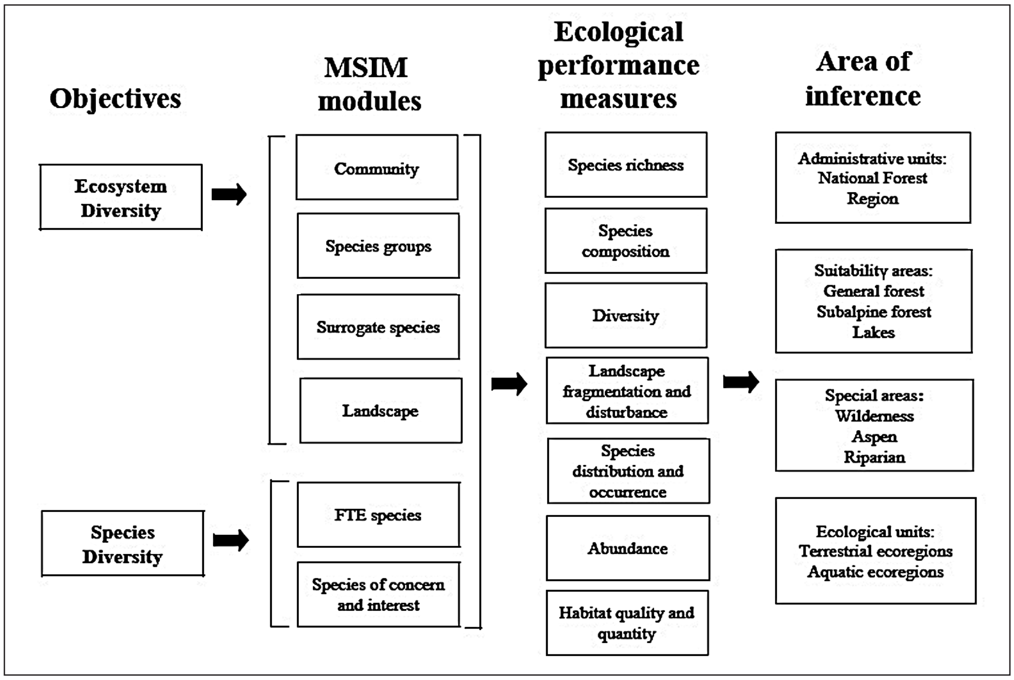
2.8.2 Evaluation of Monitoring Results

Ecosystem and Species Diversity Environmental Management Systems

Linking monitoring, research, and management through an adaptive management approach involves the development of explicit models that depict our understanding of how management influences populations. Models can document predictions about expected outcomes of management, including management objectives and desired conditions that appear to be feasible and achievable. Monitoring and evaluations check for status and change in ecological performance measures to determine, among other things, the degree to which on-the-ground management is maintaining or making progress toward desired conditions and the objectives for the monitoring plan. Multiscale monitoring approaches such as the MSIM protocol provide an opportunity to gain a greater understanding of ecosystem dynamics and management effects, and then apply that understanding to land management, thereby reducing uncertainty and improving the ability of management to achieve desired outcomes. In many cases, competing assumptions and associated outcomes can be used to form predictions that are then evaluated based on monitoring and in some cases tested through research to determine which model best fits the system. Thus, models are integrative tools that help shape and focus monitoring and research to be most effective at addressing key questions in an efficient manner.

Evaluation entails interpreting monitoring results in terms of the five principle components of land management plans (desired conditions, objectives, guidelines, suitability of areas, and special areas), plus monitoring itself. Environmental management systems (EMS) will need to be developed to evaluate monitoring results in terms of these components. An EMS for evaluating ecosystem and species diversity is needed, with the MSIM protocol being a primary source of monitoring data for the model, and FIA as another primary contributor. The Ecosystem Management Decision Support (EMDS) system is an example of an environmental management tool that is ideal to support ecosystem and species diversity monitoring (fig. 2.6) (Reynolds 1999, Reynolds et al. 2003). The EMDS system is an application framework for knowledge-based decision support of ecological assessments at any geographic scale. The system integrates a state-of-the-art Geographic Information System that provides decision support for adaptive management. An EMDS-type model can be constructed in a modular manner to evaluate various subsets of the monitoring data such as by taxa (e.g., individual species, species groups), by geographic area (e.g., forest, vegetation type, areas with specific suitability designations, wilderness), or by issue (e.g., high fire-risk areas).

Figure 2.6. *Example of an environmental management system model for evaluating MSIM monitoring data in terms of ecosystem and species diversity.*



FTE = Federal List of Threatened Species.

Management Checkpoints

Responses to monitoring results may include change in any or all of the components of a land management plan, including a change in monitoring activities. Management checkpoints are an effective method to represent desired and undesired environmental conditions and associated responses. They are the critical link between monitoring results and management decisions. Management checkpoints, also known as “triggers” or “thresholds,” represent boundary conditions that reflect desired or undesirable conditions. Management checkpoints are generally based in one or more of the following interrelated areas of interest: (1) agency goals, objectives, and management direction; (2) legal requirements; and (3) ecological limits. Ecological or otherwise “science-based” conditions could result in checkpoints such as (1) maximum rates of decline in site occupancy, (2) known physiological thresholds for environmental conditions, or (3) reproductive success rates needed to sustain a population.

Agency goals, objectives, and direction often identify specific target conditions, such as increases in the amount of old forests or meeting certain snag and log retention requirements to sustain wildlife populations (many of which are science-based, but not all). Agency-set targets are obvious sources of management checkpoints in the evaluation of population and habitat condition and change. Legal requirements result in checkpoints associated with specific legal thresholds, such as populations trending toward listing, or compliance with recovery plans for threatened and endangered species. Management checkpoints are perhaps most effective when multiple checkpoints (potentially based on a variety of interest areas) are established along a gradient of values for populations or habitats that indicate conditions ranging from desired to undesired. In addition, checkpoints can pertain to monitoring results at various spatial scales. For example, checkpoints may be established for individual species, species groups, or habitat conditions by forest, ecoregion, or region. The structure and function of checkpoints will vary across regional plans based on their unique environmental, institutional, and legal milieu.

Ideally, management checkpoints would be readily available for each species and habitat condition. More commonly, however, checkpoints will need to be estimated and then informed and revised through the course of monitoring. For example, two types of check points should be established for populations: (1) absolute number or proportion of monitoring points occupied that represents desired, concern, and undesired conditions for population size and distribution; and (2) increases or decreases of more than 20 percent (relative change) in the estimated proportion of points occupied which indicate substantial change in population dynamics. Ecological checkpoints can be derived from three main sources: (1) published literature that address our basic understanding of present-day system dynamics and sustainable conditions (i.e., population sizes, stream morphology, tree growth rates); (2) published literature on (or our own research into) historic conditions that serve as a reference or baseline for system conditions or dynamics (e.g., amount of old forests, fire regimes, air quality); and (3) using present-day conditions as a reference for interpreting favorable and unfavorable conditions.

In cases in which resource values are highly variable over time (e.g., channel flow fluctuations as a habitat measure for a frog species), selecting meaningful management checkpoints before the implementation of monitoring may be difficult, if not impossible. In these cases, the third approach, applying the concept of reference conditions, can be useful in developing a basis for checkpoints. Reference conditions consist of the composition, structure, and dynamics of specific resources over time and space under minimal human disturbance. Descriptions of "reference variability," "range of natural variability," and "historic range of variability" are often used to inform reference conditions (e.g., Committee of Scientists 1999, Landres et al. 1997, Moore et al. 1999, Stephenson 1999). Thus, in lieu of predetermined checkpoints, grid points may be post-stratified into reference and nonreference points, or into multiple categories representing a gradient of human disturbance. Checkpoints representing reference conditions can then be derived by (1) building a model of favorable conditions (a "static" description of reference conditions), or (2) comparing to nonreference sites through time (a dynamic description of reference conditions). Where dynamic descriptions of reference conditions are being employed, ecological checkpoints are determined by significant departures from reference, and what constitutes a significant departure for the forest, region, or ecoregion needs to be identified in the regional plan.

Feedback to Management

In compliance with the adaptive management approach, annual and 5-year reports and associated EMS models for each region will be reviewed by: (1) the Washington Office Wildlife, Fish, Rare Plants, Ecosystem Management Coordination, and Wildlife, Fish, Watershed, Air Research staffs; and (2) a Region-Station Monitoring Evaluation Team. Both levels of the organization will evaluate compliance with the National Framework, significance of the results, and appropriateness of planned responses. The 5-year reports should address all aspects of the monitoring program, including an evaluation of desired conditions, the validity and utility of ecological performance measures and checkpoints selected to represent desired conditions, the precision of monitoring efforts to adequately described measures of desired condition, and the functionality of the EMS models developed to support the monitoring plan. A detailed written evaluation of these elements should be developed, and recommendations provided as part of the 5-year reporting and evaluation process. This specific and detailed feedback to management is critical for monitoring to effect adaptive management.

2.9 Coordination

Coordination and partnering with other agencies will be critical to the ability of the MSIM protocol to meets its full potential. State fish and game agencies, State Foresters, and local U.S. Fish and Wildlife Service staffs will be important partners in the design and implementation of regional monitoring plans in terms of addressing concerns and in terms of coordinating efforts and sharing resources for population and habitat monitoring. Partnerships will also be important at the national level in terms of forming national agreements that can provide a foundation of cooperation and exchange that can assist State and multi-State efforts in structuring their agreements and meeting their objectives.

Chapter 3. Landbird Monitoring

Landbird monitoring is directed at terrestrial bird species. Nocturnal bird species are addressed in chapter 4. Aquatic-associated bird species are addressed in chapter 9. Terrestrial, diurnal landbirds are a target of monitoring in many agencies and by many organizations across the country. Most landbirds are readily detected by sight or sound, and the large number of species in bird communities is typically high relative to other vertebrate species groups, making bird species and community metrics attractive measures of environmental conditions and biological diversity. This chapter outlines a basic national program of monitoring on which regional programs can be built. Two survey methods are identified as core methods: (1) point counts, and (2) terrestrial visual encounter surveys (TVES). Supplemental methods include additional effort toward point count surveys, which is expected to increase the number and frequency of detections, and automated recordings, which could become an alternative to point counts if the technology sufficiently advances.

The objective of the landbird surveys described in this chapter is to provide reliable, standardized data on status and change in the distribution and relative frequency of a large number of landbird species. Overall, the Multiple Species Inventory and Monitoring (MSIM) protocol is intended to serve as a consistent and efficient method for obtaining spatially and temporally coincident detection/nondetection data and habitat condition data across a diversity of species. The National Framework and basic sampling design of the MSIM protocol is described in chapter 2. Survey methods for animal and plant species are described in the subsequent eight chapters. The National Framework identifies six core survey methods and three additional primary survey methods that together provide information on a representative sample of species in various taxonomic groups and at various trophic levels.

All survey methods associated with the MSIM protocol are designed to be implemented at MSIM monitoring points that are associated with, but offset from, Forest Inventory and Analysis (FIA) grid points on National Forest System lands. The scale of implementation is the national forest, but the primary planning scale is the region to ensure consistency in monitoring approaches for species and habitats shared among forests. The MSIM National Framework calls for a minimum of 50 percent of the FIA grid points to be selected to establish MSIM monitoring points. This core set of monitoring points is to be surveyed over a 3-year sample period with no more than a 5-year resample cycle. Sampling associated with most of the core and primary survey methods is contained within a 200-m radius (approximately 10-ha) sampling hexagon centered on the MSIM monitoring point. Species detections are used to estimate the proportion of monitoring points occupied by the species. For more details on the overall sampling design, see chapter 2.

3.1 Core Survey Methods

3.1.1 Point Counts

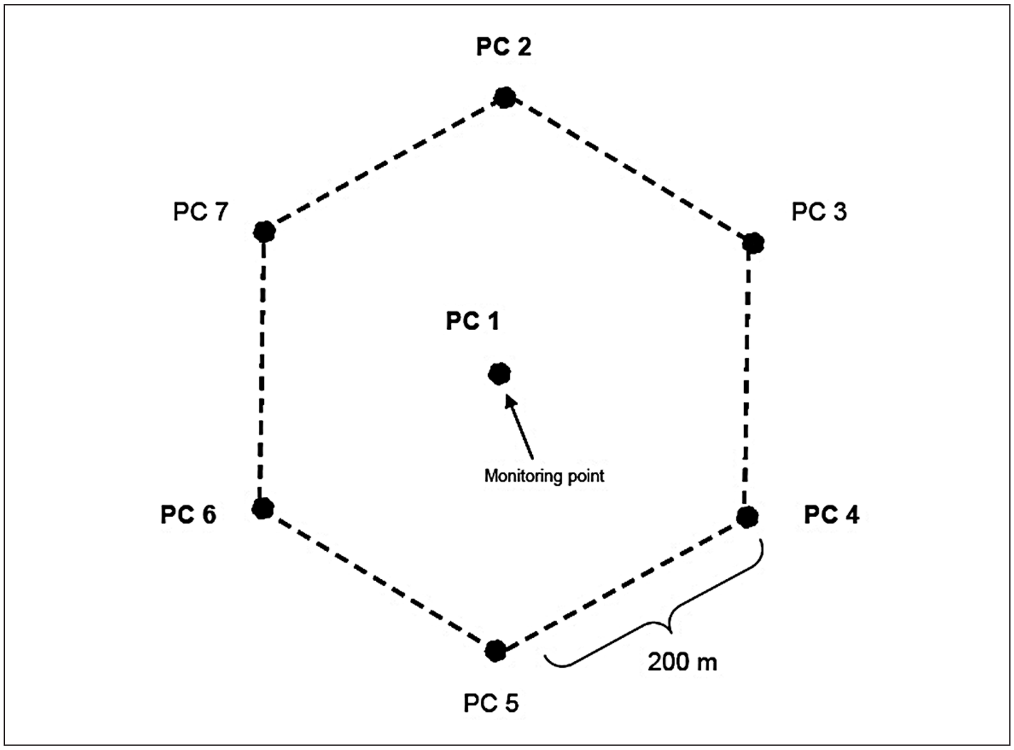
Point counts are expected to detect the majority of songbirds and woodpeckers. The method can also be very effective at detecting vocal mammals and amphibians, but is identified as a primary survey method for landbirds only. Point counts are an efficient and effective method for detecting a large number of species. The majority of bird species that use an area are present during breeding season, which is the primary season of interest. In areas with significant over-wintering waterfowl populations, or in areas along key migration routes, landbird surveys should be designed and scheduled to characterize each of the primary use seasons (section 3.2.1).

The survey method calls for intensive surveys of each monitoring point, including multiple point count stations per monitoring point, 10-minute counts, and multiple visits within a season. Most monitoring points are not located on or near roads, and therefore access requires a variable amount of driving and hiking time. Ten-minute counts provide time to get a more complete species list per visit, and multiple visits are prescribed to enable estimates of probability of detection (chapter 2, section 2.6.2).

Sampling Design

Six point count stations are located in a hexagonal array around the central point count station (located at the monitoring point) for a total of seven point count stations (PC1 to PC7) (fig. 3.1). Multiple point count stations increase the probability of sampling a greater array of habitat types and detecting species that have large home ranges or vocalize infrequently (Ralph et al. 1993). The data collected at all seven point count stations are attributed to the monitoring point. All stations are 200 m apart because most detections will be within 100 m, thus minimal overlap exists in the individuals detected at each point (Johnson 1995). When any count station falls in dangerous, extremely noisy, or otherwise unsuitable terrain (e.g., on cliffs, near loud creeks or rivers, in lakes), it is relocated in the nearest suitable location in a direction away from other stations, maintaining a 200-m minimum distance between them. In situations that require moving the station greater than 50 m, the station is shifted out to avoid hazards or borders and off of the original trajectory, but in a manner that maintains a minimum of 200 m from any other station. Count stations need to be established within each sample unit 1 or more days before conducting surveys.

Figure 3.1. *Point count station array for the MSIM protocol.*



Data Collection

Point counts are conducted in the spring to target breeding birds. Sampling begins when the majority of migrants have arrived and birds are exhibiting territorial behavior, and continues as long as territories are maintained and vocalizations are frequent enough to provide unbiased detections at each visit (Ralph et al. 1993). Regional plans should specify the start dates for geographic areas and ecotypes within the region to ensure sampling occurs during optimal times. All seven count stations associated with a monitoring point are visited on the same day, starting 15 minutes after sunrise and finishing no later than 4 hours after sunrise (Ralph et al. 1993). Counts last 10 minutes, with data recorded in three time intervals: the first 3 minutes, the next 2 minutes, and the final 5 minutes. Recording detections in this manner allow data to be consistent and comparable with other national protocols (e.g., the Breeding Bird Survey lasts 3 minutes). Ten-minute counts allow observers more time to identify species, and to detect those that vocalize infrequently.

Two separate counts (visits) are conducted at each monitoring point and are separated by at least 4 days to ensure counts represent some variation in environmental conditions (e.g., temperature, moisture). In addition, multiple visits to monitoring points are required to estimate probability of detection and proportion of points occupied. A third visit is likely to detect additional species, and is a recommended augmentation (section 3.2.1). Observers are rotated among monitoring points over the course of the survey season. Counts are not conducted during precipitation or windy conditions (table 3.2).

Observers record all bird species detected as falling within or outside a 100-m radius, as well as squirrels and amphibians that regularly vocalize and can be identified to species. Recording the radial distance from the observer (less than 100 m or greater than 100 m) of each bird seen or heard during each count ensures that individuals detected at each point count station do not overlap, thus providing an index of relative abundance if desired. Birds seen flying over and not landing or using the habitat within a 100-m radius are recorded as such. Recording the type of observation (auditory or visual) can be particularly useful to provide additional documentation for species occurrences that are rare or unusual. Observers should also record date, cloud cover (table 3.1), wind conditions (table 3.2), observer, start time, and any notable events or conditions including incidental sightings of nontarget species. Observers carry tape recorders to record calls or songs that can not be identified to species in the field.

Table 3.1. *Sky condition codes used to describe weather during point counts conducted as part of the MSIM protocol (Martin et al. 1997).*

Code	Definition
0	Clear sky, few clouds (< 25%)
1	Partly cloudy (scattered) or variable sky (25–70%)
2	Cloudy (broken) or overcast (>70–100%)
3	Rain
4	Fog or smoke
5	Snow

Table 3.2. *Beaufort wind scale used to describe weather during point counts conducted as part of the MSIM protocol (Martin et al. 1997).*

Rating	Wind speed (mph)	Indicators
0	< 1	Smoke rises vertically
1	1–3	Wind direction shown by smoke drift
2	4–7	Wind felt on face, leaves rustle
3	8–12	Leaves, small twigs in constant motion
4	13–18	Raises dust and loose paper, small branches move
5	19–24	Small trees in leaf sway

Equipment Needed

Observers should carry binoculars, a field guide to birds, bird tapes, blank tapes, tape recorder, stopwatch or watch with timer, clipboard, and range finder (optional).

Staffing, Training, and Safety

Typical bird crews consist of a mix of experienced (GS-7/9) and less experienced (GS-3/4/5) field biologists. All field crewmembers must already know the majority of bird species by sight and sound based on previous experience. It is not possible to teach individuals all bird songs within a few weeks before data collection. At least one season of training is typically required to sufficiently learn songbird songs and calls. The field crew leader should have at least 2 years of songbird survey data collection experience, and have the maturity and skill to hire, train, supervise, schedule, and oversee all data collection activities. Crew leaders are responsible for training all crewmembers, scheduling visits, promoting safety, and ensuring data quality and organization, as well as conducting point count surveys. When screening applicants, note all birding experience whether professional, volunteer, or hobby. It is not necessary for applicants to know all species of birds that occur within the sampling area as seasoned or well-trained birders learn new species quickly.

Crew size is dependent on the number of points that will be sampled during the season. In most cases, only one point count station can be visited per morning because travel time between points needs to be less than 1 hour to survey two monitoring points in one morning. In areas that are heavily roaded, two points may be visited in a morning. The staffing estimates here assume one monitoring point visit per morning. A crew of two individuals can visit 10 monitoring points during a typical work week (one monitoring point/day x five workdays x two observers), and complete both visits to monitoring points on an average sized national forest (200 FIA points, 100 monitoring points, 33 points sampled per year) within a 6-week breeding season. More simply, one person can complete both visits to about 15 monitoring points within 6 weeks. Not all visits, however, will be completed on time because of unforeseen barriers such as inclement weather, work holidays, observer illness, and navigation problems.

Observer variability exists in any avian sampling or monitoring program. Therefore, it is critical to recognize and minimize observer differences before data collection. An observer’s ability to correctly identify species either aurally or visually is a function of an individual’s experience, physical characteristics (visual and aural acuity), and psychological state (motivation, alertness) (Kepler and Scott 1981). Consequently, it is necessary to calibrate and train observers to achieve an adequate degree of comparability.

An intensive 2-week training period consisting of both indoor and field exercises is usually sufficient to prepare field crews for point count surveys. Prior to any data collection, an expected species lists is generated based on range maps, guides to local fauna, and local occurrence records (when available). In addition to the spatial extent of species ranges, elevation may also be a limiting factor and should be considered in developing species lists. When in doubt, consider the species as potentially occurring in the area and include it in the species list. The distinguishing features of each species should be noted (e.g., white wing patches, undulating flight), with particular attention called to species that may be easily confused in the field.

Field training exercises are best conducted from dawn until noon when birds are most active, leaving the afternoons for indoor exercises. Training in the field should be led by an experienced observer who initially points out, identifies, and facilitates discussion on body, flight, and song characteristics and potential identification challenges of various bird species. All crewmembers should have current field guides and a complete list of birds they may encounter within the study area. Each crewmember should also keep a field notebook in which to jot down bird identification tips, habitat associations, song mnemonics, and sketches.

Once crewmembers have demonstrated their ability to identify the majority of species (2 to 3 days), a portion of the field training each day should be set aside for practice bird surveys. Small groups of crewmembers led by an experienced observer should congregate at one point and conduct bird surveys according to the survey method. Members then compare and discuss their list of detections with each other and the experienced leader. With this approach, observers learn which species are difficult for them to identify and the crew leader will know where to direct emphasis for training. These trial surveys should continue throughout the training period.

It is important to train each observer on distance estimation. Measure and flag a radial distance of 100 m from practice points and have observers estimate whether birds detected or heard during practice point counts occur within or outside this distance. Try this at different points, especially in areas with different terrain and slope, as one's perspective of distance can be altered by these factors. A range finder can also be used in training, as well as a tool for verifying distance estimates following a count.

Afternoons are ideal for crewmembers to review and discuss protocols and to sharpen aural and visual identification skills using recorded bird songs on tapes, CDs, birding software, and/or the Internet. Many commercial bird song recordings exist and are readily available. Two of the better known and widely used CD series are the *Stokes Field Guide to Bird Songs* and the *Peterson Field Guide to Bird Songs*; both are available for Western and Eastern North America. Birding software is also readily available and is a useful tool for training observers through its use of a visual, aural, and narrative format. Some programs, such as the *Guide to Birds of North America* (from Cornell Lab of Ornithology and Thayer Birding Software) or the *North American Bird Reference Book* (from LANIUS Software), allow the user to create a unique list of birds that can be used to train and test observers. The Internet also has many Web pages that provide birding quizzes, bird songs, and other pertinent information. In addition, many sounds and calls of common squirrels and frogs are available on tape, CD, software, and the Internet. Encourage crewmembers to work together or with an experienced birder.

If a university with a museum bird collection is nearby, schedule a training session with the curator to examine bird skins of species that occur within the study area. Birds that are somewhat similar in appearance can be placed side by side to enable the examination of minute but detectable differences in features to aid in identification. Discuss how certain features appear in close proximity compared to when viewed at a distance.

Quality Control and Assurance

The potential to bias estimators is inherent in any bird surveying methodology. Therefore, all crewmembers should learn how to recognize sources of bias and how to minimize them (Bibby et al. 2000). Some sources of bias, however, are not manageable, such as the volume or intensity of species' songs, which affects detection probabilities. Other sources of bias can be controlled for, such as ensuring observers are proficient in bird identification, halting counts during periods of inclement weather, moving away from sources of noise, and wearing muted colored clothing. Potential sources of bias should be discussed thoroughly during presurvey training sessions and throughout the season. Observers should feel comfortable knowing when survey conditions are adequate and when to suspend the count should conditions (such as weather) deteriorate. Recording weather conditions and sources of noise during each visit helps observers avoid bias. Bibby et al. (2000) provides a detailed overview of potential sources of bias in the chapter titled "Census Errors."

It is imperative that all observers be trained and tested thoroughly prior to data collection to achieve similar levels of proficiency in bird identification, as described in the training section. Frequent (every 2 to 3 weeks) trial point count surveys throughout the survey season led by an experienced crew leader or supervisor will ensure that observers are consistent and up to speed. The leader should be aware of the techniques used by crewmembers to detect birds. For instance, are observers quiet and attentive? Are they turning their heads and/or bodies to listen for birds in all directions? Are they using their eyes to scan up and down trees and vegetation, on the ground, and in the sky? Are they using their binoculars? Can they determine which direction certain sounds are coming from? Are they double counting birds? Are their data legible? Each crewmember should be made aware of each of these simple techniques for conducting surveys and how they perform. Following these trial counts, discussions should be initiated to address sources of bias of estimators that may occur both by observer and in the field, identification problems, protocol issues and questions, safety, and data collection and management.

Data Storage and Analysis

Data analysis consists of creating species lists for each monitoring point across both visits, and estimating the proportion of all monitoring points occupied within the entire area of inference, using the probability of presence and detection probabilities as parameters in a maximum likelihood model (chapter 2, section 2.6.2). The freeware program PRESENCE is available for this analysis (http://www.mbr-pwrc.usgs.gov/software.html). The species detection data from each point count station are compiled to create detection histories for each visit to each monitoring point for each species. Detection histories consist of either a “1” for the entire sample unit (regardless of the number of detections) or a “0” if no detections were made. For example for two visits, the detection history for a given species will be 00, 01, 10, 11, 1x, or x1, 0x, or x0, where x represents that either the first or second visit was not conducted.

In addition to basic data handling and storage procedures, point count data may be contributed to the USGS Bird Point Count Database (http://www.pwrc.usgs.gov/point/). The Patuxent Wildlife Research Center and American Bird Conservancy have worked together to build a repository for Partners in Flight point count data. The Web-based Bird Point Count Database can be accessed and used by anyone with point count data from North America. The database was developed to meet the following goals:

- Provide easy data entry and access to everyone over the Web.
- Accommodate count data from multiple sources, allowing for small differences in protocols, such as:
  - Counts at different times of year: breeding, winter, or migration counts.
  - Counts differing in time intervals (3 vs. 5 minutes, for example) or radii.
- Store vegetation information associated with points.
- Enforce data quality control through validation routines and through distributed responsibility.

Analysis approaches specifically applicable to point count data are available in reference to a number of specific topics: general data analysis (Thompson 2002), estimating probability of detection (Farnsworth et al. 2002, Nichols et al. 2000), species richness estimates (Boulinier et al. 1998, Cam et al. 2000, Nichols et al. 1998), and proportion of points occupied (MacKenzie et al. 2002, 2003).

3.1.2 Terrestrial Visual Encounter Surveys

TVES can be an effective passive sampling technique for detecting less common or difficult to detect landbirds. Although detection rates are typically low, the technique is simple, low cost, and useful for a wide variety of species difficult to reliably detect with other multiple species methods. As a result, TVES is a core survey method for all classes of vertebrates as a companion to taxon-specific core survey methods.

Visual encounter surveys are designed to target different taxonomic groups in a variety of environments (terrestrial vs. aquatic) and at different times of year. Summer TVES focuses on terrestrial bird, mammals, and reptiles, and are described in detail in chapter 4, section 4.1.2. Spring and fall surveys focus on terrestrial amphibians and reptiles, and are described in chapter 8, section 8.1.1. Aquatic visual encounter survey methods are described in chapter 9, section 9.2.1.

3.2 Supplemental Survey Methods

3.2.1 Point Count Augmentation

Number of visits. A third visit may be conducted at some or all points if time allows. Three visits will improve the precision of estimates of species richness, species composition, and proportion of points occupied, and therefore increase the number and proportion of species for which precise estimates can be generated.

Abundance estimates. Given the amount of time required to access points and conduct point count surveys, and the high level of interest in monitoring bird abundance, regions and forests may choose to also characterize bird abundance during surveys. Bird abundance estimates can be obtained by recording the distance interval of each individual seen or heard during each count. Specifically, the number of individuals of each species is recorded based on their distance from the observer (0–25, >25–50, >50–75, >75–100, >100 m). Distance estimates enable calculations of density if desired, based on data from all seven count stations at a given monitoring point. Birds are recorded as occurring where they were first detected. All individuals detected at each count station are recorded even if they were detected at another count station during the same morning.

Distance interval estimates do not require any additional time during data collection and can provide more sensitive measures of change than simply recording presence. It is possible, however, that species could be missed because observers were distracted with recording the distances. Distance estimates are best for density calculations, but distance intervals require less consideration than exact distances, so they are suggested here to reduce any possibility that species detections may be compromised by recording distances. References that address the consideration of including abundance estimates in point count surveys include Kunin et al. (2000), and references that discuss the analysis of distance data for various applications include Buckland et al. (2001) and Rosenstock et al. (2002).

Season. Additional seasons may be considered high priority for some regions or forests. During the fall or winter, the 10-minute count duration should be adequate, but the configuration of point count stations may need to change to improve efficiency. For example, point count stations may be located on a transect that snakes across the sampling hexagon to increase efficiency in data collection in areas with snow. Additional survey techniques, such as recording detections while moving along the transect, may be added to improve the probability of detection.

3.2.2 Automated Data Collection

Sound recording devices capable of obtaining high-resolution recordings of bird songs and calls may prove an effective means of obtaining accurate count data without having to deploy field personnel. Recording technology is still in development that can be left out in the field for 4 weeks and be programmed to take multiple recordings over time, and the ability to decipher recordings remains dependent on direct human interpretation. This technology, however, is likely to develop quickly, and may provide a highly reliable method for monitoring birds in the near future.

3.2.3 Broadcast Surveys

Diurnal raptor species are typically surveyed individually by targeting suitable habitat and then eliciting vocalizations through broadcasting their calls (e.g., Northern goshawk [*Accipiter gentilis*]; USDA Forest Service 2000). Diurnal broadcast surveys (chapter 4, section 4.2.2) and TVES (chapter 4, section 4.1.2), however, can be effective at detecting multiple raptor species by surveying a range of habitat types and broadcasting the calls of multiple species. For nocturnal and crepuscular species methods, refer to chapter 4, section 4.1.1.

Chapter 4. Raptor Monitoring

Raptors, also referred to as birds of prey, are meat-eating birds and include owls, hawks, falcons, eagles, kites, vultures, and osprey (Palmer 1988). They are among the top carnivores in most ecosystems with prey size ranging from mice and reptiles to large hares and ducks (Ehrlich et al. 1988). The 16 species of North American owls are primarily nocturnal, range widely in size, and prey on a variety of invertebrate and vertebrate species. The remaining species groups are diurnal, with a wide variety of habitat associations and primary prey. Approximately 15 hawk species commonly occur in North America, with three species in the *Accipiter* genus and the remaining in the genus *Buteo* (NGS 2001). Accipiters are forest-associated hawks that are very maneuverable in dense foliage, allowing them to prey on small birds typically caught in flight, and small mammals. Accipiter species often have "plucking posts" near nest sites where they remove and discard of parts. Buteos have large, broad wings for soaring and are typically seen in open country scanning for prey, such as small rodents and snakes, while either perched or on the wing (Ehrlich et al. 1988). Four falcon species are common to North America; less common are the gyrfalcon and crested caracara, which can occur in the extreme north and south, respectively (NGS 2001). Built for speed and agility, falcons prey on other birds as large as ducks, taking them in mid-air or hitting them to the ground with closed feet; the exception is the kestrel, which feeds on large insects like grasshoppers, and small rodents (Johnsgard 1990). Most falcons hunt in open country, although the merlin will use woodlands as well. Golden eagles also hunt in open habitats, especially in mountainous or hilly terrain, while bald eagles, like osprey, are associated with rivers, lakes, and coastal areas (Ehrlich et al. 1988). There are five species of kites that all use marsh or swampy areas, although the black-shouldered kite can be found in a variety of open habitats (Ehrlich et al. 1988). Vultures, which are scavengers associated with a variety of habitat associations, feed on virtually any dead animal down to the size of a tadpole (Ehrlich et al. 1988). Vultures are often detected with point count surveys (chapter 3), which may be considered a reliable survey method for vultures.

The objective of the raptor surveys described in this chapter is to provide reliable, standardized data on status and change in the distribution and relative frequency of a large number of raptor species. Overall, the Multiple Species Inventory and Monitoring (MSIM) protocol is intended to serve as a consistent and efficient method for obtaining spatially and temporally coincident detection/nondetection data and habitat condition data across a diversity of species. The National Framework and basic sampling design of the MSIM protocol is described in chapter 2. Survey methods for animal and plant species are described in the subsequent eight chapters.

The National Framework identifies six core survey methods and three additional primary survey methods that together provide information on a representative sample of species in various taxonomic groups and at various trophic levels.

All survey methods associated with the MSIM protocol are designed to be implemented at MSIM monitoring points that are associated with, but offset from, Forest Inventory and Analysis (FIA) grid points on National Forest System lands. The scale of implementation is the national forest, but the primary planning scale is the region to ensure consistency in monitoring approaches for species and habitats shared among forests. The MSIM National Framework calls for a minimum of 50 percent of the FIA grid points to be selected to establish MSIM monitoring points. This core set of monitoring points is to be surveyed over a 3-year sampling period with no more than a 5-year resample cycle. Sampling associated with most of the core and primary survey methods is contained within a 200-m radius (approximately 10-ha) sampling hexagon centered on the MSIM monitoring point. Species detections are used to estimate the proportion of monitoring points occupied by the species. For more details on the overall sampling design, see chapter 2.

4.1 Core Survey Methods

The core survey methods for raptors are nocturnal broadcast surveys and terrestrial vertebrate encounter surveys (TVES). Nocturnal broadcast surveys are highly effective at detecting nocturnal birds during the breeding season and entail broadcasting the calls of all local owl species. TVES is a passive survey method that is considered core because of its applicability to diurnal raptors and many other vertebrate species groups. TVES is associated with several taxa monitoring chapters as an additional core method because it is a relatively inexpensive way to accumulate additional species per monitoring point. Supplemental methods consist of additional effort put toward nocturnal broadcast surveys and broadcast surveys for diurnal raptors.

4.1.1 Nocturnal Broadcast Surveys

Nocturnal broadcast surveys are directed at detecting owls, and consist of broadcasting owl vocalizations at night throughout a sample unit. Large owls, such as great horned owls (*Bubo virginianus*), can be among the top predators in some ecosystems, and all owls play important trophic role in ecosystems. Therefore, although nocturnal broadcast surveys do not detect a large number of species per unit effort, they generate reliable monitoring data on an important group of carnivores. Crepuscular species (e.g., common snipe [*Gallinago gallinago*], common nighthawk [*Chordeiles minor*], common poorwill [*Phalaenoptilus nuttallii*]) are often detected during nocturnal surveys, and are also likely to be effectively monitored with this survey protocol (Badzinski 2003).

Broadcast calling is a widely recognized technique for detecting owls during the breeding season (Badzinski 2003, Fuller and Mosher 1987, RISC 2001, Takats et al. 2001) and has repeatedly been shown to increase owl detection rates when compared to passive observational techniques (Conway and Simon 2003, Evans 1997, Francis and Bradstreet 1997, Fuller and Mosher 1981, Hardy and Morrison 2000, Haug and Didiuk 1993, Johnson et al. 1981, Takats et al. 2001).

Sampling Design

A 3-km^2 (300-ha) primary sample unit is established around each MSIM monitoring point. A sample unit of this size is likely to encompass entire home ranges of many small owl species (e.g., northern pygmy owl [*Glaucidium californicum*]) and partial home ranges of large owl species (e.g., great horned owl) (Peery 2000), thus reflecting an efficiently sized sample unit to detect most owl species. The sample unit may be a circle (800-m radius) or a square (1.7 km on a side), but should be consistent throughout the Region, and should conform to boundaries provided by any national monitoring grid that may be developed.

Observers establish broadcast calling stations within each sample unit before conducting surveys and locate as few stations as necessary for broadcasts to cover the entire 3-km^2 sample unit. The number of call stations within each sample unit typically ranges from 8 to 10, depending on the topography. Call stations are generally located 400 to 800 m (¼ to ½ mile) apart to achieve complete coverage of the sample unit. Similar interstation distances have been effective in previous owl surveys in a variety of environments (Conway and Simon 2003, Francis and Bradstreet 1997, Fuller and Mosher 1981, Hardy and Morrison 2000, Takats et al. 2001). The topography of the sample unit, however, will dictate the best location of calling stations. Proudfoot et al. (2002) found that ferruginous pygmy owls (*Glaucidium brasilianum*) responded to broadcast calls up to 700 m away when played at 60 to 70 decibels (dB), suggesting a conservative estimate that broadcasts from call stations can be expected to elicit a response, if heard, from at least 500 m away for small owls and perhaps up to a kilometer away for larger owls.

Stations are established in locations that maximize the area covered by each call station and minimize the total number of stations required to survey the sample unit. Stations are located at maximum heights along hillslopes and in areas with minimal noise (e.g., far enough away from streams, heavily used roads, and human development) so that observers can hear calling owls. Call stations are also best located to broadcast against a topographic backdrop, such as from one side of a drainage to the other. Attempting to call directly up and down drainages is not effective. Topographic maps and aerial photos are used when possible to identify potential call stations before going into the field. Roads should be used to survey as much of the sample unit as possible, but stations should not be limited to roads. Biases associated with road-based surveys have been widely recognized as a limitation of past monitoring efforts (Conway and Simon 2003, Francis and Bradstreet 1997, Fuller and Mosher 1981, Holroyd and Takats 1997). In cases where call stations are located off roads or well-established trails, observers hike to call stations in daylight, flag their route with reflective material, and return at dusk to conduct surveys. Once established, call stations are used for all subsequent visits within the sample unit across all survey years. Two observers are present for all surveys for increased safety (Johnson et al. 1981). Nocturnal broadcast surveys may be conducted at only a subset of the monitoring points due to the substantial effort required to survey each point. (See Staffing, Training, and Safety section.)

Data Collection

Each monitoring point is sampled (visited) twice during the spring and summer months. Multiple visits are important for increasing raptor detections (Conway and Simon 2003, Francis and Bradstreet 1997, Takats and Holroyd 1997), which generally occur at low densities and require high detection rates to be effectively monitored. Optimal timing of surveys will vary by location and species and, if possible, should be verified by a biologist with knowledge of local raptor phenology. The timing of each visit should be carefully considered to maximize the number of species detected. For example, some species (e.g., Boreal owl [*Aegolius funereus*]) are most vocal in early spring when snow may still be present at higher elevation monitoring points. Other vocal periods are during the nestling and post-fledging periods when many raptor species are most responsive to broadcasts (Fuller and Mosher 1981, Johnson et al. 1981, Watson et al. 1999). Broadcast calling should be avoided during egg-laying and incubation periods, as raptors may be less responsive (Watson et al. 1999) and they are susceptible to nest failure during this time period (RISC 2001). Some owl species may have a resurgence in the frequency of vocalizations later in the summer after their young fledge. Thus, the two visits should target time periods that combined have the greatest probability of detecting all species expected to occur in the area. If local raptor phenology is not known, visits during the first year of monitoring can be conducted at numerous times of year at some or all monitoring points to determine the most effective timing of visits.

Survey visits are primarily conducted from 30 minutes after sunset to around midnight. Safety and fatigue should be carefully considered in scheduling surveys. Owls generally are most active and responsive to broadcasts a few hours after dusk and preceding dawn (Takats and Holroyd 1997, Takats et al. 2001), but it is advised for safety reasons that surveys not be conducted through the night. Ideally, the visit to a sample unit is completed in one night; however, in some cases two nights will be required to complete the visit. Sampling per unit should be completed within a maximum of 3 days.

Calling is not conducted during inclement weather. High winds (greater than 3 on Beaufort scale) (Takats and Holroyd 1997), persistent rain, lightning storms, or extreme cold temperatures can decrease detection rates (Johnson et al. 1981, Takats and Holroyd 1997). Several authors have found owl species to be most responsive on bright moonlit nights (Hardy and Morrison 2000, Johnson et al. 1981, Takats and Holroyd 1997). Conducting two visits during the breeding season will help smooth any potential effects of moonphase on detection rates.

At each call station, observers play a tape containing the territorial calls of all owl species occurring in the area in approximate order of increasing size, as recommended by Fuller and Mosher (1981) and RISC (2001). This order is important because some larger species of owls may compete with or prey on smaller species; thus, smaller owls are less inclined to begin vocalizing if the larger species have already begun to vocalize. Broadcast surveys using calls of multiple owl species have been used effectively to elicit the responses of more than one species of owl in a number of circumstances (Badzinski 2003, Francis and Bradstreet 1997, Hardy and Morrison 2000, McGarigal and Fraser 1985, Takats and Holroyd 1997), and are likely to be the most efficient approach to survey for multiple species across large landscapes. Tapes can be generated from a variety of sources, including compact discs of the *National Geographic Guide to Bird Sounds* and the *Peterson Field Guide to Bird Songs*. Using high-quality taped calls of owls from the local area is preferred, however, as local dialects may increase owl detection rates (Fuller and Mosher 1981, Johnson et al. 1981). Calls are broadcast using a portable tape or compact disc player cabled to a megaphone. Each player should be standardized to output approximately 90 to 110 dB as measured by a simple sound meter (Hardy and Morrison 2000, Proudfoot et al. 2002, RISC 2001).

Sampling begins with a 2-minute listening period during which observers listen for spontaneously calling owls, a recommended strategy for detecting a few species that are known to call even when unsolicited (Penteriani et al. 2000, Takats and Holroyd 1997, Takats et al. 2001). Following the initial listening period, each species' call is broadcast three times with 30 seconds of silence between calls, and an additional 30 seconds of silence between species. Observers pause the tape during these sections of silence, and when necessary to identify calling owls. While the tape is playing, observers listen carefully and watch for birds that may fly silently into the area. During broadcasts, one observer moves around the call station at a distance of up to 50 m to increase their ability to hear owl responses that might otherwise be obscured by their proximity to the loud recording (Johnson et al. 1981). After all species' calls are completed, observers remain silent and listen for 5 minutes while visually searching the surrounding area with a spotlight (1 million candle-watt) to determine if any individuals have been drawn into the area before moving on to the next station. Night vision technology could be useful in navigating in the dark and identifying birds that fly in to investigate the calls. Such equipment, however, can be expensive and is not necessary to safely conduct the surveys.

Before calls are broadcast at each station, observers record the following information: sample unit number, call station number, time, temperature, wind speed, precipitation, cloud cover, moon phase, and moon visibility. On detection of an individual bird, the following information is recorded: species, sex (if known), time of detection, location of detection within calling series (noting the species calling on the tape when the detection occurred, or whether the detection occurred before or after the tape was played), and bird location. One observer stays at the broadcast station and continues to monitor responses as the call sequence progresses, while the other observer obtains a location using triangulated compass bearings. Three compass bearings of the bird's location are taken in rapid succession from three different locations that can be accurately located on a topographic map. If the locations from which the bearings are taken can not be accurately mapped (e.g., not on a road or mapped trail), a Global Positioning System (GPS) location may be used if it can be acquired quickly. The objective is to maximize the angle (generally between 20 and 45 degrees is ideal) between the bearings such that the size of the resulting triangle is small. The bearing must be taken quickly to limit the potential for owl movement while taking the bearings.

The bearings are drawn on a topographic map and their intersection creates a triangle that indicates the approximate location of the calling individual. If movement is known or suspected while bearings are being taken, it is noted on the map and the direction of movement indicated. The topographic map is kept as a supplemental data sheet for each visit. Mapped locations of the individuals supplement written data sheets for each visit and inform determinations of the number of individuals detected within the sample unit. The first locations obtained on each individual during each visit can also be used to assess habitat use at the stand scale.

Equipment Needed

Observers should bring an owl calling tape or CD, portable tape or CD player and megaphone (e.g., FOXPRO digital electronic caller), batteries, headlamp, 1 million candle-watt spotlight, compass, topographic maps, aerial photos, flagging, reflective flagging, tacks or tape, stopwatch or watch with timer, and appropriate gear for safety and weather conditions. Snowshoes, skis, and snowmobiles will be required for some areas.

Staffing, Training, and Safety

Nocturnal surveys are conducted by a crew comprised of both experienced (GS-7) and inexperienced (GS-3/4/5) members. A crew of four working in pairs can expect to complete visits at seven to eight monitoring points per week, assuming that some sample units require two nights to complete visits. For an average-sized forest (33 monitoring points per year), a crew of four can complete all the visits in 2.5 months or a crew of six can complete the visits in less than 2 months. The time it takes to complete visits within a sample unit depends on the accessibility and navigability of the sample unit, how amenable the terrain is to effective call stations, observer efficiency, or inclement weather. A survey crew of four to six individuals should include at least one crew leader (GS-7) with at least 2 years experience in nocturnal bird surveys. Ideally, one observer per two-person crew should possess at least one season of nocturnal bird survey experience. Oversight of surveys at the forest or multiple-forest level should be conducted by a journey-level biologist (GS-11) with at least 2 years of relevant field and supervisory experience.

The crew leader, with oversight from a journey-level biologist, is responsible for training all crew members, scheduling surveys, promoting safety, and data quality. Before data collection, an expected species lists is generated based on range maps, guides to local fauna, and local occurrence records (when available). In addition to the spatial extent of species ranges, elevation may also be a limiting factor and should be considered in developing species lists. When in doubt, consider the species as potentially occurring in the area and include it in the species list. The distinguishing features of each species should be noted (e.g., facial disk, visible ear tufts), with particular attention called to species that can be easily confused in the field. The broadcast tape is limited to species known to occur in the area, but the more comprehensive species list and associated training enables observers to identify less common species.

Two weeks of training are required for observers to be proficient at all aspects of the protocol; however, training can be conducted in the course of setting up call stations. Protocol training should include: (1) aural and visual identification of all variations of nocturnal bird calls using recorded calls, field guides, and birding software; (2) distance estimation (chapter 3); (3) reading and interpreting topography to establish call stations; and (4) practice nocturnal surveys done according to protocol. Orienteering, mountain driving, and first aid are particularly crucial skills for these positions because field workers are generally working in remote locations during off hours (at night), so outside assistance may not be readily available. Each member should be trained and proficient in navigation using a topographic map, compass, and GPS unit. Training should also include a standard procedure in the event that one or both crewmembers become lost during a survey.

All crewmembers should be comfortable with working, hiking, and navigating at night. Each crewmember should carry a headlamp and/or flashlight with extra bulbs and batteries, in addition to having appropriate clothing and boots. A hardhat is also recommended to prevent head injuries due to unseen low hanging branches. Each crew of two should remain in direct contact with one another throughout the course of each visit, and at least one member of the crew should carry a radio and/or cell phone, GPS unit, and maps at all times. It is important that at least one crewmember is familiar with each sample unit and the location of survey stations before visiting them at night. Reflective tacks and tape are useful for marking trails from station to station. The crew leader should be responsible for knowing and tracking the whereabouts of each crew at all times during the work period. A daily sign-in/sign-out sheet is recommended.

Quality Control and Assurance

Steps to ensure data quality include the recognition and discussion of sources of bias and error with crewmembers. Some sources of error cannot be eliminated, such as missed detections of silent approaches. Error and bias within the control of observers are proficiency of bird identification, avoiding poor weather conditions, and careful positioning of call stations to maximize detection probabilities (e.g., wide broadcast area, quiet locations). Crewmembers should feel comfortable knowing when survey conditions are adequate and when to suspend the visit should conditions (such as weather) deteriorate. Crew leaders will visit each sample unit and sign off on all survey route designations, and rotate working with each field crewmember throughout the field season to check on survey technique, species identification, data recording, triangulation and mapping techniques, and safety procedures.

Data Storage and Analysis

Data sheets are checked by fellow crewmembers at the end of each day to make sure that all fields are filled out correctly and legibly. This check also serves to identify discrepancies in species identification among observers and alert observers to unusual species or situations that they may encounter the next day. Crew leaders check all data sheets at the end of each week to review species identification, missed data (bird flew before confirmed identification or triangulation), and legibility.

Nocturnal broadcast data consist of tabular and mapped data. Survey route and station descriptions are also an important component of the monitoring data set for nocturnal broadcast surveys and include call station number, Universal Transverse Mercator (UTM) location, station description (e.g., habitat type, on or off road or trail), and directions to station. In a relational database, three data tables are warranted: (1) a survey route table that contains all information related to location and configuration of the survey route; (2) a survey history table that records the timing, duration, weather, and observer of each visit, including station-specific information; and (3) a detection table that records the station, call sequence, location, timing, and other information associated with each detection on a given visit. Mapped data should be scanned and images linked to tabular survey data to ensure mapped data do not become lost or disassociated from tabular data.

Data analysis consists of creating species lists for each monitoring point across both visits, and estimating the proportion of all monitoring points occupied within the entire area of inference, using the probability of presence and detection probabilities as parameters in a maximum likelihood model. (See chapter 2, section 2.6.2.) The freeware program PRESENCE is available for this analysis (http://www.mbr-pwrc.usgs.gov/software.html). The species detection data from each call station are compiled to create detection histories for the two visits to each sample unit, for each species. Detection histories consist of either a “1” for the entire sample unit, regardless of the number of detections made, or a “0” if no detections were made. For each species, the detection history within a single sample unit will be 00, 01, 10, 11, 1x, or x1, 0x, or x0, where x represents that either the first or second visit was not conducted.

Species co-occurrence patterns and habitat associations may be derived from the data as well. Sampling adequacy can be evaluated by estimating the probability of detection per unit effort, and estimating the power to detect a trend of a given magnitude and precision given the existing sampling effort. Sampling effort may then be adjusted if indicated by the analysis. Additional information on sampling efficiencies can be garnered by evaluating the circumstances of detections, such as the timing of the response relative to the species call being broadcast, time of night, moon phase, temperature, and date.

4.1.2 Terrestrial Visual Encounter Surveys

TVES is an effective passive sampling technique for detecting nocturnal and diurnal raptors. Although detection rates are low, the technique is simple, low cost, and useful for a wide variety of species (Heyer et al. 1994, Wemmer et al. 1996) that may be missed by the other core methods (bird point counts, small mammal trapping, trackplate and camera surveys), such as some ungulates, lagomorphs, and raptors (Forys and Humphrey 1997, Weckerly and Ricca 2000). TVES can detect signs of nocturnal and diurnal raptors, such as regurgitated pellets, whitewash, and plucking perches. These signs can be followed up to determine associated species. Thus, TVES is a core survey method for all classes of vertebrates as a companion to taxon-specific core survey methods. TVES can be designed to target different taxonomic groups in a variety of environments (terrestrial vs. aquatic) and at different times of year.

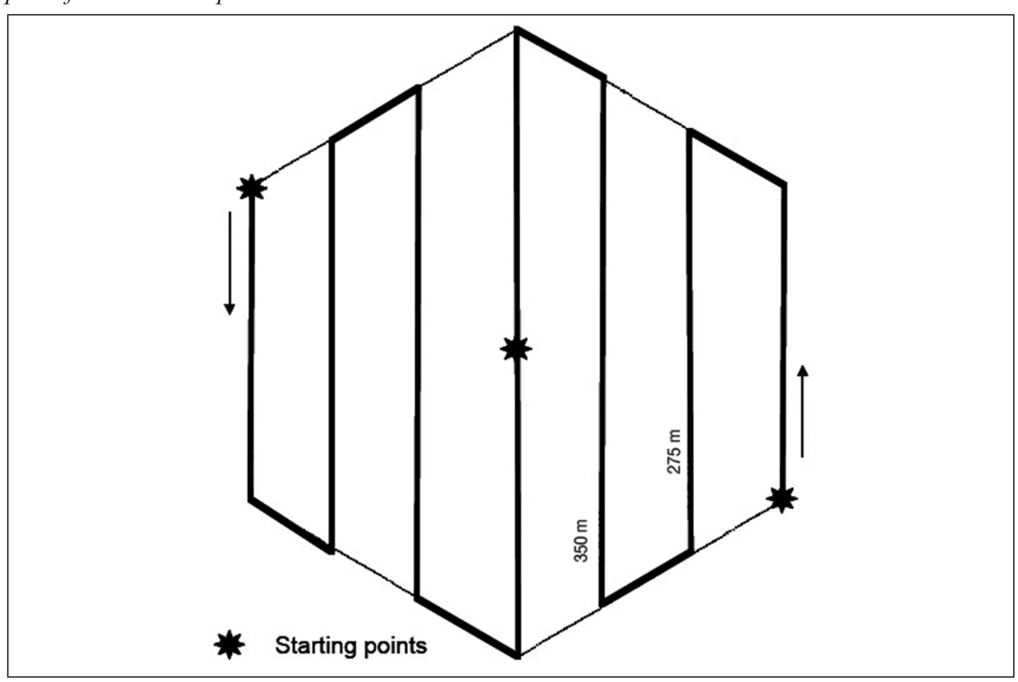
This section describes the summer TVES, which is conducted once in the summer and focuses on terrestrial bird, mammals, and reptiles. Spring and fall TVES focuses on terrestrial amphibians and reptiles, and are described in chapter 8, section 8.1.1. Aquatic visual encounter survey methods are described in chapter 9.

Sampling Design

The 10-ha sampling hexagon, centered on the MSIM monitoring point (chapter 2, fig. 2.2), serves as the sampling area for TVES. The size of the sample unit was selected to suit the detection of a broad array of vertebrate taxa (small and large-bodied) and wide variety of macro- and microhabitat types. It is also coincident with the search area used for terrestrial amphibian and reptile surveys. The boundaries of the 10-ha sample unit may be reconfigured to conform to boundaries provided by any national monitoring grid that may be developed.

One or two observers systematically survey for individuals and animal sign by traversing the sampling hexagon along set transects (Crump and Scott 1994). Observers follow a transect that loops through the hexagon at a 50-m spacing (fig. 4.1). The length of each route on each half of the sample unit is approximately 1,200 m, for a total of 2,400 m. These transects are also used for amphibian and reptile visual encounter surveys conducted during the spring and fall (chapter 8) and diurnal broadcast surveys (section 4.2.2). Two observers are recommended to reduce observer fatigue, improve consistency in identifications by comparing observations,

Figure 4.1. *Terrestrial visual encounter survey transects associated with each monitoring point for the MSIM protocol.*



and provide a second opinion for difficult identifications. If two observers search the unit, they each search half the sample unit. One of the six points of the hexagon is randomly selected as the start point for the first visit, and then the second visit randomly selects from all but the point opposite the point selected for the first visit so that the second visit is along a different route than the first visit. Observers use the flag lines and distance markers along the center line and perimeter of the hexagon and compass bearings (checked periodically) to walk the transect lines.

Data Collection

Observers walk along the transect at a pace of 5 minutes per 50 m, for a total of approximately 2 hours of search time per half of the hexagon, or 4 hours of total search time for the sample unit. Observers are expected to detect all animal sign or target animals within 5 m on either side of the transect, but can record all sign out to 25 m (halfway point between transects) or direct detections at any distance. The perpendicular distance to all detections is recorded to enable the calculation of probability of detection. Aquatic habitats, such as lakes, ponds, streams, and bogs, located within the sample unit are not surveyed as part of this protocol. They are surveyed as part of the aquatic visual encounter survey. (See chapter 9, section 9.2.1.) Surveys may be conducted any time of day, but it is recommended that they be conducted between 8 a.m. and 6 p.m.

Surveys note direct observations and sign of all less common and/or larger bodied species not well detected by the other survey methods being implemented. Animal sign can include a wide variety of features: tracks, scat, whitewash, regurgitated pellets, nests with fresh nesting material, feathers, burrows, haypiles, foraging marks, territory marks, prey remains, and food caches (Wemmer et al. 1996; Woodbridge and Hargis, in press). Observers search surfaces, vegetation, turn over objects such as logs and rocks, and look in crevices in rocks and bark, replacing all surface objects after examining the ground beneath (Crump and Scott 1994). Logs and other substrate are not torn apart to minimize disturbance to important habitat elements. Riparian or mesic habitats are searched extensively for any burrow systems, focusing under riparian vegetation for burrow openings. If nests are discovered, nest characteristics are recorded. The quantity of animal sign is not recorded, as correlations between sign frequency and species abundance/density are not consistent across species or habitats (Wemmer et al. 1996). Observers note only the presence of individuals or sign, and identify the detection to the most specific taxonomic level possible.

Not all species observed directly are recorded; only less common species or those poorly detected with other core or primary methods are recorded. For example, point count surveys are the primary survey method for songbirds and woodpeckers, so not all of these species would be recorded during visits. Only less common species, such as pileated woodpeckers (*Drycopous pileatus*), would be recorded if detected during TVES surveys. A list of target species needs to be developed for the region for this survey method to be successful.

The following information is recorded for each detection: observer, time, search time elapsed, species, detection type (e.g., visual, auditory, capture, sign), age class of captures (juvenile, subadult, or adult), and substrate type (e.g., rock, log, bare ground, etc.). The gender of individuals is also recorded if known. Recording the search time elapsed enables subsetting the data set into increments of time for the purposes of sampling adequacy and comparisons with other data sets. In addition, all unusual captures or sign are documented by taking a digital picture that illustrates the diagnostic characteristics. These photos enhance the accuracy of species identification.

The reliability and utility of TVES for vertebrate species depends on size, gregariousness, uniqueness of their sign, habitat conditions, and time of season. The probability of detecting species presence from sign is highest when species are large, individuals live in groups, or individuals habituate to particular locations for roosting or feeding (Weckerly and Ricca 2000). Also, surveys of sign of larger, less gregarious and smaller, more gregarious species such as moose (*Alces alces*), mule deer (*Odocoileus hemionus*) and collared peccary (*Tayassu tajacu*) have been widely used to document their distribution (e.g., Franzmann et al. 1976, Neff 1968). Detections based on sign will not always be sufficient to identify species, in which case detections are identified to the lowest taxonomic level possible.

The monitoring point is visited once during the summer. These data are combined with spring and fall visits to generate a species list. If additional summer visits are conducted, they should be conducted across all points or a systematic subset of points.

Equipment Needed

Observers will need a clip board, hand spade or rake, field keys, hand lens, stop watch or watch with timer, pocket ruler, resealable plastic baggies (for collecting scat and pellets), digital camera, hand lens, and binoculars.

Staffing, Training, and Safety

Field crews should consist of two biological technicians, with a crew leader at the GS-7 level for every four to six crewmembers to supervise and coordinate data collection. Each field crew of two can complete visits to an average of two monitoring points per 10-hour day, or eight monitoring points per week, depending on travel distances between monitoring points. Crewmembers should be GS-4/5 or higher with academic training in the natural history and identification of multiple vertebrate taxa and/or practical experience in tracking, animal sign, and species identification. Oversight of surveys at the forest or multiple-forest level should be conducted by a journey-level biologist with at least 2 years of relevant field and supervisory experience.

Two weeks of training are recommended regardless of previous experience to ensure that individuals are versed in the protocol, the species, and the environment. A list of species to record during TVES based on sign and direct observation should be made for each forest in the regional monitoring plan. A key should be developed that illustrates all potential sign, which species make them, and how to distinguish similar sign. Training should include: (1) visits to natural history museums to examine specimens of local species; (2) training in the identification of tracks and sign; (3) field practice of data collection with an experienced tracker/observer; and (4) testing of crewmembers to verify proficiency. (See Wilson et al. [1996] for review of field guides to vertebrate sign.)

Quality Control and Assurance

The nature of the data collected by this protocol makes quantification of management quality objectives difficult. Examination of collected data will not reveal missed detections, or misidentifications of data collected by observation without photo record. Visual species identification data are ephemeral and checking these data is extremely difficult. Digital pictures provide a valuable tool for verifying field identifications. In addition, the field crew leader should rotate working with each field crewmember to check on their techniques and field identification. If during this checkup crewmembers are missing detections, additional training should be given before that crewmember participates in data collection. In addition, observers should be rotated among sites, such that each site is visited by a different crew each visit to reduce the potential effects of observer bias on detection estimates. The photographic data on tracks, sign and captured individuals should be checked by a minimum of two people with training in species identification of multiple taxa.

Data Storage and Analysis

Data from TVES should be analyzed with data for each of the primary taxonomic groups. It is important to note that for analysis, multiple signs, and/or sightings of a single species within a sample unit represent a single detection for that species; that is, multiple detections (e.g., sign or sightings) of a single species are combined to represent presence of that species for that sample unit. TVES provides data for improving the estimate of species composition per monitoring point, but it can also be included in estimates of the proportion of points occupied using PRESENCE. (See chapter 2, section 2.6.2.) In addition to basic data handling and storage procedures, amphibian and reptile records can be sent to the Amphibian and Reptile

Monitoring Initiative (ARMI) program via the Patuxent Wildlife Research Center in Laurel, Maryland (http://www.pwrc.usgs.gov/armiatlas/). Amphibian detections will be incorporated into the ARMI *National Atlas for Amphibian Distributions*. All records submitted will be subject to verification by the appropriate authorities before inclusion into the atlas. Observation data should include species, date(s) of observation, UTM coordinates and zone, observer, and institution.

Data analysis consists of adding the species detected through TVES to those detected using other survey techniques (e.g., raptor species added to the list created through broadcast calling) and then following the steps previously identified to calculate probability of detection and proportion of points occupied across the landscape.

4.2 Supplemental Survey Methods

Additional survey effort should be directed at species that are identified as target species (e.g., species of concern, species of interest, surrogates), species that are top carnivores in the ecosystem, and species that would improve the representativeness of raptors adequately sampled to discern trends. A list of all raptor species expected to occur on each forest throughout the region needs to be generated, species adequately sampled with core methods determined, and then supplemental survey methods directed at strengthening the suite of species surveyed.

4.2.1 Nocturnal Broadcast Survey Augmentation

In areas where detection rates are low, a larger sample unit can be established or additional visits can be conducted. Once initial data are obtained, power analyses can be conducted to evaluate the most advantageous allocation of effort (i.e., larger sample unit, additional visits, additional monitoring points). Sample unit sizes may be enlarged if suitable habitat for one or more owl species occupies a small proportion of the landscape, or if species expected to occur in the area are not detected in the primary sample unit. In these cases, only areas of suitable habitat in some or all of the remainder of the hexagon would be surveyed. Suitable habitat would need to be well defined and mapped, and consistently interpreted across all forests in the region for data from enlarged sample units to be useful for monitoring. No more than four visits should be conducted in a season because birds may become habituated to broadcast calling (Johnson et al. 1981), or may be adversely affected due to the high level of disturbance, increased predation risk (Holroyd and Takats 1997), or disruption to breeding (Johnson et al. 1981).

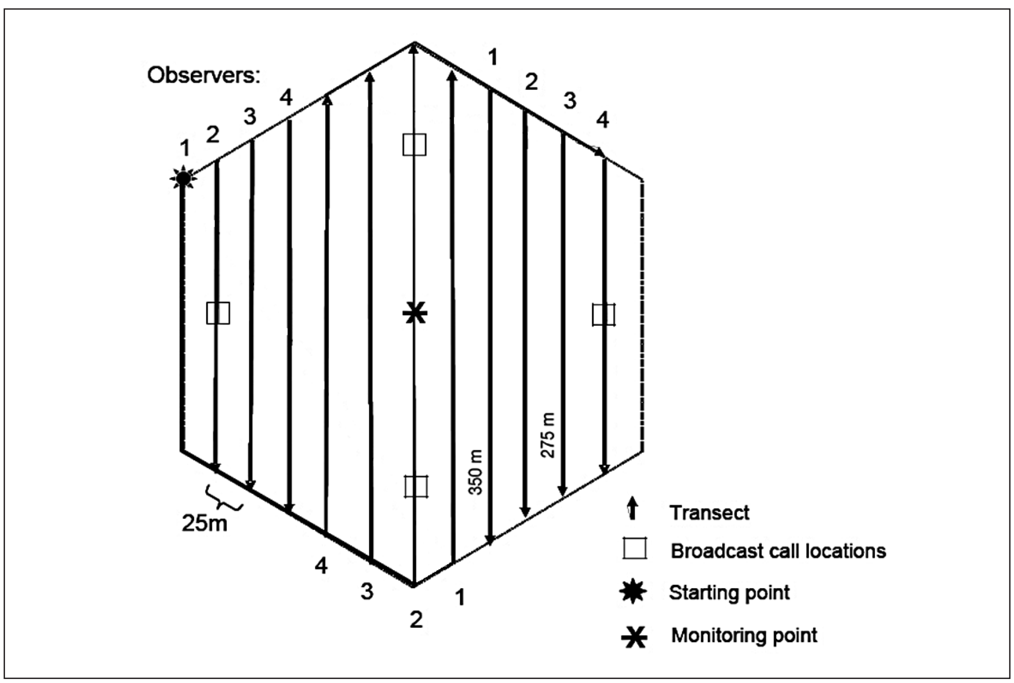
4.2.2 Diurnal Broadcast Surveys

Diurnal raptors do not lend themselves to multiple species survey techniques, although broadcast surveys can be effective at detecting a few species. The national protocol for intensive searches for northern goshawks (*Accipiter gentilis*) based on the Reynolds (1982) approach is adapted here as a multiple species survey method for accipiters (forest hawks) (Woodbridge and Hargis, in press). Additional diurnal raptor surveys may be conducted as supplemental to detect species not readily detected with core survey methods for raptors or other species (e.g., point counts).

Sampling Design

This survey method essentially augments the TVES with broadcast calls of accipiters along the transects. Three or four observers walk along parallel transects, spaced 25 m apart (fig. 4.2) at a leisurely pace, approximately 50 m every 5 minutes. The middle of three observers broadcasts recorded goshawk or other accipiter vocalizations (depending on target species) at points every 250 m along the transect, on every third transect line. One of the six points of the hexagon is randomly selected as the start point (fig. 4.2). Observers use the flag lines and distance markers along the center line and perimeter of the hexagon and compass bearings (checked periodically) to walk the transect lines.

Figure 4.2. *Accipiter survey transects and broadcast calling locations for the MSIM protocol.*



Data Collection

A brief description of the survey method is described here. For more detail, see the intensive search method in Woodbridge and Hargis (in press). Observers scan the ground, logs, and low limbs for sign. Sign includes feathers, whitewash, prey remains, and nests. The location of all detections are recorded by transect location and detection type. Feathers should be collected and labeled by transect location, and should be identified by comparison to known feathers (e.g., the U.S. Department of Agriculture, Forest Service CD, *Feathers of Western Forest Raptors and Look-Alikes*).

The calls of accipiter species that occur in the area (one, two, or all three species), are broadcast in order from small to large body size at four set locations as observers walk along three designated broadcast transects (fig. 4.2). It is recommended that observers conduct the accipiter survey, and then double back and survey for sign of other species as per the TVES survey method.

To reduce the potential for disturbance, surveys do not start before the estimated hatching date of northern goshawks, if the survey area is within its geographic range. Surveys should be conducted between mid June and the end of August. Only one survey is conducted; the later the survey, the more abundant the sign but the less likely that accipiters will respond to broadcast calling.

4.2.3 Northern Goshawk Bioregional Monitoring Design

The Northern Goshawk Bioregional Monitoring Design (Hargis and Woodbridge, in press; Woodbridge and Hargis, in press) was developed to meet the following monitoring objectives: (1) to estimate the frequency of occurrence of territorial adult goshawks over large geographic areas; (2) to assess changes in frequency of occurrence over time; and (3) to determine whether changes in frequency of occurrence, if any, are associated with changes in habitat. The design is intended to be implemented in each of 10 bioregions that together cover the entire range of the northern goshawk in the coterminous United States and Alaska. Because of the broad-scale objectives of the bioregional monitoring design, the sample units are larger and the transect spacing is greater than described for the diurnal raptor survey method in section 4.2.2.

The primary sample units are 1,484-ac (1600-ha) squares that correspond to the approximate size of a goshawk territory, so that each sample unit represents approximately one pair of territorial adults, and each sample unit also represents one-fourth of the area of an FIA hexagon. Depending on the size of the bioregion and on budgetary constraints, 100 to 400 sample units are randomly selected from the entire bioregion, using a stratified random sampling design and four strata: two strata that differentiate high- and low-quality habitat, and two that differentiate high-cost and low-cost survey efforts.

Within each sample unit, observers use the broadcast acoustical survey method at call stations that are systematically spaced throughout the sample unit: 10 transect lines 250 m apart, 13 call stations per transect, and call stations 200 m apart (113 call stations per sample unit). Call stations on adjacent transects are offset 100 m to maximize coverage. Observers start in the best quality habitat of each sample unit and sample until a detection is made or until the entire sample unit is covered. The protocol also calls for listening for goshawks and looking for freshly molted feathers while walking between call stations. A freshly molted feather is considered a detection.

Each sample unit is sampled (visited) twice during one breeding season: the nestling period and the fledgling period. The two visits result in a detection history and data analysis similar to that described in section 4.1.1.

Chapter 5. Small Mammal Monitoring

Most small mammals are primary consumers and represent the primary prey items of many carnivores, including many raptors and medium-sized mammals. They are abundant in many ecosystems and serve important ecological roles in terms of influencing their prey and their predators. Sherman live trapping is the core survey method for small mammals. Supplemental survey methods, such as Tomahawk trapping and pitfall trapping, are offered as methods to expand the breadth of species detected.

The objective of the small mammal surveys described in this chapter is to provide reliable, standardized data on status and change in the distribution and relative frequency of a large number of small mammal species. Overall, the Multiple Species Inventory and Monitoring (MSIM) protocol is intended to serve as a consistent and efficient method for obtaining spatially and temporally coincident detection/nondetection data and habitat condition data across a diversity of species. The National Framework and basic sampling design of the MSIM protocol is described in chapter 2. Survey methods for animal and plant species are described in the subsequent eight chapters. The National Framework identifies six core survey methods and three additional primary survey methods that together provide information on a representative sample of species in various taxonomic groups and at various trophic levels.

All survey methods associated with the MSIM protocol are designed to be implemented at MSIM monitoring points that are associated with, but offset from, Forest Inventory and Analysis (FIA) grid points on National Forest System lands. The scale of implementation is the national forest, but the primary planning scale is the region to ensure consistency in monitoring approaches for species and habitats shared among forests. The MSIM National Framework calls for a minimum of 50 percent of the FIA grid points to be selected to establish MSIM monitoring points. This core set of monitoring points is to be surveyed over a 3-year sample period with no more than a 5-year resample cycle. Sampling associated with most of the core and primary survey methods is contained within a 200-m radius (approximately 10-ha) sampling hexagon centered on the MSIM monitoring point. Species detections are used to estimate the proportion of monitoring points occupied by the species. For more details on the overall sampling design, see chapter 2.

5.1 Core Survey Methods

Live trapping was selected as the primary protocol for small mammals because it is an effective, efficient, and benign technique for detecting the presence and estimating the abundance of most small mammal species.

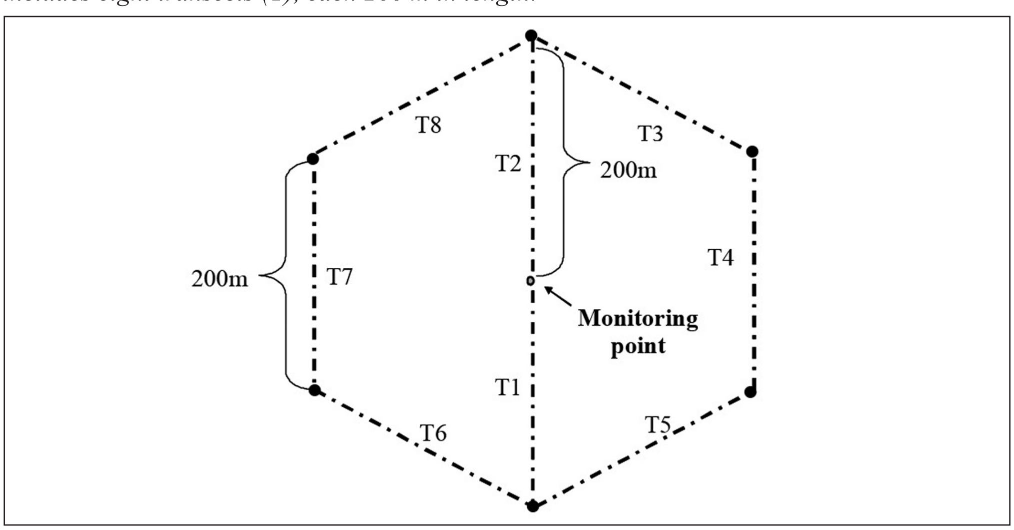
5.1.1 Sherman Live Trapping

Sherman extra long (7.6 by 9.5 by 30.5 cm, model XLK) and extra large (10.2 by 11.4 by 38 cm, model XLF15) folding traps are sized to accommodate a range of small mammals including members of the families soricidae (shrews), muridae (mice, voles, rats), heteromyidae (kangaroo rats), and small-bodied sciurids such as chipmunks, ground squirrels, and tree squirrels (http://www.shermantraps.com/default.html).

Sampling Design

The two sizes of Sherman traps are deployed alternately along eight transects, each 200 m in length, arrayed in a hexagonal pattern, and centered on the monitoring point (fig. 5.1). Transects connect point count stations around the monitoring point (see chapter 3, fig 3.1), with two additional transects passing through the center of the hexagon (400 m north to south). Traps are placed 20 m apart on a transect, starting at each point station and ending 20 m before the next point count station, for a total of 10 traps along each transect and 80 traps overall. Traps are placed within 2 m of the intended location at habitat features such as logs, burrows, the base of trees, runways, and always in areas that provide cover from weather (e.g., under shrubs, in

Figure 5.1. *Sherman live trap array for the MSIM protocol. The hexagonal arrangement includes eight transects (T), each 200 m in length.*



tall grass). Transects and trap locations can be established and flagged as the traps are being set. Efficiency can be gained, however, when the hexagon is first flagged for point count sampling by hanging flags every 20 m along the flag line between point count stations. These flags then mark where small mammal traps are to be placed.

A space of 20 m between traps is within the range generally recommended for rodent community inventory, and approximates the radius of a circle representing the smallest home range size of species expected to be detected (Jones et al. 1996). Thus, at least one trap would fall within each home range intersected by each transect.

Capture rates of small mammal species vary with trap size, type, and locality (Lawrence 1992, Quast and Howard 1953, Slade et al. 1993, Williams and Braun 1983, Whittaker and Feldhamer 2000, Whittaker et al. 1998), and a combination of trap types and sizes is thought to be most effective at determining small mammal community composition. Thus, two different sizes of Sherman live traps are prescribed for sampling small mammals. Although wooden box traps can be a successful alternative for some small mammals (e.g., larger sciurids, rabbits) they can be more difficult to transport in quantity. Transects are used rather than a grid because they appear to be more effective and efficient at detecting the composition of small mammals at a site, given similar trap effort (Pearson and Ruggiero 2003, Petticrew and Sadlier 1970, Read et al. 1988, Steele et al. 1984). Further, transects have a greater effective sampling area, and the large hexagonal array has a greater probability of intersecting a variety of habitats/microhabitats containing different species compared to a grid (Pearson and Ruggiero 2003). The hexagonal transect configuration corresponds with the spatial array of most of the primary survey methods (e.g., point count stations, visual encounter surveys).

Data Collection

Live trapping is conducted once per year, primarily during the summer breeding season in temperate zones. However, it could be informative to conduct multiple times per year in warmer climates; specific timing depends on latitude and local climatic conditions. In locations with year-round mild weather (e.g., the Southern United States), special considerations, such as timing of activity cycles, may preclude summer sampling. In areas with more than 1,000 m of topographic relief, surveys at lower elevations are conducted first to control for the delayed activity cycles at higher elevations. Locations within the survey area (national forest) that are likely to have early breeding (e.g., east or south side of mountain ranges) should be surveyed earliest in the season relative to other locations. Trapping should be avoided during periods of unseasonably cold, hot, or wet conditions to avoid unnecessary mortalities. Surveys conducted at the same locations in different years should maintain similar survey conditions and timing across years (e.g., same survey months).

Traps are covered with "Coroplast" (corrugated plastic) covers (not black) to regulate temperatures within traps, and particularly to reduce maximum temperatures (http://www.coroplast.com/product.htm). Polyester batting (e.g., Dacron®) is placed in traps (~ 2-in diameter ball at back of trap) to provide warmth in locations where temperatures are likely to drop near or below freezing. Because trapping during weather extremes increases metabolic stress on animals, increasing their risk of mortality, precautions to reduce stress and mortality are critical (Animal Care and Use Committee 1998).

Sherman traps are baited with a mixture of rolled oats and mixed bird seed (containing sunflower seeds and millet). A good rule of thumb to follow in proportions is one gallon rolled oats to one gallon mixed bird seed. Oats provide carbohydrates, and sunflower seeds are a high protein and fat food. Other items may be added, but bait should be consistent throughout the region. Bait type can influence capture rates of small mammals (Jones et al. 1996, Weihong et al. 1999), so whatever mixture is used for monitoring should be used consistently throughout the season and over time. Mealworms are a recommended addition, as they provide a high protein food source for shrews, and are frozen prior to use to keep them from leaving traps after baiting. Likewise, the addition of peanut butter is recommended primarily to aromatize the bait, although in some areas this can be problematic (e.g., the scent attracts fire ants in the Southeastern United States). Bait for each trap may be placed in a small piece of folded plain paper to improve efficiency of baiting and avoid fouling the trap mechanism.

Trap locations along transects are uniquely numbered in groups of 100 corresponding to each of the eight transects (transect 1 = 101–110, transect 2 = 201–210, etc.). Trap locations may be marked in any number of ways. In pilot testing (Manley et al. 2002, Roth et al. 2004), the transect lines were flagged every 20 m where traps were to be placed, and wooden clothes pins were then used to indicate the exact location (within 2 m of flag) and number of each trap. Clothes pins were spray painted bright pink and numbered with permanent black ink. This technique proved to be simple and efficient.

All traps are set, opened, and baited in the late afternoon of the first day, and checked a minimum of twice daily starting on the morning of the second day, for a minimum of 3 consecutive 24-hour days. That is, if traps are set Monday afternoon they are checked and removed on Thursday afternoon (three nights).

Length of the trapping session (i.e., number of days) can influence the number of species detected (Olsen 1975, Steele et al. 1984). Three consecutive days is the minimum trapping period required for sampling small mammal communities to determine species richness. This trapping period was chosen based on data analysis from pilot testing in the Sierra Nevada, which suggested that the largest gains in the detections of small mammal species occurred over the first 3 days, when an average of 84 percent of the small mammal assemblage likely to occur at each site was detected (Manley et al. 2002). A 3-day trapping period equates to a 40-hour work week for field crews. The fourth night of trapping only increased the estimated proportion of the assemblage detected by 2 percent, and required at least 5 hours of overtime per person each week to accomplish. The addition of a fourth night of trapping is recommended for abundance estimates, where traps would be collected Friday morning as opposed to Thursday afternoon (see section 5.2.1).

Morning trap checks are completed before temperatures can rise and potentially stress the trapped animal (by 10 a.m. is recommended), and afternoon checks are completed before dark. Traps are rebaited as necessary. All nonfunctional traps (e.g., trap door closed but no animal captured, bait gone from trap without an animal being captured, or trap missing) are noted on data sheet, reset and rebaited, or replaced, so they become functional (Nelson and Clark 1973).

Releasing trapped animals into a plastic (shrews and mice) or cloth (squirrels) bag then working them into a corner makes grasping the nape area easier. Holding small mammals in this manner is the most efficient method for examination. Capture cones (hand-crafted mesh cones with a cloth entryway) are also an option, particularly for larger species. (See chapter 6, section 6.2.2.) Each observer should carry a thick leather glove in the event a mustelid (e.g., weasel) is captured.

Captured animals are identified to species, sexed, aged (as juveniles, subadults, or adults), examined for breeding status (e.g., pregnant, lactating, enlarged testes, or nonbreeding), marked by cutting a patch of fur near the base of the tail, weighed, and released. Additional information is recorded to discern similar species within genera (e.g., *Tamias*, *Peromyscus*, *Microtus*, and *Sorex*), including relevant body measurements such as the lengths of the hind foot, ear, tail, and head/body. Marking animals enables the calculation of relative abundance estimates for capture data. If at all possible, any trap capturing a mustelid should be replaced and then cleaned before reuse because the strong smell can negatively affect subsequent rodent captures. Trap mortalities are collected and frozen as soon as possible, labeled with date of collection, county and State of capture, collector's name, project name, agency office of contact, description of habitat type at the trap location, and a description of the specific locality where the animal was collected (e.g., edge of dry creek bed at north end of meadow). Species identification is confirmed and animals are donated to a local museum collection. Deer mouse (*Peromyscus maniculatus*) and other known vectors of hantavirus (e.g., *P. leucopus, P. gossypinus*, *Sigmodon hispidus*) should not be routinely collected due to the associated risk.

All traps are cleaned and disinfected after sampling is completed at each location. Traps are emptied of all loose bait, organic material, and polyester batting before being placed into a mild bleach/water (the Center for Disease Control recommends 3 T/1 gal) solution or 5 percent Lysol solution where they remain for approximately 10 minutes. Heavily soiled traps are scrubbed with brushes while submerged in the mild bleach or Lysol solution until clean. Traps are then rinsed with water and allowed to dry fully before being used for the next survey. Polyester batting is also soaked in mild bleach or Lysol solution for 10 minutes and placed in plastic bags before disposal. Cleaning traps with mild bleach or Lysol solution is recommended after each site survey is conducted where species that are hosts for hantavirus are captured (Mills et al. 1995). A mild bleach solution does not appear to affect subsequent captures of small mammals (Yunger and Randa 1999).

Equipment Needed

Each site requires the following items: 84 Sherman traps (80, plus replacements), trap bait, polyester batting, 1-gallon plastic bags for bait (Ziploc-brand bags preferred), scales (30, 50, 100, and 300 grams), field rulers, small scissors, clipboard, mammal field guides or keys, rubber gloves, leather gloves (for weasels and larger squirrels), backpacks for carrying traps (one per transect), hand lens (shrew identification), cloth face masks or respirators (as needed), and hand sanitizer (the latter two for protection from hantavirus). Cleaning equipment requires two 30-gallon garbage cans, water supply, bleach, hose with nozzle, scrub brush, protective eyewear, and a large flat area to spread out traps while drying.

Staffing, Training, and Safety

Field crews are comprised of a minimum of four people, with one designated as field crew leader (GS-7/9). A crew of four individuals can be expected to sample four points per week (each crew of two can sample two sites per week). Four people are a minimum crew size because many sites require more than two people to transport traps in and out. Trappers will often need at least one additional person on the days that traps are set and pulled at sites. The crew leader should have at least 2 years of experience capturing and handling small mammals and the ability to effectively train and supervise field crews. Crewmembers can be GS-3/4/5 biological technicians, preferably with academic training in mammalogy and some experience handling animals. Inexperienced individuals can perform well, but potential problems include lack of attention to detail in implementing the protocol, and difficulty coping with stress imposed on some individual animals.

Before any data collection, an expected species list is generated based on range maps, guides to local fauna, and local occurrence records (when available). When in doubt, consider the species as potentially occurring in the area and include it in the species list. The distinguishing features of each species should be noted (e.g., strongly bicolored tail, hind foot length), with particular attention called to species that could be easily confused in the field.

Two weeks of training are recommended and should include the following as a minimum: (1) work with study guides that identify and discuss the defining features of each species, (2) visit university museums to observe and study the variability of defining characteristics that could be encountered in the field, and (3) practice trap setting and animal handling in a variety of environmental conditions. Oversight of surveys at the forest or multiple-forest level should be conducted by a journey-level GS-11 or higher employee with at least 2 years of relevant field and supervisory experience.

Crews should work in teams of two whenever possible because of the dangers of hiking cross-country with heavy backpacks and the potential for injury from handling animals. Each crew should have at least one radio, and it is recommended that each crew also have a cell phone. Cell phones facilitate rapid and efficient communication with supervisors and coworkers. Safety precautions recommended for handling possible vectors of hantavirus can be found in Mills et al. (1995); however, crew leaders should check specific regional recommendations for handling small mammals. Animal handling follows guidelines defined by the American Society of Mammalogists (Animal Care and Use Committee 1998).

Quality Control and Assurance

Protocols for the use of baited live traps for small mammal surveys are well established, with recognized sources of bias that can affect data quality. Factors affecting data quality that should be discussed in detail with crewmembers include: (1) setting traps so they are effective at capturing animals and animals have a high probability of survival once captured, (2) observer care in handling animals to minimize escape before marking or mortality of stressed animals, and (3) observer error in species identification and the identification of marked animals. Ideally, all traps are fully functional and set properly to capture animals; it is reasonable to expect less than 1 percent of all traps to be improperly placed and set. Proper trap placement and function can be determined subjectively through field reviews by supervisors. Mortalities should be less than 1 percent, and reported to the field supervisor at the end of each day. Mortality rates can be determined by examining field data. Escapes rates can be reasonably expected to be less than 1 percent of all animals captured. It may be difficult to meet this objective for individual species, specifically for larger and more difficult to handle animals (e.g., weasels). Escape rates, however, can be kept at less than 5 percent even for these animals with the proper gear and training. Escape rates per species and across all animals can also be determined by examining field data. Species identification and correct classification of marked animals is difficult to quantify. Swapping observers among sites and transects in the course of a trapping period can help reveal and reconcile differences in species identification among observers.

Data Storage and Analysis

Data analysis consists of creating species lists for each monitoring point and estimating the proportion of all monitoring points occupied within the entire area of inference, using the probability of presence and detection probabilities as parameters in a maximum likelihood model. (See chapter 2, section 2.6.2.) The freeware program PRESENCE is available for this analysis (http://www.mbr-pwrc.usgs.gov/software.html). The species detection data from all traps are compiled to create detection histories for each day of trapping (morning and afternoon checks combined) for each species at each monitoring point. Detection histories consist of either a “1” for the entire sample unit (regardless of the number of detections) or a “0” if no detections were made. For 4 days of trapping, the detection history for a given species may be any combination of 0s and 1s, such as 0100, 0011, or 1111.

Data sheets are checked by fellow crewmembers at the end of each day to make sure that all fields are filled out correctly and legibly. These checks also identify discrepancies in species identification among observers and alert observers to unusual species or situations that they may encounter the next day. Field supervisors check all data sheets at the end of each week to review species identification, escape rates, trap function, mortalities, and legibility.

Relative abundance of species across points each year can be estimated by counting the number of unique individuals captured for each species (based on the number of first captures per species). Sampling adequacy can be evaluated by estimating the probability of detection per unit effort, and estimating the power to detect a trend of a given magnitude and precision given the existing sample effort. Sample effort may then be adjusted if indicated by the analysis.

5.2 Supplemental Survey Methods

Sherman trapping is an effective method to detect most small mammal species. Supplemental survey methods should be directed at detecting species not readily detected by the core Sherman trapping method. The list of species expected to occur in the area should be consulted and species most likely to be detected with a modest level of additional effort should be targeted by supplemental survey methods.

5.2.1 Sherman Live Trapping Augmentation

Trap session duration. While 3 days and 80 traps are the recommended effort for the primary method, a longer trapping period may be desired for detection of a greater percentage of the small mammal community or to obtain more precise estimates of abundance (Olsen 1975, Steele et al. 1984). Trapping for one additional night, and removing traps on Friday morning, will improve estimates of species richness, composition, and relative abundance. Additional traps are not as likely to yield additional benefits as one additional night (e.g., Manley et al. 2004). Species accumulation curves can be produced from preliminary data collected on any forest, region, or ecoregion to determine the level of survey effort at which various percentages of the small mammal community are detected (Cam et al. 2002).

Trap grids. The addition of trapping grids in association with the primary method may be warranted in cases in which population densities or other additional population data are desired for one or many species. The addition of a grid will increase the proportion of individuals using the area that are captured. Trap grids of 50 or more additional traps may be established on either side of the center trap line. An option that resembles a typical grid pattern is to establish three transects on each side of the center line 15 m apart, 200 m long, for a total of 60 additional traps placed 20 m apart, creating a trap grid of 80 traps.

Trap placement. Placement of traps at various heights above ground (i.e., placement of traps in trees) has been shown to be effective at detecting arboreal small mammals (Lawrence 1992), such as flying squirrels (Loeb et al. 1999, Risch and Brady 1996). Therefore, monitoring programs established in areas with arboreal species of interest should consider the placement of an additional extra long or extra large Sherman trap along each transect at 3 to 4 m above ground in nearby trees to increase the capture frequency of such species.

5.2.2 Tomahawk Live Trapping

Tomahawk traps can be effective at increasing detection rates of larger rodents such as ground squirrels and woodrats; however, the additional cost of using Tomahawk traps is not typically warranted for simply increasing squirrel detections (http://livetrap.com/). Tomahawk traps are most effective at detecting medium-sized mammals, and if they are used for that purpose squirrel detections are likely to increase. (See chapter 6, section 6.2.2.) During pilot testing, however, trackplate and camera surveys were more effective at detecting a wider array of medium-sized mammals compared to Tomahawk traps (Manley et al. 2002).

5.2.3 Pitfall Traps

Pitfall traps can be more effective at detecting some of the smaller bodied rodents compared to Sherman trapping, particularly shrews and gophers, which are typically not well sampled with Sherman traps (Szaro et al. 1988). Caution is recommended in using pitfall traps for monitoring, however, because they are often lethal to captured mammals, particularly shrews, and thus have the potential to impact local populations. If pitfall traps are configured to capture mammals, options for minimizing impacts on local populations include shorter sample periods and truncating sampling once all species potentially occurring at the site are detected. See chapter 8 for a detailed description of pitfall trapping.

5.2.4 Trackplate and Camera Surveys

Trackplate and camera surveys are identified as a primary protocol for medium and large mammals (chapter 6), but they can also be effective at detecting smaller mammals. Tracks of many of the larger squirrel species can be identified to species, and a variety of tree and ground squirrels are attracted to bait at cameras, particularly when bait consists of a mixture of animal and vegetable matter. Trackplate and camera surveys are too expensive relative to their effectiveness for small mammals to be used to augment Sherman trapping alone. Detections of many species of small mammals, however, will be enhanced when trackplate and camera surveys are used to target detections of other taxa.

Chapter 6. Medium and Large Mammal Monitoring

Larger mammals consist of a wide variety of species from different trophic levels, ranging from herbivores (e.g., rabbits), to mid-level carnivores (e.g., skunks), to top carnivores (e.g., weasels, mountain lions, bears). The density of medium to large mammals is less than lower trophic level species, and therefore the species detected per unit effort is relatively low. Carnivores, however, play a significant role in structuring populations and communities, and their status has implications for many aspects of sustainability. Further, carnivores are often species of concern, so they may be of specific interest at the forest or regional level. Trackplate and camera surveys and terrestrial visual encounter surveys are identified as the core survey methods for medium and large mammals.

The objective of the medium and large mammal surveys described in this chapter is to provide reliable, standardized data on status and change in the distribution and relative frequency of a large number of mammalian species. Overall, the Multiple Species Inventory and Monitoring (MSIM) protocol is intended to serve as a consistent and efficient method for obtaining spatially and temporally coincident detection/nondetection data and habitat condition data across a diversity of species. The National Framework and basic sampling design of the MSIM protocol is described in chapter 2. Survey methods for animal and plant species are described in the subsequent eight chapters. The National Framework identifies six core survey methods and three additional primary survey methods that together provide information on a representative sample of species in various taxonomic groups and at various trophic levels.

All survey methods associated with the MSIM protocol are designed to be implemented at MSIM monitoring points that are associated with, but offset from, Forest Inventory and Analysis (FIA) grid points on National Forest System lands. The scale of implementation is the national forest, but the primary planning scale is the region to ensure consistency in monitoring approaches for species and habitats shared among forests. The MSIM National Framework calls for a minimum of 50 percent of the FIA grid points to be selected to establish MSIM monitoring points. This core set of monitoring points is to be surveyed over a 3-year sample period with no more than a 5-year resample cycle. Sampling associated with most of the core and primary survey methods is contained within a 200-m radius (approximately 10-ha) sampling hexagon centered on the MSIM monitoring point. Species detections are used to estimate the proportion of monitoring points occupied by the species. For more details on the overall sampling design, see chapter 2.

6.1 Core Survey Methods

A broad suite of species are included in the medium and large mammal section. Medium-bodied mammal species include members of many families such as large sciurids that may be too large to be effectively detected with Sherman live traps, mustelids, procyonids, ursids, ungulates, and leporids. Core survey methods are trackplate and camera surveys combined with visual encounter surveys. Many supplemental survey methods are available and several are discussed.

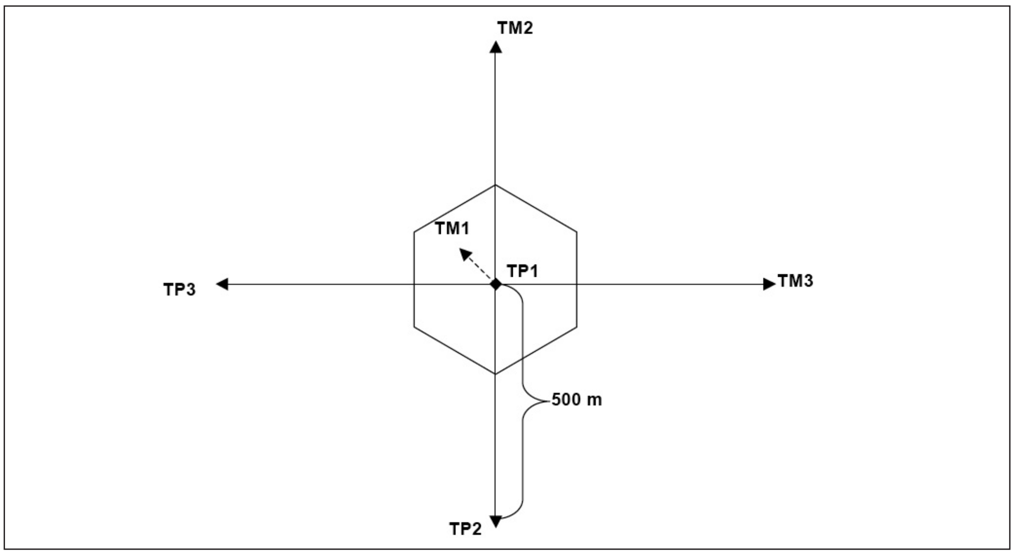
6.1.1 Trackplate and Camera Surveys

Trackplates are very effective at detecting bears and mesocarnivores (Zielinski 1995), but are less effective at detecting herbivores. Tracks of cottontail rabbits can be prevalent, however, when trackplates are baited to attract forest carnivores (Loukmas et al. 2003). Cameras are effective at detecting a wide range of larger mammal species, including carnivores and herbivores, depending on the setup and bait used. Motion-triggered cameras are being used more often to inventory and monitor ungulates and lagomorphs (Cutler and Swann 1999, Jacobson et al. 1997, Jennelle et al. 2002, Main and Richardson 2002, McCullough et al. 2000, Sweitzer et al. 2000). Cameras have increased in use, in part, because of the high probability of detecting a variety of species, including many species that are otherwise difficult to detect (Foresman and Pearson 1998). The reliability of the method is greatest when cameras are placed at sites where target species are lured in with food or water (Cutler and Swann 1999, Jacobson et al. 1997, Koerth and Kroll 2000, Sweitzer et al. 2000). Thus, the survey method described here is a combination array of trackplates and cameras designed to detect as broad an array of medium- and large-bodied mammals as possible. The survey method is geared toward summer sampling; however, cameras are also effective at detecting species during the winter (section 6.2.1). Habitat is characterized at each trackplate and camera station, including the central monitoring point (chapter 11).

Sampling Design

One covered trackplate station is placed within 2 m of the monitoring point (centerpoint) and labeled TP1. One camera station is located 100 m from the centerpoint at a random bearing and labeled TM1. A second camera is located 500 m from the centerpoint at 0 degrees and is labeled TM2. A third camera is located 500 m from the centerpoint at either 90 or 270 degrees and labeled TM3. A trackplate station is located 500 m from the centerpoint at 180 degrees, and labeled TP2. The remaining trackplate station TP3 is located 500 m from the centerpoint at the opposing bearing to TM3 (fig. 6.1). The exact location of the camera station is determined based on the nearest tree to which the camera and bait can be attached. If trees or other suitable substrates are not available within 20 m of the prescribed location, detection devices and bait may be mounted on stout, short stakes such that they remain stable and intact even when subject to weather or animal activity.

Figure 6.1. *Trackplate and camera array (sample unit) for the MSIM protocol. The 200-m radius hexagon represents the area within which the majority of survey methods in the MSIM protocol are employed; at the center is the FIA monitoring point.*



TM = camera station; TP = trackplate station.

Visiting each monitoring point before attempting to install detection devices generally decreases setup time, but different strategies will be necessary for different points (Truex 2004). Ideally, all trackplate and camera stations in a sample unit are setup and baited, and the travel route between stations flagged in 1 day. By inspecting monitoring points on a topographic map before set up, crew leaders can determine distance from roads and topography and develop the best strategy for establishing the sample unit. For example, remote points in difficult terrain take longer to setup than roadside sites, and may require additional crewmembers to complete in 1 day.

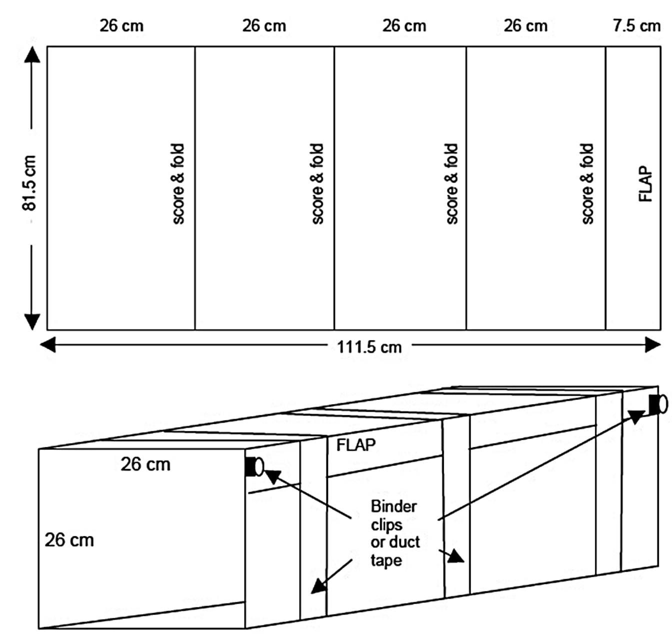
Data Collection

Each survey consists of one 10-day sample period during the summer months. Stations are visited every other day for a total of 5 visits. Trackplate boxes are constructed with a Coroplast™ enclosure and a removable aluminum trackplate (http://www.coroplast.com/product.htm). The Coroplast enclosures are lighter weight (2.5 vs. 6 lbs) and less expensive (approximately half the cost) compared to previously used polyethylene enclosures. They are less durable, however, and in areas with severe weather or for winter surveys in areas that receive snow, the more durable polyethylene enclosures are recommended (section 6.2.1).

The Coroplast cover has the approximate dimensions of 111.5 cm (44 in) long by 81.5 cm (32 in) wide, and is folded into a rectangular tube by scoring the material at the prescribed dimensions (fig 6.2). It is important that the corrugations run parallel to the longest length for maximum strength. The boxes are assembled in the field using duct tape and/or binder clips. The aluminum trackplates are made of 0.08 or 0.15 cm thick galvanized sheet metal that measure 70 cm (30 in) long by 20 cm (8 in) wide. Trackplates collect track impressions in soot on white contact paper. Approximately 35 cm (14 in) of one end of the trackplate is covered in soot, 30 cm (12 in) by contact paper, and 10 cm (4 in) on the opposite end remains uncovered for placement of the bait. The enclosure protects the sooted trackplate from rain, and also helps prevent animals from getting the bait from the back of the enclosure without leaving any tracks when the back of the enclosure is abutted against a large tree, boulder, or log. Soot is applied to the plates using an acetylene welding torch without compressed oxygen. Toner used in photocopying machines is a useful alternative to applying soot from a torch (Belant 2003), especially when carrying presooted plates into remote locations is prohibitive. In these situations toner can be reapplied to plates that are already in the field, after they are cleaned.

The bait is frozen chicken drummets. The bait is replaced on each visit (old bait is packed out) and the trackplate is replaced if tracks are detected or the plate is inoperable due to precipitation or high density of nontarget (small mammal) tracks. A large chicken or turkey feather is hung with string approximately 1.5 m above

Figure 6.2. *Trackplate box construction for detecting medium-bodied mammals for the MSIM protocol.*



the track box to act as a visual attractant. At stations where there are no natural attachment points for the feather, a 1.5 m pole is used.

Camera stations consist of a 35 mm Canon Sureshot A1 camera in conjunction with a Trail Master® TM550 dual sensor, passive infrared detector (http://www.trail-master.com/index.php). The film is 35-mm ISO 400 and a flash is used throughout the survey. Settings for the TM550 passive infrared are P = 5 and Pt = 2.5 such that five full windows have to be interrupted for at least 2.5 seconds for the camera to be triggered; the camera delay between photo events is 2 minutes. Digital cameras are becoming a viable alternative, but caution should be exercised because many have poor resolution, greater delay, additional components that may be necessary to purchase, downloading and storage issues, and greater rate of battery drain.

The camera and infrared detector are attached to a tree or other suitable substrate, with the bait no higher than 0.5 m above the ground, and the camera positioned to detect visitation to the base of the bait tree. The camera and sensor are generally arranged vertically on the same tree or on adjacent trees. Cameras and detectors are attached to trees using a mini tripod and various combinations of nylon straps, 22-gauge wire, and duct tape. If trees are not available, other substrates such as boulders, fence posts, or stakes may be used as long as they are sturdy and will not move readily (thus setting off the camera).

Camera stations are baited and set to maximize detections of a variety of species. The primary bait is half of a chicken (approximately 2 lbs and recently frozen) that is secured to the vertical substrate with durable 22-gauge cloth mesh (e.g., sturdy window screen material; open-mesh chicken wire may be used but is not recommended) and duct tape if necessary, approximately 0.5 m from the ground. The camera is positioned such that any visitation to the tree will trigger the camera. A 10 by 15 cm (4 by 6 in) note card displaying the station number is placed above the bait and attached to the tree with pushpins or wire. A large chicken or turkey feather is hung with string above the bait approximately 1.5 m above the ground, to act as a visual attractant.

For both camera and trackplate stations a mixture of Gusto (Minnesota Trapline Products, http://www.minntrapprod.com/), a skunk scent gland derivative, and lanolin (M&M Furs, Inc., http://mandmfurs.com/) is used as a long-distance attractant. The Gusto mixture is prepared by combining a 1 oz jar of Gusto with 32 oz of heated lanolin in liquid form. Approximately 1 to 3 tablespoons (T) of Gusto mixture is placed within 4 m of the station on a substrate such as a tree branch. The Gusto mixture is applied on the setup day and is not reapplied or removed for the duration of the survey. Local conditions will influence the amount and, perhaps, the type of lure used. For example, where humidity or frequent rain render lure less potent it may need to be applied in greater quantities and reapplied over the duration of the sample period. Local commercial trappers are an important source of information about the types of lures that are effective, and their advice about a good multiple-species lure should be considered. A consistent approach should be used across all sites within a region and documented in the regional plan.

Bait can be augmented to attract a greater variety of species; augmentations should be consistent across a region and over time. Augmentations can include 2 T fruit jelly (applied to the chicken), three or four baby carrots, or two or three cotton balls soaked in fish emulsion, apples, and alfalfa pellets to attract omnivores and herbivores. These additional food items can be added to the bait by inserting them into the chicken enclosure and placing additional items on the ground at the base of the structure supporting the chicken bait.

Camera stations are active immediately after station setup, verified by a test shot, and record events 24 hours a day for 10 days. Camera stations are visited on the same days as the trackplate stations. Film is replaced any time 18 exposures or more are recorded on any given visit. Bait is replaced if absent or as the observer deems necessary. Bait will vary in its attractiveness to species among seasons, and in some areas some species may avoid baited stations due to the presence of other species. For example, when natural forage is plentiful, lagomorphs and ungulates may be reluctant to approach bait (Cutler and Swann 1999); in southern Texas, Koerth et al. (1997) indicated that when collared peccaries (*Tayassu tajacu*) frequented camera stations, white-tailed deer (*Odocoileus virginianus*) did not. Thus, the timing of sampling can have an effect on the detectability of species.

Human scent may deter some species from visiting the stations or, alternatively, may attract the attention of species (e.g., black bears) that may damage the equipment. If this problem is anticipated, consider the application of a commercial deodorizer, especially on camera components. One popular product is Carbon Blast (Robinson Outdoors, Inc., http://www.robinsonoutdoors.com/osc/index.php).

Equipment Needed

The camera stations require three cameras and mini tripods, three infrared detectors, 100 feet of 22-gauge bailing wire, three 10 by 15 cm (4 by 6 in) note cards, permanent marker, 8 to 12 pushpins, three cloth mesh chicken enclosures, three frozen half chickens, jelly, carrots, apples, alfalfa pellets, fish emulsion, three cotton balls, turkey feather, nylon string, 3 T Gusto/lanolin, 3 rolls ISO 400 35-mm film, necessary batteries. The trackplate stations require three Coroplast boxes, six binder clips, 50 feet duct tape, three sooted trackplates with contact paper, three frozen chicken drummets, turkey feather, nylon string, 3 T Gusto/lanolin. Observers should also bring straps, nails, and a hammer or heavy duty pliers.

Staffing, Training, and Safety

Field crews should be comprised of four to eight people, each supervised by a field crew leader (GS-7) that has had at least 1 year of experience working on a mesocarnivore survey crew. Crewmembers can be drawn from the ranks of GS-4/5 biological technicians and need not have any previous experience with the methods. Volunteers can also be easily trained to assist in the application of this protocol. Individuals with an attention to detail and outdoor experience are required, due to complexity of camera setup and the physical requirements of carrying equipment over rough terrain. A crew of two individuals can complete surveys at four sites every 14 days, on a schedule of 10 days on duty and 4 days off. This schedule equates to approximately eight sites surveyed per month per two-person crew. Oversight of surveys at the forest or multiple-forest level should be conducted by a journey-level GS-11 or higher employee with at least 2 years of relevant field and supervisory experience.

Before any data collection, an expected species list is generated based on range maps, guides to local fauna, and local occurrence records (when available). In addition to the spatial extent of species ranges, elevation may also be a limiting factor and should be considered in developing species lists. When in doubt, consider the species as potentially occurring in the area and include it in the species list. The distinguishing features of each species should be noted (e.g., number of toes, shape of pad), with particular attention called to species with similar tracks that could be easily confused.

Crews should spend a minimum of 1 week in training that includes (1) orienteering on the ground to establish stations; (2) track and photo identification; (3) use of an acetylene torch, or alternative methods, for the application of soot to trackplate; and (4) the setup and running of several practice trackplate and camera stations in different habitats. A good tracking field guide and a reference collection of track impressions are essential to become trained in track identification. Examples of track impressions from mammals that occur in the Pacific States are available at the U.S. Department of Agriculture, Forest Service Pacific Southwest Research Station Web site http://www.fs.fed.us/psw/topics/wildlife/mammal/tracks.shtml.

Quality Control and Assurance

Protocols for the use of baited trackplates are well established and technical guides are available (Truex 2004, Zielinski and Kucera 1995). Moreover, standardized surveys very similar to those proposed here have been conducted for the previous 7 years (Zielinski et al., in press) and were recently adopted to monitor fishers (*Martes pennanti*) and martens (*M. americana*) in the Sierra Nevada of California (USDA Forest Service 2001, Zielinski and Mori 2001). Fortunately, the detections are independently verifiable and the data are subject to very little interpretation. Trackplate surfaces and photographs are retrievable and can be stored for assessment by one or a few people qualified in track identification. A library of tracks from many known species are available for comparison and a quantitative method for distinguishing the tracks of several closely related species are also available (e.g., Orloff et al. 1993, Zielinski and Truex 1995). Very few sources of technician error are found in this form of wildlife sampling, contrary to other taxa for which identification in the field is required (e.g., songbirds, herpetofauna) or for which observer variation can affect sampling effort (e.g., time-constrained searches). For these reasons, we do not recommend separate quality assurance survey teams or the need to assess the between-crew variation in results. Quality control, however, is critical in the setup and operation of the stations themselves. Improperly set or unstable trackplate boxes may discourage animals from entering and leaving tracks, or allow bait to be taken from the back, causing missed detections. This problem would not be discovered by examining the data and must be prevented by quality control spot-checking during the field season. For example, camera stations that are improperly set may result in wasted film and/or loss of data. Field crews and arrays should be spot-checked by crew leaders to assure proper setup and operation.

Data Storage and Analysis

Data analysis consists of creating species lists for each monitoring point across all five visits, and estimating the proportion of all monitoring points occupied within the entire area of inference, using the probability of presence and detection probabilities as parameters in a maximum likelihood model. (See chapter 2, section 2.6.2.) The freeware program PRESENCE is available for this analysis (http://www.mbr-pwrc.usgs.gov/software.html). The species detection data from each detection station are compiled to create detection histories for each visit (i.e., check of detection stations every other day) to each monitoring point for each species. Detection histories consist of either a “1” for the entire sample unit (regardless of the number of detections) or a “0” if no detections were made. For example for the five station checks, the detection history for a given species could be any combination of five 0s and 1s, such as 00011, 11100, or 11x10, where x represents a visit was accidentally skipped.

Data sheets are checked by fellow crewmembers at the end of each day to make sure that all fields are filled out correctly and legibly. This check also serves to identify discrepancies in species identification among observers and alert observers to unusual species or situations that they may encounter the next day. Field supervisors check all data sheets at the end of each week to review species identification, missed detections (bait missing, no tracks or photo), detection device function, and legibility.

The number of devices with detections can serve as a measure of level of activity, but can not serve as a reliable measure of relative abundance. Habitat characteristics in the vicinity of devices with and without detections of a given species can be used to evaluate conditions that are conducive to visitation and occupancy. Time and date stamps on detections obtained from camera data may be used to evaluate activity levels at various times of day in various types of environments. Sampling adequacy can be evaluated by estimating the probability of detection per unit effort, and estimating the power to detect a trend of a given magnitude and precision given the existing sample effort. Sample effort may then be adjusted if indicated by the analysis.

Trackplate and camera data can be archived and kept for verification of species identification by qualified personnel, and all such records should be checked by a minimum of two individuals. All tracks and images are keyed to species whenever possible and a national library of images could be developed and maintained as a result of MSIM protocol implementation. No special considerations or procedures are identified for the management or analysis of trackplate and camera data. Estimates of probability of detection and the proportion of points with detections should be evaluated, however, to determine if sample duration and number of devices should be increased or decreased to meet trend detection and management quality objectives.

6.1.2 Terrestrial Visual Encounter Surveys

Terrestrial visual encounter surveys (TVES), including recording all forms of vertebrate sign, is an appealing method because of low cost and few logistical burdens (Heyer et al. 1994, Wemmer et al. 1996). Although detection rates are low, the technique is simple, low cost, and useful for a wide variety of species (Heyer et al. 1994, Wemmer et al. 1996), particularly larger bodied species that are less amenable to multiple species methods, such as some ungulates and lagomorphs (Forys and Humphrey 1997, Weckerly and Ricca 2000). As a result, TVES is a core survey method for all classes of vertebrates as a companion to taxon-specific core survey methods.

Visual encounter surveys are designed to target different taxonomic groups in a variety of environments (terrestrial vs. aquatic) and at different times of year. Summer TVES focuses on terrestrial bird, mammals, and reptiles, and is described in detail in chapter 4, section 4.1.2.

Spring and fall surveys focus on terrestrial amphibians and reptiles, and are described in chapter 8, section 8.1.1. Aquatic visual encounter survey methods are described in chapter 9, section 9.2.1.

6.2 Supplemental Survey Methods

Trackplate and camera arrays combined with TVES are effective methods to detect a large proportion of medium to large mammal species. Supplemental survey methods should be directed at detecting species not readily detected by the core methods. The list of species expected to occur in the area should be consulted and species most likely to be detected with a modest level of additional effort should be targeted by supplemental survey methods.

6.2.1 Trackplate and Camera Survey Augmentation

Sampling intensity. The adequacy of the protocol can vary geographically. It is prudent to evaluate the adequacy of sampling after the first year or as soon as an adequate sample is obtained. Specifically, the number of detection devices and the duration of each sample period should be evaluated. They should not be reduced below the prescribed levels in the primary survey method, but they can be expanded to better meet local needs. Specifically, lengthening the sample duration to 12, 14, or 16 days is likely to improve the probability of obtaining detections of species that are present. A less expensive alternative to an extended sample duration is to set up the sampling array with bait 1 to 2 weeks before the official sample period. This allows more time for novelty of the devices at the site to diminish. Any augmentation of the protocol should be done consistently throughout a forest or region, and the station at which individuals were detected should accompany all records to ensure that the data from the basic sampling array can be identified in the data set for regional summaries of status and change.

Polyethylene enclosures. In severe weather conditions or in areas that receive considerable precipitation in the form of snow, researchers should consider using polyethylene enclosures (Zielinski 1995) in lieu of the lighter Coroplast enclosures prescribed in the primary protocol. Trackplate boxes would then be constructed of a two-piece, black, high-density polyethylene cover with the dimensions of 70 cm (28 in) long by 40 cm (16 in) wide by 1/3 cm (1/8 in). The two pieces are connected using duct tape and bent to form a half cylinder. The trackplate bottom trays are constructed of 5052 aluminum 76 cm (30 in) long by 27.5 cm (11 in) wide. The aluminum trackplates are the same as described in the primary protocol. The front entrance of the box remains unobstructed and has an opening that is 27 cm (10.75 in) wide by 28.5 cm (11.4 in) tall. The back of the box is covered by 1.25 cm mesh steel screen that is attached to the bottom tray with binder rings and secured at the top using duct tape.

Open trackplates. Some species reluctant to enter closed trackplates (e.g., coyote, bobcat) may not demonstrate the same hesitation at open plates. Other species (e.g., mountain lion, badger, wolf) are simply too large or too tall to easily enter the enclosed trackplates with opening heights of approximately 27 cm. Thus, open plates can be an effective augmentation to the closed trackplate-camera array for increasing detection probabilities for some carnivore species (Foresman and Pearson 1998). Open trackplates consist of a 1m^2 metal sheet covered with soot with the bait placed in the center (Zielinski and Kucera 1995). Bait can be as simple as a punctured can of tuna cat food, but could be augmented with a turkey feather, as per the primary trackplate-camera method. Open trackplates are less effective in moist environments (e.g., fog, precipitation), and in open, hot environments where plates are subject to direct sun.

6.2.2 Tomahawk Live Trapping

Tomahawk traps are open-mesh wire live traps that are 19.5 cm by 19.5 cm by 50.5 cm long (http://livetrap.com/). Tomahawk traps are effective at detecting a wide range of medium-sized mammals, including procyonids, mustelids, lagomorphs, and small felids and canids. The benefit to using Tomahawk live traps in combination with Sherman live trapping (chapter 5) and trackplate-camera arrays is that for many species no one method is highly effective at detecting individuals, so multiple methods may be required to raise the probability of detection to a useful level. Species of *Sylvilagus* can be difficult to identify using morphology and pelage traits (Nowak 1991); Tomahawk traps enable positive identification of individuals to species in geographic regions where multiple species are sympatric. Thus, it is more likely that identification of species will occur with individuals in hand compared to techniques that rely on sign or when cottontails are observed briefly as they flee to cover.

Sampling Design and Data Collection

Live traps are established and maintained in coordination with the small mammal monitoring methods (chapter 5). A Tomahawk or other medium-sized, wire-mesh live trap is established within 3 m of every third Sherman trap, resulting in a total of 24 traps (three per transect, eight transects). Live traps are baited with an oat/seed mixture that can be augmented with a variety of food items to attract a diversity of species, such as alfalfa pellets (about 1/4 cup per trap), apples (about one slice per trap), and cat food (small can with punctured lid).

As with Sherman traps, all traps are set, opened and baited in the afternoon of the first day, and checked twice daily (early morning to be completed by 10 a.m., late afternoon to be completed before 8 p.m.) starting on the morning of the second day for 3 consecutive days. Traps are checked and removed during the last trap check on the afternoon of the fourth day for a total of 3 nights and 4 days of trapping. Observers check a box on a tracking sheet for each trap checked to ensure that no traps are missed during any given check.

Captured animals are identified to species, sexed, and released. Insofar as it is possible, species identification should be done while the animal is in the trap. If identification requires handling, the removal of large animals usually requires the use of capture cones, which are hand-crafted cones (in a variety of sizes) with a cloth entryway leading to a wire or nylon mesh cone. Sharp edges of wire mesh cones can cut animals. Standard, inexpensive window-screen material (nylon mesh) does not last as long as wire mesh but is gentler on captured animals. Given the low capture rates of medium-bodied mammals, and the difficulty in handling them, this protocol does not require marking animals. An index of the number of individuals of a given species using a site, however, can provide some insights into the sensitivity of the monitoring effort to population declines. If marking is desired, a small patch of fur can be cut off near the tail with relative ease; skunks are marked with a minimum amount of colored hair dye on the back of the head while the animals are in the trap. To release skunks from traps, drape a large plastic garbage bag over the trap to minimize stress to the animal and decrease the chance of spraying, then prop open the trap door with a stick. In the event that a skunk sprays while inside a trap, the trap is cleaned with a mixture of baking soda and hydrogen peroxide (wearing gloves and goggles). Cleaning and disinfecting of traps should follow the methods outline for Sherman traps (chapter 5).

Equipment Needed

Crews should bring 24 Tomahawk traps (single door, collapsible, model 205, 19.5 cm by 19.5 cm by 50.5 cm) plus a few extras as replacements, trap bait, knife (for slicing apples), plastic bags (Ziploc bags preferred), field rulers, scissors, mammal field guides or keys, bleach or colored hair dye (for marking skunks), large garbage bags (for skunk captures), rubber gloves, leather gloves, capture cones (one or two per person), backpacks for carrying traps (one per transect).

Staffing, Training, and Safety

The addition of Tomahawk traps to the Sherman trap array will require one additional person per crew. The capture and handling of live mammals requires a great deal of experience and skill. This should not be undertaken by inexperienced personnel and should always be conducted under the supervision of a person with a trapping permit and who is authorized to set live traps and handle wild animals. It may be necessary to acquire special permits when the capture of rare or protected species is possible. For example, in California a special Memorandum of Understanding (acquired after demonstrating safe handling skill) with the State Department of Fish and Game is necessary before setting traps that could capture either martens or fishers. The same may be true for others species and in other States. Moreover, the possibility of being bitten may make it necessary for all employees to have a pre-exposure rabies vaccine.

Quality Control and Assurance

The same potential sources of error and pitfalls identified for Sherman trapping apply to Tomahawk traps (chapter 5).

6.2.3 DNA Methods

Molecular markers hold promise as the yardstick for reliability because, by definition, a species must have a genetic profile unique from any other species (Mills et al. 2000). Molecular marker techniques are based on noninvasive approaches to collect animal cells (such as scat or hair samples) so that DNA can be extracted and assayed. The assayed DNA can then be used to identify species. Where morphologically similar species (e.g., white-tailed deer and mule deer) with ostensibly similar tracks and feces occur in sympatry, molecular markers offer the greatest potential for distinguishing species detected. In fact, for most taxa, molecular tools exist to identify genetic samples, collected non-invasively or otherwise, to the species and subspecies level (Foran et al. 1997a,b, Litvaitis and Litvaitis 1996, Mills et al. 2000). For many species, it is possible to identify *individuals* from non-invasive samples allowing for the estimation of population size (Eggert et al. 2003). In addition to the possibility of estimating population size from non-invasive genetic methods, this method can be used to identify sex (yielding population sex ratios), estimate gene flow, determine relatedness, detect historical or contemporary genetic ‘bottlenecks,’ and address other population genetic and demographic questions.

Molecular genetic approaches to species identification are practical for detecting and identifying many species and individuals, but the use of a genetic approach requires working closely with a laboratory designed to analyze genetic samples collected from hair or scat. To maximize the success of identification, samples must be collected, handled, and processed using protocols established by these laboratories. Usually this involves little more than using techniques that prevent cross-contamination between samples, and storing the sample (whether it is tissue, feces, hair, guano, regurgitates, or other sources) in a field-friendly medium to prevent DNA degradation.

The great variety of body shapes and behaviors exhibited by medium-sized mammals make it very difficult to conceive of a single device that can effectively snare hair from all of them (unlike the collection of tracks or photograph). Multiple devices, however, could be deployed relatively cheaply to maximize the potential for collecting hair or feces from different taxa. The use of scat-sniffing dogs to find mammal scats for genetic analysis (Smith et al. 2001, Wasser et al. 2001) is a developing field and has promise as a multiple species detection technique. This technique has been used primarily in arid environments, and research to compare detector dogs with traditional detection methods is uncommon. The comparative work by Long (n.d.), suggests that detector dogs can be superior to traditional camera and track plate methods. It is currently difficult, however, to provide the number of trained dogs that would be necessary to implement a detector dog component to a nationwide multiple species inventory program. Similarly, it would be a logistical challenge to arrange for the laboratory support for genetic identification of each of the scats collected in this fashion.

6.2.4 Spotlight Visual Counts

Similar to the limitations with survey methods for sign, spotlight visual counts are reliable for detecting the presence of some but not all species of ungulates and lagomorphs in the United States. The greatest limitation is observing species that are difficult to see because of obstruction from dense vegetation and terrain or when species are solitary, small in size, secretive, and most active at night (Focardi et al. 2001, McCullough et al. 1994). Hence, the probability of detecting and correctly identifying smaller, secretive *Sylvilagus* that inhabit densely vegetated habitats is lower than larger, gregarious ungulates like elk (*Cervus elaphus*) or bison (*Bison bison*) in open habitats (Thompson et al. 1998).

Chapter 7. Bat Monitoring

Bats comprise a large proportion of the mammalian species in terrestrial ecosystems, but they are often not included in monitoring programs because they are challenging to sample. They are nocturnal, they can forage and roost alone or in groups, and their calls are inaudible to humans. As a result of these challenges, we also know significantly less about bats than just about any other vertebrate group. Bat monitoring is not a priority in all regions, so no core survey methods exist for bats, though monitoring these species is highly recommended. The recommended survey methods are referred to as primary survey methods, which are equivalent to core methods in that they are the most efficient single or combined approach to detecting the majority of species.

The objective of the bat surveys described in this chapter is to provide reliable, standardized data on status and change in the distribution and relative frequency of a large number of bat species. Overall, the Multiple Species Inventory and Monitoring (MSIM) protocol is intended to serve as a consistent and efficient method for obtaining spatially and temporally coincident detection/nondetection data and habitat condition data across a diversity of species. The National Framework and basic sampling design of the MSIM protocol is described in chapter 2. Survey methods for animal and plant species are described in the subsequent eight chapters. The National Framework identifies six core survey methods and three additional primary survey methods that together provide information on a representative sample of species in various taxonomic groups and at various trophic levels.

All survey methods associated with the MSIM protocol are designed to be implemented at MSIM monitoring points that are associated with, but offset from, Forest Inventory and Analysis (FIA) grid points on National Forest System lands. The scale of implementation is the national forest, but the primary planning scale is the region to ensure consistency in monitoring approaches for species and habitats shared among forests. The MSIM National Framework calls for a minimum of 50 percent of the FIA grid points to be selected to establish MSIM monitoring points. This core set of monitoring points is to be surveyed over a 3-year sample period with no more than a 5-year resample cycle. Sampling associated with most of the core and primary survey methods is contained within a 200-m radius (approximately 10-ha) sampling hexagon centered on the MSIM monitoring point; however, bat sampling is an exception. Species detections are used to estimate the proportion of monitoring points occupied by the species. For more details on the overall sampling design, see chapter 2.

7.1 Primary Survey Methods

Mist netting combined with acoustic surveys were selected as the primary survey methods because together they provide the most effective method for surveying bats when definitive identification of species present is required. Because bat activity can be highly variable spatially and temporally, augmentation of this primary method to increase species detections is discussed in section 7.2.

7.1.1 Bat Mist Netting

Mist nets are the primary device used to capture flying bats and are easily deployed in a variety of situations (Kunz et al. 1996). Capture success, however, is dependent on the placement of nets in environments that bats use while traveling to and from roosting or foraging sites. Bats forage throughout terrestrial environments, including natural and road-based canopy corridors through forested environments, but captures can be improved in areas where individuals congregate over waterbodies. In general, riparian and aquatic habitats are important activity areas for bats (Hayes 2003).

The majority of North America bats are insectivorous. Some bats forage and roost primarily in forests, others forage in habitats in close proximity to forests such as meadows, while others rarely occur in forests (Hayes 2003). Small-bodied bats are more maneuverable and able to exploit relatively cluttered (forested) environments, while larger bodied bats exploit more open habitats such as gaps in forest stands, forest edges, and the area above the canopy (Fenton 2000a).

Despite these differences in foraging strategies, most insectivorous bats appear to require drinking in addition to the water intake associated with their insect prey (Hayes 2003). Further, studies have shown that insectivorous bats of temperate North America forage at disproportionately higher densities in aquatic and riparian areas than adjacent forested uplands (Grindal et al. 1999, Thomas 1988), that small- and medium-sized insects are significantly more abundant in streamside samples as compared to forest samples (Cross 1988), and that noise created by fast-flowing streams interferes with bats' echolocation (Mackey and Barclay 1989). Thus, quiet water environments are most likely to be visited by the greatest array of bat species and afford the best probability of capture in mist nets.

Sampling Design

Bat sampling occurs at one aquatic site located within a primary sample unit of 4 km^2. Aquatic habitats chosen for conducting bat surveys are referred to as sites associated with the monitoring point. The 4-km^2 sample unit may be configured as a circle or a square centered on the monitoring point, but should be consistent throughout the Region, and should conform to boundaries provided by any national monitoring grid that may be developed.

High-quality survey sites are the target for selection within the sample unit, and are a composite of various features. Slow-moving or standing water (e.g., lakes, ponds, low-gradient stream habitat types such as pools, runs, and riffles) are highly productive aquatic environments for foraging bats, and small bodies of calm water with little to no emergent vegetation or surface obstruction (e.g., duckweed, pond scum) can be particularly high-quality sites for foraging bats and mist net surveys. The water surface and the air space immediately above it need to be clear of obstructions to enable bats to drink water by skimming the surface. Ponds tend to be very productive net sites, as well as pools, runs, and glides associated with low gradient stream reaches (less than 4 percent slope) (Bisson et al. 1981, Rosgen 1996), particularly when small enough to stretch nets across the entire width. Because water can be especially critical for bats in arid regions (Szewczak et al. 1998), they may readily use such minor sources as cattle troughs and road ruts. When netting small water sources such as these it is best to surround them with nets, effectively blocking all access and ensuring bat captures.

The vegetation immediately surrounding potential survey sites is an important consideration. Overhanging riparian vegetation and other natural features that restrict the flyway can act as a funnel, directing bats toward nets. For example, canopy corridors that are the approximate height of the net poles restricts the upper limits of travel space for bats while still providing an open flyway for foraging or drinking. When selecting net stations be aware of natural features that can improve chances of capturing bats.

If no high-quality survey site is present within the sample unit, then lower quality sites are considered, roughly in the following order of priority: less constrained waterbodies (e.g., larger lakes, open wet meadows, large rivers), mid-gradient streams, meadows, and roads. Although wet meadows and lakes can also concentrate a diverse selection of bat species, they lack the overhead vegetation that serves to funnel bats into nets. While it is sometimes possible to capture bats in these habitat elements, the success is often very low.

High-quality survey sites within the sample unit are identified, and the closest high-quality survey site to the monitoring point within the sample unit is selected. If no high-quality site is present within the sample unit, then all lower quality sites are identified, and the closest site is selected. If aquatic sites are selected as the primary survey site for bats, they also serve as the primary survey site for other aquatic vertebrates (chapter 9). Monitoring point locations are a function of the randomly located FIA point within each FIA hexagon (fig 2.1). A nearest-neighbor selection approach can be biased if used to select elements (e.g., aquatic sites, trees) that have clumped spatial distribution, resulting in a higher probability of selecting elements on the edge of clumps relative to those in the center. At the scale of the 4-km^2 sample unit, suitable survey sites are either rarely occurring or common, but it is too small a scale for them to exhibit a clumped distribution. As a result, this nearest-neighbor selection approach (i.e., selecting the nearest high-quality survey site to the randomly located monitoring point) should result in an unbiased selection of suitable survey sites in the hexagon.

Digital orthophoto quadrangle field maps (digital raster graphic electronic topographic maps) in a Geographic Information System (GIS) are an effective tool for identifying the location of potential survey sites in proximity to each monitoring point. In addition to lakes and ponds, blue hatch marks and outlines represent seasonal waterbodies that can be productive survey sites. Stream gradients can be calculated by the ratio of rise over run (i.e., vertical distance represented by topographic lines divided by the map distance); however, low-gradient stream portions are also depicted by widely spaced topographic lines. Stream confluences can be productive if bats are using the corridors as travel routes.

Field reconnaissance of potential survey sites occurs before conducting surveys. In many cases, sites that appear to be suitable based on maps will not be suitable in the field. Therefore, two to three alternate sites are selected in addition to what appears to be the closest suitable site, and all sites are field checked. Once a survey site is selected, its location is entered into a Global Positioning System (GPS) unit and the route from the site to the vehicle is flagged to help exit the station safely at night (e.g., flagging with adhesive reflective tape).

It is a challenge to articulate and apply consistent site selection criteria because site use by bats and the ability to effectively capture bats at a site are affected by many factors that vary spatially and temporally (Hayes 1997). For example, the quality of sites for foraging and sampling often changes over the course of a summer, particularly standing waterbodies, which are likely to shrink or become dry during the summer. Further, the subjective nature of site selection and net placement introduces a potential bias associated with particular observers. To combat this potential bias, we recommend that site selection be conducted by a team of two or more individuals who work together to select all the survey sites across a forest, and ideally across multiple forests.

Data Collection

Timing of mist net surveys for bats will vary by geographic area but generally extends over the summer months, beginning once evening insects are apparent and ending before colder temperatures and concomitant bat migration. In many areas, midsummer surveys have the highest capture rates because of newly volant young. If possible, before conducting surveys, biologists should consult with bat biologists who have conducted surveys in the region to determine the best survey season. Each site is surveyed twice during the sample season. In addition to facilitating estimates of probability of detection, multiple surveys are important because individual bats forage at multiple sites, but may not visit all of them in a given night. Thus, species that frequently use a site may not be present on a night it is surveyed. Surveys should be separated by at least a week, but all surveys should be conducted before the period of migration and dispersal triggered by cold evening temperatures in late summer and early fall. Such temporal spacing allows surveys to document species that may be present at different times during the survey season and to prevent avoidance of nets or the habitat element by bats.

Each site is surveyed for 3.5 hours beginning at sunset. Crews should arrive at least 1.5 hours before sunset to set mist nets. At each site, three nets are set that vary in length from 6 m to 18 m, depending on the configuration of the site. The goal is to maximize the net coverage of habitat elements at the site that can be monitored by available personnel without compromising the safety of bats. Three nets are optimal in terms of maximum area coverage that can be monitored by two people, but physical characteristics of the site should dictate if fewer or up to five nets (recommended maximum) are needed. For example, cattle troughs and small ponds too deep to enter may need only one to two nets to obstruct the flyway, which may be monitored by one person (depending on capture rates). Most often, three nets will be needed to survey an area, such as multiple pools along a stream reach or a large, shallow pond that can accommodate multiple nets at varying angles. Even if sites can accommodate more, three nets are recommended so that survey effort is consistent among sites, unless sites can not be effectively sampled with fewer nets.

Nets are placed over calm water within natural corridors created by overhanging vegetation, maximizing coverage of the flyway with net. The number, size, and location of nets deployed at a station can vary with the subsequent survey. Location of nets during the second survey should account for physical changes to the site (e.g., varying water levels) and capitalize on any behavioral observations made during the first survey to maximize the number of species captured. The goal is to determine which species are using the area. Standardization of number and location of nets is secondary to this goal.

Mist nets made specifically for bats, as opposed to songbirds, need to be used because there is less “bag” in the shelves (e.g., Avinet, http://www.avinet.com/), allowing the net to be deployed just above the water surface without the risk of soaking a bat captured in the lowest shelf. Net poles are secured with guy lines to keep nets from sagging due to temperature fluctuations or dew; nets set too loose increase entanglement. All nets are erected at least 10 minutes before sunset but not opened until sunset to avoid capturing birds. Just before opening nets, a thermometer is hung from a tree in the shade to give adequate time to reflect local conditions by the time it is read at sunset. Because acoustic surveys are conducted simultaneously, one crewmember will open nets at sunset while the other begins the acoustic survey (section 7.1.2).

Nets are inspected nearly continuously for the first 1.5 hours for captured bats, as this is typically when bat activity is at its peak. After this time, net checks are dependent on activity, but occur at least every 10 minutes. Frequent net inspection prevents bats from escaping or becoming increasingly entangled and minimizes damage to nets caused by chewing bats. All bats are securely placed in small, breathable, cotton bags (e.g., GSA mailing bags, https://www.gsaadvantage.gov/), one individual per bag. Bats should be kept in a temperate, quiet environment until processing (inspecting and measuring bats) to reduce stress; this is particularly important for pregnant females, which are typically encountered during the first half of the survey season. In warm temperatures, bat bags can be securely hung from trees while waiting to be processed. In cold temperatures, additional measures may be necessary to ensure that bats are kept warm and are ready to fly immediately after processing, such as inserting bagged bats inside the jacket of a crewmember until processing. Pilot study work revealed no correlation between the number of bats captured and temperatures ranging from 0 to 26 ºC (Manley et al. 2002), and species such as red bats (LaVal and LaVal 1979) and long-eared *Myotis* (Manning and Jones 1989) have been reported to forage at relatively low temperatures (between 6 and 12 ºC). In addition, no significant correlations between minimum temperatures (10.5 to 20.8 ºC) and time spent roosting or flying were reported during radio-tracking studies of Indiana bats (Murray and Kurta 2004). Therefore, netting may be conducted at temperatures down to around freezing, but does not occur on nights with precipitation. Netting in below freezing temperatures should be avoided because of the potential for bat mortalities associated with hypothermia.

If possible, bats are processed in batches after every net check, focusing first on lactating and pregnant females. External inspection and morphological measurements are used to identify all captured individuals to species and include species (four-letter code: first two letters of genus and species), sex, reproductive status, age, and forearm length. Reproductive status is recorded according to Racey (1988): males = descended testes, not descended, juvenile or unknown; females = pregnant, lactating, post-lactating, nonreproductive, juvenile or unknown. Age is determined by checking the knuckle of the third and fourth (two outer) finger bones for full (adult) or partial (juvenile) ossification (Adams 1992, Anthony 1988). In addition, the potential stage of reproduction for females is noted, including a physical description of the condition of nipples and vulva, as well as indications that the animal has likely never bred (i.e., mammaries extremely small and difficult to locate). For all *Myotis* species, whose genus often includes very similar and easily confused species, the ear is measured and the calcar is checked for a keel. Regional bat biologists should be consulted for a key to local bats as thumb and foot lengths may also be needed to discriminate between two closely related *Myotis* species. Observations that may be used to confirm species identification are included as comments.

Other pertinent information recorded on data sheets for each survey include time, net, and temperature bats were captured, net open and close time and temperature, the number and size of nets used, and netting habitat type.

Equipment Needed

Crews should bring the following general equipment: headlamps, spare bulb and batteries, GPS unit, thermometer (Celsius, with lanyard for hanging), flagging and reflective tape (for hiking out at night), and waders and felt-soled boots (for traction on slippery surfaces). For netting, they should bring 3-m poles (three-sectioned poles make packing easier), cordage and tent stakes, bat mist nets (available from Avinet; 4 shelves, 38-mm mesh, 2.6 m high, 6 to 18 m long), cotton bat-holding bags (available from GSA; mailing bags, 8 by 10 inches, 50 quantity), and a thin leather glove such as batting or golf glove for handling bats. The following items are also recommended: a three-ring binder containing data forms, four-letter code sheet for all potential bat species, dichotomous key for bat identification, protocol, sunset/sunrise chart for area (available at http://aa.usno.navy.mil/data/docs/RS_OneYear.html), pencil case to hold small metric rulers, and small scissors (in the unlikely event a badly entangled bat needs cut out), all marked with reflective tape.

Staffing, Training, and Safety

This survey method can be efficiently employed by a two-person crew (GS-7 biologist, GS-4/5 biological technician) per site when a maximum of three nets are set and nightly bat captures average 30 or less; in areas with higher expected averages additional personnel are recommended to ensure bats are extracted and processed in a timely manner. Assuming a two-person crew is sufficient to survey each site within an 8-week sample period, a crew of four individuals can complete both surveys to all sites on an average-sized forest (33 sites per year surveyed twice). A minimum of 1 year of field training is required for biologists conducting surveys to become proficient in extracting animals from nets and to develop proper handling techniques. It is beneficial if technicians have experience extracting animals (birds or bats) from mist nets. Bat working groups exist across the country, and are valuable sources of collaboration and expertise needed to build tools and proficiency for consistently correctly identifying bats.

Similarity in physical and call features of many co-occurring bat species makes it important to develop a list of potential bat species for each sample unit (i.e., 4 km^2 sample unit) before surveys are conducted. Expected species lists can be generated using range maps, guides to local fauna, and local occurrence records (when available) for the surrounding area (roughly a 2360 ha square area around the point, approximating the size of the FIA hexagon). In addition to the spatial extent of species ranges, elevation may also be a limiting factor and should be considered in developing species lists. When in doubt, consider the species as potentially occurring in the area and include it in the species list. The species list is used for training, as well as augmentation of the primary survey methods (section 7.2.1).

Before conducting mist net surveys for bats, personnel must receive more specialized field training from a regional bat biologist that can instruct in recommended placement and tension of nets to maximize capture success, proper morphologic measurement techniques, local timing and determination of female reproductive stages, and identification of local bat species.

Training to handle and identify bat species includes methods for extracting bats from nets, holding bats, and taking morphologic measurements. Dichotomous keys to the identification of captured bats are generally available from regional bat biologists and should be used consistently at the outset of work. Species within most genera have gross morphological characteristics that make them readily identifiable. Species within the *Myotis* genus, however, can be more difficult to discriminate, and a series of morphological measurements are taken that reduce the chances of misidentification and enable a supervisor to confirm measurements are within expected ranges for specific species. Certain *Myotis* species can be nearly impossible to differentiate morphologically but may be differentiated based on recordings of echolocation calls on release. Region-specific protocols to address specific challenges in species identification need to be developed and included in field manuals for data collection.

Night work in aquatic environments can be challenging, requiring personnel be comfortable working at night while negotiating varied terrain such as rocky stream beds and sticky mud pond substrates. For these reasons, crewmembers should always work in pairs and be trained in first aid/CPR. All personnel potentially handling bats should receive rabies pre-exposure vaccinations as a precautionary measure. Although rare, some States (e.g., California) require a Memorandum of Understanding from State wildlife officials before conducting any work that requires handling bats.

Quality Control and Assurance

Mist nets are a well-established method for the capture of free-flying bats, and detailed guidance on their use is available in published literature (e.g., Kunz et al. 1996); however, lack of proper training in the use of nets can potentially lower capture rates. Weather conditions that should preclude mist net surveys include high winds and precipitation; crews need to be certain they understand when survey conditions are adequate and when surveys should be canceled or suspended. All potential sources of bias should be discussed during training sessions and the field supervisor should accompany crews on surveys periodically throughout the season to check and recalibrate, if necessary, measurement techniques and net placement.

Data Storage and Analysis

Data analysis consists of creating species lists for each site across both surveys, and estimating the proportion of all monitoring points occupied within the entire area of inference, using the probability of presence and detection probabilities as parameters in a maximum likelihood model. (See chapter 2, section 2.6.2.) The freeware program PRESENCE is available for this analysis (http://www.mbr-pwrc.usgs.gov/software.html). The species detection data from each survey are compiled to create detection histories for each monitoring point for each species. Detection histories consist of either a "1" for the entire sample unit (regardless of the number of detections) or a "0" if no detections were made. For example for two surveys, the detection history for a given species will be 00, 01, 10, 11, 1x, or x1, 0x, or x0, where x represents that either the first or second survey was not conducted.

Other data of value associated with the capture of each species (stratified by presence, by gender, by age class) include date, time, temperature, habitat type, and elevation. We do not recommend making inferences based on the number of individuals captured because these data are highly dependent on timing of sampling and configuration of nets. Sampling adequacy can be evaluated by estimating the probability of detection per species per unit effort (e.g., site, visit, net-hour [no. survey hours * no. nets]), and estimating the power to detect a trend of a given magnitude and precision given the existing sample effort and given additional sites or surveys per site. Sample effort may then be adjusted if indicated by the analysis.

Data sheets are checked by fellow crewmembers by the end of each week to make sure that all fields are filled out correctly and legibly. In addition, all associated field crews should begin each week with a brief meeting to review and discuss field observations and challenges, such as species identification, escape rates, mortalities, sampling problems, access problems, and safety.

7.1.2 Acoustic Surveys

Acoustic surveys are conducted by using an ultrasound or echolocation detector, known more commonly as a bat detector. Acoustic surveys are conducted to augment the species captured using mist net surveys because not all species present at a survey site on a given night are captured. Combining capture and acoustic techniques has proven the best strategy for maximizing the number of species present that are detected in a variety of situations because species are variously detectable by each method (Duffy et al. 2000, Kuenzi and Morrison 1998, Murray et al. 1999, O'Farrell and Gannon 1999). For example, some bat species tend to fly or forage 30 m or more above the ground (Barclay 1986, Humphrey et al. 1977, LaVal et al. 1977), providing little chance for capture using ground-based mist nets. Bat detectors, however, are effective at detecting free-flying bats from more than 50 m. For species with unique calls, detectors are an effective means of obtaining species detections, and serve as a valuable complement to mist netting to obtain a more comprehensive species list for a site (O'Farrell and Gannon 1999). Species identification is still subjective and many species are difficult to distinguish, so as a primary method acoustic surveys are considered an addition to mist net surveys and only identifications that are certain should be included in species lists for each survey night.

The most popular types of detectors for this type of work are zero-crossing systems (e.g., AnaBat, http://www.titley.com.au/tanabat.htm) and time-expansion systems (e.g., Pettersson, http://www.batsound.com/). Each system has its unique advantages (Corben and Fellers 2001, Fenton 2000b, Fenton et al. 2001). A system that maximizes the chances of identifying individual species rather than those that track bat activity levels should be selected. AnaBat is a relatively inexpensive option, but it offers fewer tools for definitive identification compared to Pettersson detectors. Regardless of the system chosen, there is no widely accepted key to the identification of bat species from their echolocations nor are there any commercially available automated procedures to identify species by their echolocation calls. Some species have very unique calls, such as red bats (*Lasiurus borealis)*, that are easily distinguished with most bat detectors. Options for investing in call identification tools range from consulting with regional experts and reviewing the latest literature, to recording and analyzing echolocation calls for the purpose of developing a reference call library from species in the region (Jones et al. 2004). The higher levels of investment in acoustic sampling and call identification are considered an augmentation to the primary protocol (section 7.2.1).

Data Collection

Acoustic surveys are conducted over the same time period as mist net surveys (3.5 hours starting at sunset). Logistics, however, may limit the ability to constantly monitor the detector. Removing bats from the net is priority for the safety of the bats, and both crewmembers may be needed to process bats if a large number of bats are captured. In these instances, a minimum of 120 minutes (2 hours) of acoustic monitoring is conducted, starting at sunset and completed before nets are closed. It is most important that acoustic monitoring takes place during the first hour after sunset, when bat activity is often at its peak.

The goal of acoustic surveys is to detect as many different species as possible at the site, particularly those that are not well sampled using mist nets. The crewmember should move around the site, if possible to do so safely, to survey as many areas and microhabitats as possible, but should stay confined to an area within 100 m of the nearest net location. Crewmembers should consider switching roles halfway through the 3.5-hour survey time to avoid fatigue.

Echolocations are recorded to the internal memory of the bat detector which must then be transferred to another medium for storage. It is best to use headphones for recording calls to eliminate excess external noise. Calls can be stored on cassette tapes or a laptop computer. The advantages of storing directly to computer are improved call quality and elimination of the time necessary to transfer calls from tape to computer, where they are analyzed for species identification, at a later date. One disadvantage of using computers is that batteries on many laptops do not last 3.5 hours so supplemental power must be provided. Computers also are not nearly as portable as cassette recorders. Calls should be recorded to a laptop when logistically feasible. When the vehicle can be driven to the site, using an inverter to run the computer off the car battery is the preferred option. Even on such nights, however, it may be necessary to record some calls to tape recorder, particularly if the call is recorded far from the computer. Returning to the vehicle to store the call would be time more effectively spent recording additional calls.

Equipment Needed

Crews should bring the following general equipment: bat detector, recording device (laptop computer or tape/digital voice activated recorder), bat detector-recording device connector cables, batteries. AnaBat systems require a bat detector, ZCAIM detector-computer interface, Pentium laptop computer, voice activated tape recorder, and a connector cable between detector and recording device. Pettersson systems require a bat detector (minimum model D240), headphones, Pentium laptop computer with at least 128 MB of RAM, SonoBat™ bat call analysis software, connector cable (stereo-to-mono plug) between detector and recording device. Field equipment is relatively expensive. The AnaBat option includes the detector for $600, ZCAIM interface for $600, "low-end" laptop computer for $600, and the voice activated tape recorder for $100. The Pettersson option includes the detector for $1,200, SonoBat software for $300, and "high-end" laptop for $1,500.

Staffing, Training, and Safety

The ability to identify bat species from their echolocation calls requires training, practice, and substantial time investment. Introductory training in the use of bat detectors and the identification of bat calls using software such as Analook (calls collected using AnaBat detectors, http://users.lmi.net/corben/anabat.htm) and SonoBat (calls collected using time-expansion detectors such as Pettersson detectors, http://www.sonobat.com/) are available annually at several locations in the United States. (See Bat Conservation International workshops, http://www.batcon.org/.) Another source of training is from regional bat biologists, who may be able to provide training in identification of echolocation calls from the species present in a particular ecoregion. Unlike most of the other field methods, postfield processing time is required to identify recorded calls. Staffing for call analysis is estimated at 2 hours of office time per survey.

Quality Control and Assurance

Data quality is best maintained by thorough training of crew members before the initiation of acoustic surveys. Training should address the use of detection equipment used to record bat calls and the use of software to store and analyze the call. Detectors may appear operational in the field but call quality is compromised if connections are improperly made. It is critical in the setup and operation of the acoustic survey equipment that detector settings and volume are checked before each survey, and that connector ends are in the proper unit. To avoid this common mistake, visibly mark plug ends that go to the detector and recording device. Sources of noise that affect recording quality and are difficult to control include background noise from wind and fast-moving creeks. Other sources of noise that can and should be controlled include observer-generated noise, inclement weather (e.g., high winds), and distance to roads or dwellings.

Call analysis software requires extensive use to become proficient to distinguish difficult to identify calls; however, if call identification is limited to readily identified calls as per the primary protocol, then training time should be reduced to a few days. Any calls that are difficult to discern should be saved as “species unknown.” In general, most bats echolocate starting around 15 to 20 kilohertz (kHz) and above, with species tending to echolocate within generally recognized ranges. Therefore, it may be helpful to separate unknown calls into folders of various kHz ranges (e.g., 20 to 30, 30 to 40) in the event that call identification techniques advance in the near future. Two or more individuals should extract parameters from a set of known calls to quantify variation in the measurement of various call parameters. Because of the potential for geographic variation in the echolocation calls of bat species, caution should be applied to even simple identifications.

Data Storage and Analysis

In the context of the primary survey method, the call identification task is simplified because only those calls of species that have not been captured in mist nets during that survey need to be identified. For instance, big brown bats and silver-haired bats emit similar calls. If both of these species are captured during a survey, then there is no need to identify calls from that survey that appear to belong to these species.

The identification of a bat call to species (or species group based on kHz) requires visual inspection of each call individually using bat call analysis software. Assignment of a call to a species or species group must be done subsequent to collection of calls in the field (i.e., on a subsequent day, in the office). Investigators should use a dichotomous key that highlights the key features used to assign a call to species (or species group). The region should create a key in consultation with the literature and regional bat biologists and use it to assign calls to species. It is essential that investigators document and quantify the features of the call used to assign it to species (e.g., minimum and maximum frequency, slope, duration) rather than rely on qualitative identifications that are not repeatable by others.

As with mist netting data, analysis consists of creating species lists for each site across both surveys, and estimating the proportion of all monitoring points occupied within the entire area of inference, using the probability of presence and detection probabilities as parameters in a maximum likelihood model. (See chapter 2, section 2.6.2.) The freeware program PRESENCE is available for this analysis (http://www.mbr-pwrc.usgs.gov/software.html). The species detection data from each site are compiled to create detection histories for each survey to each monitoring point for each species. Detection histories consist of either a "1" for the entire sample unit (regardless of the number of detections) or a "0" if no detections were made. For example for two visits, the detection history for a given species will be 00, 01, 10, 11, 1x, or x1, 0x, or x0, where x represents that either the first or second survey was not conducted.

It is important that sample effort per survey is consistent, including netting time (3.5 hours) and recording time. It is likely that acoustic survey time will be the most variable among sites and surveys, so the start and stop time of the survey and the time of each call detected need to be included in acoustic data sets to make it possible to subset surveys to derive a standard survey duration.

Data yields from mist netting alone can be compared to the combination of mist net and acoustic relative to estimating the probability of detection per unit effort, latency of first detection, and estimating the power to detect a trend of a given magnitude and precision given the existing sample effort. Advantages of identifying the full suite of calls recorded are discussed in section 7.2.1 below.

7.2. Supplemental Survey Methods

7.2.1 Bat Mist Netting and Acoustic Survey Augmentation

Additional survey sites. Sampling additional sites per monitoring point is likely to increase the number of bat species detected per monitoring point, which improves estimates of species richness, composition, and estimates of proportion of points occupied. Pilot study work indicated that increasing the number of survey sites associated with a monitoring point, as opposed to increasing the number of surveys at a site, provided the greatest probability that new species would be detected (Manley et al. 2002). The objective of additional effort beyond the primary survey site is to improve the probability of detecting a greater proportion of species occurring in an area. Therefore, a list of species likely to occur in association with each monitoring point should be developed. Given the limited knowledge of the environmental associations of bats in many areas, the expected composition of bats will most likely be based on range maps.

Bats have large home ranges, varying from approximately 10 to 100 km^2, depending on the species, colony size, and time period. It is safe to assume that the same individuals will be present at multiple sites throughout a larger sample unit. Larger sample areas are likely to have a greater array of sample sites that will be fruitful for detecting the array of species in the area. Thus, the supplemental survey targets one or two additional sample sites within a larger, 25-km^2 area (i.e., the area of a FIA hexagon). Site selection must be accomplished in a manner by which the probability of selection is known. To this end, the sample unit is decomposed into 100 by 100 m cells and each cell is classified into a few predetermined ecotypes that reflect primary terrestrial and aquatic ecosystems and that are used consistently throughout the region. Ecotypes should be defined in a manner that makes them easily classified using existing GIS data layers. For example, cells may be classified into one of six categories: (1) constrained slow water (i.e., ponds less than 0.1 ha, less than 4 percent gradient), (2) unconstrained slow water (larger area), (3) fast water (greater than or equal to 4 percent gradient), (4) meadow, (5) roads or other openings in conifer forest, (6) roads or other openings in deciduous forest, and (7) other. The classification of areas within the supplemental sample unit becomes part of the data set, serving as a description of the relative availability of each type within the supplemental sample unit.

It is recommended that a variety of ecotypes be sampled, not just sites with constrained slow-moving water. Habitat associations, if known, may be used to help select a diversity of ecotypes that are most likely to yield the greatest variety of bat species. If two or more sites must be established at the same habitat element, such as a stream, the sites should be separated by at least 500 m to increase chances of sampling different individuals and species. As with the primary survey site, the ability to sample a site must be confirmed in the field. Once site selection is completed, each site is sampled in the same manner as the primary sample site: two visits consisting of mist netting and acoustic surveys.

Statewide surveys. Statewide bat survey efforts are being initiated in some States (e.g., Oregon and Washington), and forests may want to participate in these efforts. Additional sample effort beyond the additional surveys at one to two sites within the supplemental sample unit may be directed at statewide or other regional efforts, if they exist. If they do not exist, additional sites may be selected within the supplemental sample unit, and single visits may be conducted at these additional sites. Surveying a diversity of vegetation types and aquatic conditions is likely to further increase the diversity of species detected. Bridges, buildings, meadows, cliffs, rock outcrops, or open woodlands are candidates if species associations indicate that these habitats could be fruitful survey sites for target species.

It is recommended that a combination of mist net and acoustic surveys be conducted at any additional sites that are sampled, but not all sites are readily sampled with both methods. Mist net survey sites are limited to sites that are conducive to capturing bats, but such limitations do not apply to acoustic surveys. Virtually any aquatic environment such as wet meadows, small- to medium-sized lakes, and moderate gradient streams may be productively sampled with acoustic surveys. If only acoustic surveys are conducted, all detections must be identified to the extent possible. (See section below on additional analysis of acoustic recordings.) The selection of survey sites and survey methods should be determined through consultation with bat experts and applied consistently across the region.

Additional analysis of acoustic recordings. A complete identification of acoustic detections, beyond those species not captured in mist nets, will require more time and expertise than considered appropriate for the primary survey method. If all calls recorded during acoustic surveys are keyed out, including species detected with mist nets, then two additional analyses are possible. First, acoustic data can serve as a stand-alone set of detections that can be used to improve the probability of detection and precision of estimates of proportion of points occupied when combined with mist net data. Second, it can be used in combination with other acoustic survey data (perhaps at sites that are not readily surveyed with mist netting or other survey efforts) to evaluate species distributions and habitat associations.

Additional training is required to use software to extract parameters from calls that are used to identify species. Two or more individuals should extract parameters from a set of known calls to quantify variation in the measurement of various call parameters. Species identification should only be accomplished via repeatable methods. Ideally, two different observers should identify all calls, and then compare results. Dichotomous keys or quantitative methods such as discriminant function analysis (Murray et al. 1999, Vaughan et al. 1997) or artificial neural networks (Parsons 2001, Parsons and Jones 2000) developed from the calls of local species assemblage should be used to identify species. Such methods have only recently been developed and are not widely available. Because of the potential for geographic variation in the echolocation calls of bat species and changes in the species that make up regional assemblages, identification tools will need to be developed locally to identify species.

The most widely used method for obtaining reference calls is to record bats immediately after being released from the hand; another alternative is the use of a tethered zipline. (Szewczak 2000). While both methods have their limitations (Szewczak 2004), they are readily employed when conducted in conjunction with mist net surveys. Bat call recordings are collected in relatively quiet areas of the survey site where it is safe to move about at night (i.e., no dangerous obstacles).

7.2.2 Roost Site Monitoring

Roost sites are habitat elements (e.g., caves, mines, bridges) where one or more individuals of one or more bat species roost during the day and night. These sites can provide valuable information on the number and status of these special habitat features that can readily limit bat populations. Thus, the objective of roost site monitoring is to track the status and change of roost sites themselves, as well as the populations using them. They can provide an index of abundance at broad scales for some species, such as Townsend's big-eared bat (*Corynorhinus townsendii*), which is not easily detected or identified with mist nets or acoustic surveys but roosts in large numbers in caves, mines, and sometimes bridges. Roost site monitoring as part of the MSIM protocol is relevant to forests interested in supplementing bat survey data across the forest. Roost sites are similar to nest sites in that the population of known sites is likely to be a subset of all sites, and it is not necessarily meaningful to monitor a subset of an undefined population. For roost sites to be used to make inferences about populations throughout some area, there needs to be an unbiased process by which new roost sites are discovered and incorporated into the sample of sites that are monitored. Such a process would require the use of radio-telemetry to discover roost sites. Known roost sites may then be monitored over time to evaluate the status and change of roost sites throughout an area. Regional protocols for monitoring bat populations, if they exist (e.g., Zielinski et al., n.d.), should be consulted to further augment MSIM sampling for bats at forest, multiple-forest or regional scales.

Chapter 8. Terrestrial Amphibian and Reptile Monitoring

Terrestrial environments host a range of amphibian and reptile species for some or all of their life stages. The phenomenal diversity of species and life history strategies in these two vertebrate classes makes it critical that they be surveyed. It is impossible, however, to represent such diverse species easily with a few multiple species survey protocols. Many species are highly specialized, and it is expected that an effective forest and regional monitoring program will need to combine core and supplemental survey methods with species-specific survey efforts to obtain detections to make inferences about species diversity and species of concern. This chapter offers a modest national program of monitoring on which the building of regional and local programs is encouraged. Concomitantly, regional amphibian and reptile monitoring programs provide an important support mechanism to meet national monitoring objectives by providing a local source of information, expertise, and tool development.

The objective of the terrestrial amphibian and reptile surveys described in this chapter is to provide reliable, standardized data on status and change in the distribution and relative frequency of a large number of herpetofauna. Overall, the Multiple Species Inventory and Monitoring (MSIM) protocol is intended to serve as a consistent and efficient method for obtaining spatially and temporally coincident detection/nondetection data and habitat condition data across a diversity of species. The National Framework and basic sampling design of the MSIM protocol is described in chapter 2. Survey methods for animal and plant species are described in the subsequent eight chapters. The National Framework identifies six core survey methods and three additional primary survey methods that together provide information on a representative sample of species in various taxonomic groups and at various trophic levels.

All survey methods associated with the MSIM protocol are designed to be implemented at MSIM monitoring points that are associated with, but offset from, Forest Inventory and Analysis (FIA) grid points on National Forest System lands. The scale of implementation is the national Forest, but the primary planning scale is the region to ensure consistency in monitoring approaches for species and habitats shared among forests. The MSIM National Framework calls for a minimum of 50 percent of the FIA grid points to be selected to establish MSIM monitoring points. This core set of monitoring points is to be surveyed over a 3-year sample period with no more than a 5-year resample cycle. Sampling associated with most of the core and primary survey methods is contained within a 200-m radius (approximately 10-ha) sampling hexagon centered on the MSIM monitoring point. Species detections are used to estimate the proportion of monitoring points occupied by the species. For more details on the overall sampling design, see chapter 2.

8.1 Core Survey Methods

8.1.1 Amphibian and Reptile Visual Encounter Surveys

The amphibian and reptile visual encounter survey (ARVES) is a standard method for terrestrial herpetofauna inventories (Campbell and Christman 1982, Corn and Bury 1990, Crump and Scott 1994, Heyer et al. 1994). Several survey techniques exist to inventory and monitor multiple amphibian and reptile species (e.g., pitfall traps, funnel traps, coverboards, visual encounter searches, transects), each with its own inherent biases with regard to the species detected, applicability across habitat types, and assumptions (Heyer et al. 1994). Certainly the use of multiple survey techniques will effect a more complete characterization of any fauna, including herpetofaunal communities (Clawson et al. 1997, Corn and Bury 1990, Greenberg et al. 1994, Morrison et al. 1995). Given the option of selecting just one survey method, however, ARVES has the broadest utility with regard to effectiveness across all habitat conditions and ease of implementation (Crosswhite et al. 1999, Welsh 1987). It also has some important additional benefits: (1) it is low impact on site conditions compared to other standard methods requiring digging or debris clearing (e.g., pitfalls and coverboards); (2) it poses virtually no threat to the well-being of individual animals; and (3) it is effective in a diversity of environments, including both terrestrial and aquatic ecosystems. Therefore, ARVES is a favorable core method for surveying amphibians and reptiles. ARVES can have a low probability of detection for many species, depending on the ecosystem and search effort. The search effort prescribed here reflects a moderate intensity search effort per unit area, which may be augmented with additional search effort or with secondary methods as deemed necessary and appropriate for the region to increase the number and breadth of species detected. The exact timing of surveys will also need to be determined at the regional scale and specified in the regional plan.

Sampling Design

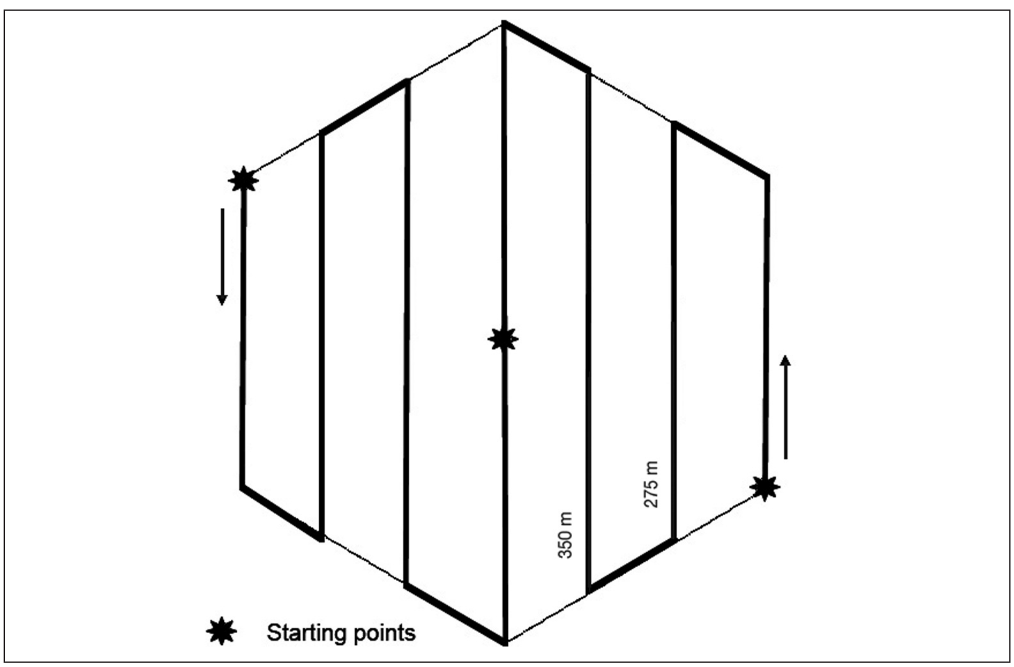
The 10-ha sampling hexagon, centered on the monitoring point (chapter 2, fig. 2.2), serves as the primary sampling unit for the ARVES. The size of the sample unit was selected to suit the detection of a broad array of vertebrate taxa (small and large bodied) and collocate amphibian and reptile surveys with surveys for other taxa. The sample unit is a relatively large survey area when compared to studies using similar types of visual encounter surveys for identifying herpetofaunal assemblages (Clawson et al. 1997, Doan 2003, Pearman 1997, Smith and Petranka 2000). Such a large area, however, is likely to encompass a variety of microhabitats and possibly multiple habitat types, increasing the probability of detecting a more representative assemblage of species associated with each monitoring point.

Two observers systematically survey for individuals and sign by traversing the sampling hexagon (Crump and Scott 1994), with one observer searching each half of the hexagon. Observers follow a transect that loops through the hexagon at a 50 m spacing (fig. 8.1). The length of each route on each half of the sample unit is approximately 1,200 m for a total of 2,400 m. These transects are also used for terrestrial visual encounter surveys conducted during the summer season (chapter 4). One of the six points of the hexagon is randomly selected as the start point for the first visit, and then the second visit randomly selects from all but the point opposite the point selected for the first visit so that the second visit is along a different route than the first visit. Observers use the flag lines and distance markers along the center line and perimeter of the hexagon and compass bearings (checked periodically) to walk the transect lines.

Data Collection

Two observers simultaneously search throughout the 10-ha sampling hexagon (fig. 8.1) for 4 hours, or a total of 8 person-hours. Investing 8 person-hours per survey reflects a balance between reasonable coverage of the sample unit and the ability of observers to maintain their concentration. Sampling is conducted generally between 10 a.m. and 6 p.m., targeting times of day when ectotherms are expected to be active and visible. In hot parts of the country, however, many species are most active and/or visible early in the morning, at dusk, or at night. Nocturnal sampling is more dangerous and less feasible than daytime sampling, but it is described as a secondary

Figure 8.1. *ARVES transects associated with each monitoring point for the MSIM protocol.*



ARVES = amphibian and reptile visual encounter survey.

survey method because of its high effectiveness for detecting some species (section 8.2.1). The most appropriate times for surveys will depend on the geographic area, and should be determined for the region, specified in the regional plan, and implemented consistently throughout the region.

The sampling unit is visited a minimum of twice per non-winter season (spring and fall) for a total of four surveys per year to maximize the number of species detected and facilitate the calculation of probability of detection within the season and among different seasons. If funding allows, additional visits would increase the number of species detected, the probability of detection for individual species, and the precision of estimates of proportion of points occupied (section 8.2.1).

Observers search within 1 m on either side of the transect, but can leave the transect to investigate high-quality habitats (e.g., logs, seeps, riparian areas, talus, areas of high density of natural cover objects) within 10 m on either side of the transect line. Aquatic habitats, such as lakes, ponds, streams, and bogs located within the sample unit are not sampled as part of this protocol—they are sampled as part of the aquatic visual encounter survey (chapter 9).

Observers search surfaces and vegetation, turn over objects such as logs and rocks, and look in crevices in rocks, stumps, and bark, replacing all surface objects after examining the ground beneath (Crump and Scott 1994). Logs and other substrates are not torn apart to minimize disturbance to important habitat elements in the sample unit. Observers pace themselves, focusing on the most fruitful habitat components (e.g., under logs, rocks, bark) while leaving enough time to move along the transect. Observers need to move along the transect at an average pace of approximately 50 m every 10 minutes. Observers note only presence of individuals or sign, and identify the detection to the most specific taxonomic level possible. Animals are captured only when necessary to confirm identification; however, in areas with high species richness and difficult to distinguish species (e.g., some co-occurring *Plethodontid* salamanders), it is recommended that observers capture individuals to confirm identification. Voucher specimens may be needed to confirm identification of rare species that are difficult to identify. Time used for species identification and data recording is not included in the total search time.

The following information is recorded for every detection: observer, time, search time elapsed, species, detection type (e.g., visual, auditory, capture, sign), age class of captures (juvenile, subadult, adult), snout-vent length, substrate type (e.g., rock, log, bare ground), and location along the transect. Use rubber gloves when handling amphibians to reduce the risk of transmitting harmful chemicals (e.g., sunscreen, DEET) or disease (e.g., fungus) to the animal. If plastic bags are used to temporarily contain the animal, the bag must not be reused for another amphibian. The detection of rare species should be documented by taking a picture of the individual, being careful to display the diagnostic characteristics of the species. All mortalities are collected, properly stored, reported to the field crew leader, and provided to a local university museum.

Equipment Needed

Crews should bring a hand lens, clipboard, hand spade or rake, field keys, stop watch or watch with timer, pocket ruler, plastic baggies (for handling specimens; Ziploc brand preferred), digital camera, binoculars (optional).

Staffing, Training, and Safety

Field crews should consist of two biological technicians, with one GS-7 for every six to eight crewmembers. The GS-7 should also serve as a field crew leader to supervise and coordinate data collection. Crewmembers should be GS-4/5 or higher with academic training in the natural history of herpetofauna and, ideally, herpetology training or experience. Oversight of the surveys at the forest or multiforest level should be conducted by a journey-level biologist with at least 2 years of relevant field and supervisory experience. Each field crew of two can survey an average of two monitoring points per 10-hour day, or eight points per week, depending on travel distances between monitoring points. Based on the average of 200 FIA points per forest, and therefore approximately 33 monitoring points sampled per year for 3 years (n = 100 monitoring points), a crew of four could complete the two visits to all monitoring points on a forest within a 1-month period in the spring and the fall. Given the short season for these crews, it is advisable to hire individuals that have the skills or can be trained to conduct summer survey methods (e.g., small mammal trapping, trackplate and camera surveys).

Before any data collection, an expected species lists will be generated based on range maps, guides to local fauna, and local occurrence records (when available). In addition to the spatial extent of species ranges, elevation may also be a limiting factor and should be considered in developing species lists. When in doubt, consider the species as potentially occurring in the area and include it in the species list. The distinguishing features of each species should be noted (e.g., key scales for reptiles, web or nose shapes for species like bullfrogs/pig frogs, ventral color patterns, etc.), with particular attention called to species that could be confused in the field. The species list is used for training as well as for augmenting the core survey methods (section 8.2.1).

A minimum of 1 week of protocol-specific training is recommended regardless of previous experience to ensure that individuals are versed in the protocol, the species, and the environment. Training should include (1) visits to natural history museums to examine specimens of local species, (2) field practice in data collection with an experienced herpetologist, and (3) testing of crewmembers to verify proficiency. (See Heyer et al. [1994] for further recommendations on training.)

Quality Control and Assurance

The nature of the data collected by this protocol makes quantification of management quality objectives difficult. Examination of collected data will not reveal missed detections or misidentifications of data collected by observation without photo record. Data quality rests largely with a strong training and testing program before data collection. Digital pictures provide a valuable tool for verifying questionable field identifications. In addition, the field crew leader should rotate working with each field crewmember to check on their techniques and field identification. If during this checkup crewmembers are missing detections, additional training should be given before that crewmember participates in data collection. In addition, observers should be rotated among sites, such that each site is visited by a different crew each visit to reduce the potential effects of observer bias on detection estimates.

Data Storage and Analysis

Data analysis consists of creating species lists for each monitoring point across both visits in both spring and fall, and estimating the proportion of all monitoring points occupied within the entire area of inference, using the probability of presence and detection probabilities as parameters in a maximum likelihood model. (See chapter 2, section 2.6.2.) The freeware program PRESENCE is available for this analysis (http://www.mbr-pwrc.usgs.gov/software.html). The species detection data from the survey are compiled to create detection histories for each species. Detection histories consist of either a "1" for the entire sample unit (regardless of the number of detections) or a "0" if no detections were made. For example, the detection history for a given species across all four visits may be any combination of 0s and 1s, such as 0100, 0011, 1111, or 1x01, where x represents a visit that was not conducted.

Other data of value associated with the capture of each species include: date, time, elevation, substrate associations, snout-vent length frequencies, and species co-occurrence frequencies. We do not recommend making inferences based on the number of individuals detected because these data are highly dependent on timing of sampling and observers. Sampling adequacy can be evaluated by estimating the probability of detection per unit effort, and estimating the power to detect a trend of a given magnitude and precision given the existing sample effort and the potential addition of sites or surveys per site. Sample effort may then be adjusted if indicated by the analysis.

Data sheets are checked by fellow crewmembers by the end of each week to make sure all fields are filled out correctly and legibly. In addition, all associated field crews should begin each week with a brief meeting to review and discuss field observations and challenges, such as species identification, handling individuals, access problems, and safety.

Species detections should be contributed to the National Resource Information System database and State heritage programs. Also, they may be sent to the Amphibian and Reptile Monitoring Initiative (ARMI) program via the Patuxent Wildlife Research Center in Laurel, MD (http://www.pwrc.usgs.gov/armiatlas/). Amphibian detections will be incorporated into the ARMI National Atlas for Amphibian Distributions. All records submitted will be subject to verification by the appropriate authorities before inclusion into the atlas. Observation data provided to ARMI should include species, date(s) of observation, Universal Transverse Mercator coordinates and zone, observer, and institution.

8.2 Supplemental Survey Methods

Supplemental survey methods consist primarily of augmentation of the ARVES to increase detection probabilities for species well detected with this method, and pitfall traps and coverboards, which are likely to detect species not as readily detected with ARVES. Nocturnal auditory amphibian counts are a potential supplemental survey in some, but not all, regions or forests. Supplemental survey methods should be selected to increase the number and array of species detected relative to species readily detected by the ARVES survey method. Species expected to occur in the region that may be detected by secondary methods need to be identified in monitoring plans and included in training materials.

8.2.1 ARVES Augmentation

Additional surveys. Additional visits are likely to yield detections of additional species. One to two additional visits, for a total of three to four visits per monitoring point per nonwinter (spring or fall) season, would be fruitful in most areas. Additional survey time should focus on habitat conditions within the sample unit where species that are expected would occur. This will require summarizing the species detected over the first two visits of a given season before conducting additional visits. Given that most other survey methods require 3 to 4 person-days to complete, it is not unreasonable to conduct three to four ARVES visits per season, each of which requires 1 person-day to complete. The additional visits, however, are presented as part of the supplemental methods because the effort might be more productively allocated to other supplemental survey methods, depending on the region. Additional search time per visit may also be beneficial in habitats containing highly diverse herpetofauna. In such cases, search time may exceed 8 person-hours, but search time elapsed at the time of each detection needs to continue to be recorded so the original 8 person-hours (or subsets thereof) can be extracted from the data set. In addition, the increased search time should be conducted consistently across all sites surveyed within a given forest.

Nocturnal surveys. Nocturnal surveys can be employed as a supplemental approach to increase detections of nocturnally active species (Doan 2003, Downes et al. 1997, Emmons 1983, Heyer et al. 1994, Smith et al. 1997). If species of particular interest are nocturnal, one or more additional searches could be conducted within a given season to improve detectability of nocturnal species. Nocturnal searches, however, carry a greater risk of injury and should be employed with caution, particularly given that many sites will be remote and lack roads or trails.

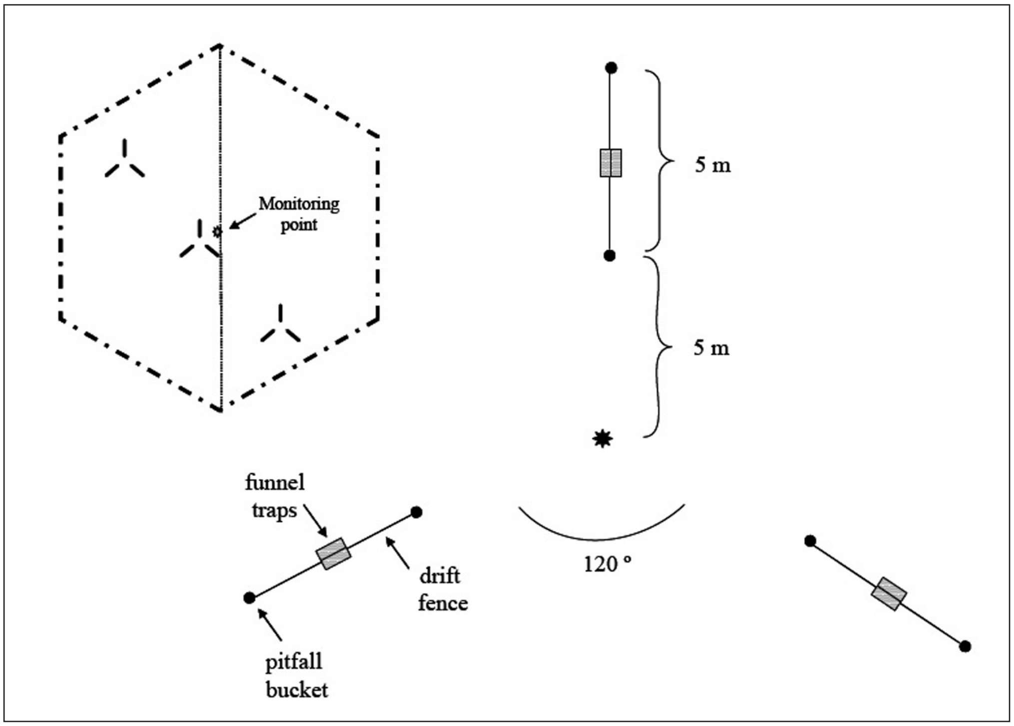
8.2.2 Pitfall Traps

Pitfall arrays and coverboards are commonly used sampling techniques that can be highly effective at surveying herpetofaunal communities (Campbell and Christman 1982, Clawson et al. 1997, Crosswhite et al. 1999, Corn and Bury 1990, Gibbons and Semlitch 1981, Greenberg et al. 1994, Morrison et al. 1995, Ryan et al. 2002). The combination of pitfall traps and coverboards is likely to substantially increase the number of amphibian and reptile species detected, but they will not be feasible for implementation on all national forests. Pitfall traps are a supplemental survey method, however, because they are more labor intensive relative to vertebrate area searches (Corn 1994, Corn and Bury 1990), standard pitfall designs are often associated with high rates of mortality for nontarget species such as small mammals (Bury and Corn 1987), and detection probabilities may be low for many species (e.g., Dodd 1991, Enge 2001). Pitfall traps, however, are effective at detecting a broad array of species (although arboreal species and species with good climbing/jumping ability are often missed) (Corn 1994, Corn and Bury 1990). Coverboards are discussed in more detail below (section 8.2.3).

Sampling Design

Many different configurations of pitfall arrays have been used in studies; the pitfall array described here is most likely to be suitable for most sites (Corn 1994). Each pitfall trap array consists of six pitfall traps and six funnel traps set in a triangular pattern and connected by 5 m long drift fences (fig. 8.2). Drift fences are effective at increasing capture rates in pitfall traps (Campbell and Christman 1982, Corn and Bury 1990, Moseby and Read 2001). Three arrays are established at each monitoring point, one randomly located 20 m from the center point, and the other two randomly located in each half of the hexagon, with at least 50 m between arrays. Arrays, arms, and traps are uniquely numbered to indicate the location of captured. The arrays are labeled as center (C), left (L), and right (R), arms are labeled as top (T), left (L), and right (R), the pitfall traps are labeled as proximal (P) and distal (D), and funnel traps are labeled as left (L) and right (R), based on facing the center of the array. The trap code is as follows: trap type-array-arm-trap, such as PIT-C-T-D.

Figure 8.2. *Pitfall trap array configuration (Bury and Corn 1987).*



The pitfall array prescribed here generally follows Bury and Corn (1987). Pitfall traps consist of 8- to 19-L (2- to 5-gallon) plastic buckets sunk in the ground so the top of the bucket is flush with ground level. The bucket should have dimensions such that it is at least twice as deep as wide. Bucket size should be consistent throughout the region, and selected based on the size and escape potential of species expected to be captured. Plastic buckets are recommended because they do not conduct heat (as opposed to metal) and the sides are slippery making escape more difficult. Thus, survival may be improved and escapes reduced with the use of plastic buckets. The plastic buckets should come with snap-on lids so the traps can be easily closed and collars can be fashioned. Posthole diggers or narrow shovels work best to dig holes for the buckets. If the majority of the region or a multiforest area cannot be readily sampled with pitfall traps because of substrate limitations (rocky or wet), or if mortality rates are expected to be high for target or nontarget taxa, then funnel traps may be substituted for pitfall traps at the ends of the drift fences.

An aluminum drift fence connects the two pitfall buckets in each arm of the array. The drift fence is made out of aluminum flashing, 0.3 m tall and 5 m long for each arm of the array, for a total of 15 m of fencing, the minimum length suggested for amphibian and reptile community inventories (Corn 1994, Vogt and Hine 1982). The drift fence is sunk into the ground approximately 20 cm and soil is pressed along each side of the fence along its length to ensure that animals can not crawl under. Wooden stakes can be used to steady the fence vertically and staples can be used to secure the fence to the stakes. A slit can be cut in the pitfall bucket to make sure there is no space between the end of the fence and the bucket.

Funnel traps are laid on each side of the fence at their midpoint. Funnel traps consist of cylinders with funnel-shaped entrances on each end (Corn 1994). A brief description is provided here; a detailed description is provided by Corn (1994). Funnel traps may be available commercially from vendors or hand crafted. In either case, the dimensions of the traps should be tailored to maximize capture success of target species. Generic dimensions are provided here which are useful for capturing most amphibian and snake species. Hand-crafted funnel traps are constructed of window screen (Karns 1986) or rigid hardware cloth (Vogt and Hine 1982). The trap cylinder is 0.75 to 1 m long and about 25 cm in diameter, with actual dimensions determined in part by efficient use of standard-sized materials. The edges of the cylinder are stapled together along its length. The funnel is created by taking a square piece of screen and rolling it into a cone. The large end of the cone matches the diameter of the cylinder and the small end of the cone should be just large enough to admit the larger sized animals expected to be trapped in the funnel. Funnel traps are particularly effective at trapping snakes, so the small end of the cone should be as small as possible. The length of the cone should be approximately 25 cm, such that 50 cm of the cylinder remains open to house captured animals. The cones are stapled into shape and then attached to mouth of the cylinder. One cone is secured with staples while the other end is secured with clips so it can be removed to check the trap.

Several modifications are made to the pitfall buckets to reduce animal mortality and increase overall trap effectiveness. First, small holes are punched into the bottom of each bucket to drain any water that might accumulate during sampling, thus reducing the risk of mortality due to hypothermia or drowning captured individuals (Corn 1994). In areas where rain is frequent or soils are naturally highly saturated (e.g., Pacific Northwest), a piece of polystyrene, or similar floating material/shelter, may be placed inside traps to prevent animals from drowning (Kogut and Padley 1997). Second, a handful of dry duff and soil is placed into each bucket to provide additional warmth to captured animals and is replaced if soil becomes saturated. Any soil in buckets needs to be carefully checked during each visit to ensure animals are not buried in it. Third, collars are commonly affixed to the top of the pitfall buckets, such as those described in Corn (1994). Collars (i.e., funnel rims) help to keep certain species (e.g., frogs) from escaping, which can be particularly important when using smaller buckets (less than 5 gallons) (Vogt and Hine 1982). When using plastic buckets as pitfalls, the majority of the center of a bucket lid can be cut out, leaving a horizontal lip of plastic around the bucket while retaining a reasonably large opening to the bucket (if using metal cans as pitfalls, collars can be created by cutting the bottom out of plastic margarine tubs with the same diameter opening as the pitfall buckets). Fourth, covers consisting of cedar shingles or Coroplast (corrugated plastic, http://www.coroplast.com/product.htm) covers are placed over the top of each pitfall trap during sampling and are propped up on one side with a small diameter (1- to 2-cm diameter) object (Corn 1994). Covers are used to entice individuals to crawl under the cover and fall into the trap and to reduce heat stress on captured individuals (Adams and Freedman 1999, Corn 1994, Hobbs and James 1999). Traps are closed between sampling sessions using plastic lids that snap tight to the buckets, with additional materials placed on the lid (e.g., rocks) to ensure that lids remain in place.

Data Collection

Pitfall trap arrays are established in the spring during the wet season. In areas with snow, this could be as soon as snow melts enough to access survey points and the ground is no longer frozen. Pitfall traps should be checked daily, but in some areas where this is not an option they should be checked no less than once every 3 days (Corn 1994, Enge 2001, Fellers and Drost 1994, Hobbs and James 1999, Marsh and Goicochea 2003). Twice weekly checks are intended to reduce mortality rates in pitfall traps. Sample periods are a minimum of 2 weeks in the spring and 2 weeks in the fall. It is important that sample periods approximate activity patterns of herpetofauna in the survey area to maximize detection of entire species assemblage. Sample effort can be extended by opening traps for more than one 2-week session, for example for 2 weeks per month (e.g., Crosswhite et al. 1999), which would most likely improve detections for reptiles and amphibians.

Pitfall checks consist of lifting the cover and removing all animals with each visit. Captured animals are removed one at a time, processed, and released. As with visual encounter surveys, the following information is recorded for every detection: observer, time, species, detection type (e.g., visual, auditory, capture, sign), age class of captures (juvenile, subadult, adult), and snout-vent length. If turtles are captured, carapace length is recorded. Poisonous vertebrates require special skill, training, and care, including the use of leather gloves. Use rubber gloves when handling amphibians to reduce the risk of transmitting harmful chemicals (e.g., sunscreen, DEET) or disease (e.g., fungus) to the animal. If plastic bags are used to temporarily contain the animal, the bag must not be reused for another amphibian. The detection of rare species should be documented by taking a picture of the individual, being careful to display the diagnostic characteristics of the species. All mortalities are collected, properly stored, reported to the field crew leader, and provided to the local university museum.

Equipment Needed

Crews should bring a clipboard, shovel (to sink buckets), plastic bags (quart and gallon), ruler, leather and rubber gloves, species keys, headlamp (optional), and knee pads (optional). Each monitoring point requires 18 plastic buckets with two sets of lids (one for collars, one for covers), 45 m of aluminum flashing, wooden stakes and heavy duty staple gun and staples (optional), and 18 preassembled funnel traps.

Special Considerations

Pitfall trap covers made of insulation foil should used in areas where temperatures regularly exceed 40 to 45 ºC during the sampling period, as they may be more effective at reducing heat-related mortality. They may, however, reduce capture frequencies (Hobbs and James 1999).

Funnel traps are used in conjunction with pitfall traps to increase snake species detections, as funnel traps seem to be more effective than pitfall traps at detecting them, and perhaps lizards (Campbell and Christman 1982, Enge 2001, Vogt and Hine 1982). Funnel traps can be used to replace pitfall traps in areas where digging holes for pitfall traps is impossible, or in areas of high snake diversity.

Large pitfall traps (18 to 19 L) with fairly large mouths, such as those used by Vogt and Hine (1982), may be added in addition to standard 2-gallon pitfall traps if turtles or high-jumping frogs (e.g., ranids) are present in the reptile assemblage.

In addition to amphibians and reptiles, small mammals are frequently caught in pitfall traps. Small mammals may eat herptiles, and shrews have a high mortality rate in most traps, particularly pitfall traps. Daily pitfall checks are recommended to reduce mortalities and potential biases associated with predation. To more effectively decrease shrew mortality in pitfall traps, a common and well-documented problem (Bury and Corn 1987, Karraker 2001), small mammal escape mechanisms may be provided. Specifically, twine can be hung from the underside of the cover (tied or stapled) to enable the escape of small mammals without aiding the escape of amphibians and reptiles (Karraker 2001).

Staffing, Training, and Safety

A crew of six people is preferred to efficiently install or conduct preseason maintenance of pitfall arrays to initiate surveys; however, a crew of three could be employed if relatively few points are to be surveyed on a given forest with this method. Only one to two person crews are needed for checking arrays once they are installed. A crew of six people working together could install pitfall arrays at an average three monitoring points per day. Thereafter, all six individuals can work independently to conduct subsequent pitfall checks. Each individual can conduct pitfall checks at one to three points per day. Crewmembers can be GS-3/4/5 biological technicians, preferably with academic training in mammalogy, herpetology, some experience handling small mammals, amphibians, and reptiles, and prior experience conducting field protocols.

All field crews should be supervised by a field crew leader (GS-7/9) who should have at least 2 years of experience capturing and handling small mammals, reptiles, and amphibians, is familiar with the distinguishing traits of species occurring in the local area, is capable of effectively training and supervising field crews (e.g., good communication skills, positive attitude, pays attention to detail), and has experience working in remote areas.

Two weeks of training are required (or less for returning employees or individuals working with herpetofauna in the local area in recent years) and should include the following as a minimum: (1) work with field guides that identify and discuss the defining features of each species of small mammal, amphibian and reptile occurring on the forest; (2) visit one or more university museum collections to study the variability of defining characteristics that could be encountered in the field, paying particular attention to similar co-occurring species (e.g., *Plethodon* salamanders); (3) conduct several practice pitfall checks both with entire field crew together, as well as one-on-one sessions between crewmembers and their crew leader; and (4) target areas with representatives of the species occurring on the forest, and targeting various habitat types for crewmembers to gain experience with the variety of conditions and sites encountered in the field. All field personnel must have a minimum of basic first aid training, and preferably training in wilderness medicine (e.g., wilderness first responder) and be prepared to respond to any potential safety hazard encountered in the field.

Quality Control and Assurance

The most critical elements for quality control of pitfall surveys include (1) proper installation of pitfall traps and maintenance of their integrity for maximum ability to detect terrestrial herpetofauna; (2) observer care in handling animals to minimize escape before completion of all data collection on the individual; (3) proper use of precautions in handling amphibians to avoid the transmission of harmful chemicals (e.g., sunscreen, DEET) or pathogens (e.g., fungus) to amphibians (chapter 9); (4) cleaning and disinfecting buckets with bleach before they are moved to a different location; (5) maintaining frequent checks to pitfall arrays to keep captured individuals alive and in good condition; and (6) recording data completely, consistently, and legibly on all data sheets.

Mortalities should be less than 1 percent and can be determined by examining field-collected data periodically. Mortalities can be reduced by securing pitfall covers to provide adequate shading, in hot areas by providing a source of moisture (e.g., moist dirt, litter, or soaked cloth) at the bottom of the trap to aid in survival of captured amphibians, and increasing the frequency of trap checks to each array. For all target species and taxonomic groups, escape rates resulting from mishandling should also be less than 1 percent of all captures. Minimal levels of escapes can be achieved with adequate training and practice with handling animals before conducting surveys. Animals should be handled by securing the body and appendages while allowing the animal to maintain easy breathing.

Rotating observers between trap checks at survey sites is important for ensuring correct species identification at a given survey location, and occasional paired observer surveys (e.g., once every 2 weeks) will also aid in maintaining accurate species identification across observers. Occasional field visits by the program supervisor with each observer will help ensure that field crews are following the standardized protocol correctly and consistently, that species identification is accurate, abundance estimates are comparable between observers, and that surveyors are recording data with appropriate accuracy, detail, and penmanship.

Supplemental Survey Effort

If desired, animals can be marked to enable calculations of relative abundance. Marking can take substantial additional time. A variety of marking techniques are available for amphibians (ASIH 2001, Donnelly et al. 1994), reptiles (ASIH 2001, Ferner 1979) and small mammals (Rasanayagam 1996). Temporary marking techniques are sufficient as long as the marks are not lost within the sample period. More permanent marking would create the potential for calculating some measures of population demography, but only if a sufficient number of animals were captured and recaptured over a multiyear period.

8.2.3 Coverboards

Coverboards are fairly simple to install, but can have variable success, depending on the environment (moist or dry, cover abundant or limited) (Grant et al. 1992, Heyer et al. 1994).

Sampling Design

Coverboards (i.e., artificial cover objects) can be used alone or in association with the pitfall arrays. Coverboards consist of a 1-m^2 sheet of woody material at least 1cm thick to allow a wide range of herpetofauna to use it as cover (Fellers and Drost 1994). Wood, although heavy, is a natural material that is not foreign to animals. The type of wood used for coverboards does not appear to influence total detections of terrestrial salamanders (Bennett et al. 2003); however, use of plywood may be less effective and is not recommended (Corn 1994). Each coverboard may be cut into four 0.5 by 0.5 m square pieces for transport to the survey point, but should be rejoined in some manner when placed in the field to enhance microclimatic conditions near the center of the coverboard. One coverboard is placed in each of six directions from the monitoring point, along the same azimuths at which point count stations are established. Starting at due north and continuing clockwise every 60 degrees, coverboards are placed 30 m out from the monitoring point. Coverboards are placed along the slope such that the edges of the board are parallel and perpendicular to the fall line (to better intersect individuals moving up or down the slope) and are placed flush with the soil surface. Correct placement of coverboards may require removal of litter layer on the ground surface.

Data Collection

Coverboard checks consist of quickly lifting up the coverboard and capturing all individuals present (Fellers and Drost 1994). If they are used in conjunction with pitfall traps, they should be checked at the same interval as the pitfall array. If they are used alone, they can be checked in conjunction with other site visits. More frequent checking (once or twice a week) will result in more detections, but because they pose no threat to the well-being of animals, they can be checked less frequently. It is recommended that the regions determine the value of coverboards and design a sampling scheme that maximizes the detections per unit effort based on other monitoring activities taking place at the monitoring points. A standardized sample period and visitation frequency needs to be established, however, and consistently applied across the region. Captured animals can be placed temporarily in plastic bags or jars. Observers process individuals in order of decreasing likelihood of escape and collect the same information from specimens as described above for pitfall captures. Individuals are not placed back under the coverboard but are released next to it and the coverboard replaced flush with the ground surface.

8.2.4 Nocturnal Auditory Amphibian Counts

Nocturnal auditory amphibian counts are part of the North American Amphibian Monitoring Program (NAAMP), which is a collaborative effort among regional partners, such as State natural resource agencies and nonprofit organizations, and the U.S. Geological Survey, to monitor populations of vocal amphibians. The auditory amphibian count protocol designed by NAAMP is a road-based approach, but it could be adapted for use at MSIM monitoring points. For more information, visit the Patuxent Wildlife Research Center Web site at http://www.pwrc.usgs.gov/naamp/.

Chapter 9. Vertebrate Monitoring at Aquatic Ecosystems

Aquatic environments are often the most productive and biologically diverse habitat types in a landscape. Aquatic habitats can be divided into two basic types: riverine (moving water) and lacustrine (standing water) (Maxwell et al. 1995). Riverine habitats include streams (perennial, ephemeral, and intermittent), seeps, springs, and marshes. Lacustrine habitats include lakes, ponds, bogs, fens and wet meadows. A wide variety of vertebrate biota are closely associated with aquatic environments, making it challenging for any one monitoring approach to effectively detect the full array of species. Recent advances in design, detection, analysis techniques, and protocols, however, have made this challenge more feasible. For example, the Aquatic Ecological Unit Inventory (AEUI) technical guide (Hixson et al. 2005) identifies key biophysical features and attributes of riverine habitats to measure and standardized methods by which to measure them. The Multiple Species Inventory and Monitoring (MSIM) protocol, as reflected in this chapter and chapter 11, implements the AEUI protocol for riverine habitats as part of this integrated national monitoring program for plants and animals. All aquatic-associated vertebrates use or are affected by terrestrial environments, thus they are directly affected by both terrestrial and aquatic habitat conditions. This chapter serves to provide a spatially collocated terrestrial and aquatic habitat monitoring program that integrates AEUI attributes and population data for aquatic-dependent and aquatic-associated species to offer a comprehensive approach to monitoring vertebrates across National Forest System (NFS) landscapes.

The objective of the aquatic vertebrate surveys described in this chapter is to provide reliable, standardized data on status and change in the distribution and relative frequency of a large number of aquatic-associated vertebrate species. Overall, the MSIM protocol is intended to serve as a consistent and efficient method for obtaining spatially and temporally coincident detection/nondetection data and habitat condition data across a diversity of species. The National Framework and basic sampling design of the MSIM protocol is described in chapter 2. Survey methods for animal and plant species are described in the subsequent eight chapters. The National Framework identifies six core survey methods and three additional primary survey methods that together provide information on a representative sample of species in various taxonomic groups and at various trophic levels.

All survey methods associated with the MSIM protocol are designed to be implemented at MSIM monitoring points that are associated with, but offset from, Forest Inventory and Analysis (FIA) grid points on NFS lands. The scale of implementation is the national forest, but the primary planning scale is the region to ensure consistency in monitoring approaches for species and habitats shared among forests. The MSIM National Framework calls for a minimum of 50 percent of the FIA grid points to be selected to establish MSIM monitoring points. This core set of monitoring points is to be surveyed over a 3-year sample period with no more than a 5-year resample cycle. Sampling associated with most of the core and primary survey methods is contained within a 200-m radius (approximately 10-ha) sampling hexagon centered on the MSIM monitoring point. Species detections are used to estimate the proportion of monitoring points occupied by the species. For more details on the overall sampling design, see chapter 2.

9.1 Aquatic Sampling Design

All primary and supplemental survey methods are conducted at aquatic sample sites within a 25-km^2 (5- by 5-km^2) primary sample unit. A sample unit of this size approximates the size of a sixth-field Hydrologic Unit Code (HUC). Sixth-field HUCs are subwatersheds of approximately 2500 to 6000 ha (6,000 to 14,000 ac), and are commonly identified as an appropriate size for characterizing the condition of streams and watersheds. A HUC is a consistent, continent-wide hierarchical scheme that represents nested hydrologic basins (http://water.usgs.gov/GIS/huc.html). Hydrologic units are a drainage defined by hydrologic and topographic criteria.

HUCs were not specifically selected as the sample unit for MSIM aquatic sampling primarily because the MSIM protocol is designed to be compatible with the development of a national grid of nested sample units. In regions where HUCs are the sample unit for other inventory and monitoring efforts, however, it is recommended that the primary sample unit be expanded to include what remains of the sixth-field HUC in which the monitoring point is located that is outside the bounds of the square 5-km^2 sample unit.

The National Framework calls for 50 percent of the FIA points to be selected for establishing monitoring points. Because the sample unit for aquatic sites is approximately the size of an FIA hexagon, however, aquatic sites are only sampled in association with half of the monitoring points. (See chapter 2 for more details.) Half the monitoring points will be randomly selected for aquatic habitat monitoring, constrained by forest, and the HUCs or grid cells within which the selected monitoring points occur become the aquatic sample units. This sampling intensity equates to an average-size national forest having aquatic sites in approximately 50 subwatersheds sampled over a 3-year period.

Primary and supplemental survey methods target a different number of aquatic sites to be sampled within each sample unit, but all site selection starts with a full accounting of aquatic habitats within the primary sample unit so that sites can be selected with a known probability of selection. All aquatic habitats within the sample unit should be categorized using the classification scheme provided by the National Hydrography Dataset, which is a simple classification of riverine and lacustrine types: lakes/ponds (intermittent/perennial, salt/freshwater), streams/rivers (intermittent/perennial), springs/seeps (alkaline/hot/sulpher/freshwater), reservoirs (earthen/tailings/artificial, primary purpose), swamps/marshes, and estuaries (USGS and EPA 1999). More detailed classifications may exist in various regions (e.g., Moyle 1996) and may be used to further refine evaluations of monitoring data.

Most aquatic habitats are fairly discrete units with readily discernable boundaries in the field, but streams and rivers are continuous linear features. Within the aquatic sample unit, all aquatic habitats, including discrete units and the entire length of intermittent and perennial streams and rivers, are mapped to facilitate survey site selection. Given that U.S. Geological Survey (USGS) maps generally underrepresent small waterbodies and intermittent streams, it is likely that the identification of all aquatic sites within the sample unit will require aerial photo interpretation.

Once all the aquatic waterbodies have been identified, they are classified into five basic types: perennial river/stream, intermittent stream, lake/pond, bog/fen, and wet meadow. Aquatic survey sites consist of the entirety of a discrete aquatic unit or a 300-m segment of a stream or river. Discrete aquatic units are selected randomly from all units and types occurring in the sample unit. Stream reaches are selected by randomly selecting a point along any of the mapped streams. The 300-m segment will extend upstream from the selected point. If a subsequently selected point occurs within 300 m upstream from a previously selected point, the point will be reselected. The AEUI technical guide defines reaches as lengths of channel that have a high degree of uniformity in channel morphology and flow, particularly gradient. If the randomly selected 300-m segment includes parts of two uniform lengths of stream, the sample segment may be extended to include the remainder of the uniform reach length.

Within each primary sample unit, survey methods will be conducted at three stream or river segments and three other types of aquatic habitat, including any lacustrine or other riverine types. If bat monitoring is being conducted (chapter 7), the primary bat survey site for the monitoring point will be included as one of the aquatic habitat sites surveyed.

9.2 Primary Survey Methods

Primary survey methods consist of Aquatic Visual Encounter Surveys (AQVES) for all classes of vertebrates (birds, mammals, amphibians, and reptiles) and aquatic point counts directed at detecting waterbirds. Additional effort and the use of automated survey techniques are discussed as supplemental survey methods.

9.2.1 Aquatic Visual Encounter Surveys

AQVES is the primary survey method for detecting mammals, amphibians, and reptiles associated with aquatic habitats. Many aquatic-associated bird species may also be detected, but aquatic point counts (section 9.2.2) are expected to yield the majority of detections of aquatic-associated bird species. AQVES is conducted at all types of aquatic habitats and targets direct observations and sign of vertebrates in all taxonomic classes. For birds and mammals, larger bodied species are the primary target, such as waterfowl, American dipper (*Cinclus mexicanus*), osprey (*Pandion haliaetus*), beaver, (*Castor canadensis*), mountain beaver (*Aplodontia rufa*), mink (*Mustela vison*), muskrat (*Ondatra zibethicus*), and otter (*Lutra canadensis*).

Sampling Design

The entire perimeter of lake, pond, seep, and spring sites are surveyed, whereas wet meadows are surveyed throughout their extent. When two observers are present at a lake or pond, they begin at the same point and survey in opposite directions until they meet. In meadows, observers zig-zag from side to side, covering the entire width of the meadow with each new trajectory. In meadows, when standing water is too deep to walk through, observers walk the perimeter of the waterbody. When multiple observers survey a meadow, the meadow is divided among the observers so that the entire meadow is covered. Streams and rivers are surveyed by observers walking along the stream bank; in larger streams where both banks can not be surveyed simultaneously by one observer, one observer surveys each side of the stream.

Data Collection

Prior to field data collection, a list of all target species that may be encountered is created for the area (e.g., national forest or ecoregion). Each aquatic sample site is sampled (visited) twice during the spring/summer season, with surveys separated by at least 2 weeks.

Surveys are conducted generally between 8 a.m. and 5 p.m. In all habitat types, observers spend approximately 15 minutes per 100 m sampled, with the clock stopped when extra time is needed to identify species, count individuals, or maneuver around obstacles. Observers spend most of the time walking in the water, searching through emergent vegetation with a long-handled dip-net, and overturning rocks, logs, and debris to reveal individuals and signs (e.g., Fellers and Freel 1995).

Observers record detections of all aquatic-associated species, as well as all species identified as target species for Terrestrial Visual Encounter Surveys (TVES) (chapter 4, section 4.1.2), which consist primarily of less common or larger bodied vertebrates not frequently encountered. In addition to recording species, observers record life stage (egg, tadpole, metamorph/juvenile, adult), number of individuals (or egg masses), and substrate. In stream reaches, the location of the detection is recorded as the distance from the downstream end of the reach. This is important to enable the identification of detections obtained within the standard 300-m reach versus those that were obtained in an extended portion of the reach.

Amphibians and reptiles are captured only when necessary to confirm identification. Use rubber gloves when handling amphibians to reduce the risk of transmitting harmful chemicals (e.g., sunscreen, DEET) or disease (e.g., fungus) to the animal, and if plastic bags are used to temporarily contain the animal, the bag must not be reused for another amphibian. All mortalities and detections of special status species are reported to the field crew leader.

Minimally, the presence or absence of fish is determined by visually scanning the habitat and identifying them to the lowest taxonomic level possible. It is important that observers wear polarized glasses to enhance underwater visibility. If no fish are observed during the survey, then the aquatic unit may be surveyed using a mask, snorkel, and fins. This additional effort, discussed in section 9.3.1 as a supplemental survey method, can be important for understanding the potential limitations of the co-existence of fish and amphibians, given that nonnative trout may prey on amphibian species to the extent that they may be extirpated from sites.

Equipment Needed

Crews should bring boots or waders with felt soles or skid-proof soles, polarized sunglasses (for seeing through water surface), binoculars, dip net, clipboard, watch, field guides for individuals and signs of birds, amphibians, reptiles, and mammals.

Staffing, Training, and Safety

Observers can be organized into two-person teams, and may work together or alone, depending on the size of the aquatic sites being surveyed. Each observer can expect to survey an average of two aquatic sites (an average of less than or equal to 800 m) per day (including measuring associated habitat/environmental variables) assuming no more than 3 hours for travel and preparation for two sites. Larger lakes and meadows (greater than ca. 2,400-m perimeter) may require one or more individuals to survey appropriately in a single day.

Crew members can be GS-4/5 biological technicians, preferably with academic training in herpetology, ornithology, and mammalogy, prior experience handling animals and identifying diagnostic characteristics in the field, and conducting standardized field survey protocols (e.g., Fellers and Freel 1995). Knowledge of fish species is also desirable. It is especially important that each crew member is capable of conducting the following tasks: follow the specified protocol, pay close attention to detail, take high-quality notes in the field, understand the risk of disease and harm to amphibians, implement the necessary precautions to eliminate disease transmission (e.g., disinfecting equipment between sites), and limit stress on captured individuals.

All field crews of four to six individuals include a field crew leader (GS-7) with the following training: (1) at least 2 years of experience capturing and handling reptiles and amphibians; (2) ability to identify aquatic-associated bird species by sight and sound; (3) familiarity with the distinguishing features of mammal species by sight and signs occurring in the local area; (4) capable of effectively training and supervising field crews (e.g., good communication skills, positive attitude, pays attention to detail); (5) aware of potential risks and vulnerabilities that face amphibians (e.g., spread of disease, chemical sensitivity); and (6) experience working in remote areas (Fellers and Freel 1995). Crew leaders are responsible for training all crewmembers to a common standard level of skill, setting and enforcing strict data quality and penmanship standards, maintaining equipment in good working order, setting an example of safe/efficient field working habits, and identifying questions/concerns from crewmembers that need to be addressed by the program supervisor. Oversight of surveys at the forest and multiforest level, including logistical and administrative support and acquisition of all required permits, is the responsibility of field crew leaders and should be supervised by a journey-level biologist.

Two weeks of training are required for new employees, and at least 1 week of training is recommended for returning employees. A list of aquatic-associated biota expected to occur in each sample unit is developed, and species of concern and interest are indicated, including fish species (same as AEUI national attribute of aquatic biota species for valley segments) (Hixson et al. 2005). The species targeted by TVES (chapter 4, section 4.1.2) are added to the list to create a composite AQVES species list. A field key should be developed for each ecoregion that notes the distinguishing features of each species and their sign. Training consists of the following efforts at a minimum: (1) work with visual and auditory field guides that identify and discuss the defining physical and auditory (if applicable) features of each aquatic-associated species potentially present; (2) visit one or more university museum collections to study the variability of defining characteristics that could be encountered in the field, paying particular attention to similar co-occurring species; (3) conduct several practice surveys with the entire field crew and one-on-one training of crewmembers by crew leaders; and (4) target geographic areas with representatives of the species occurring on the forest and a variety of aquatic habitat types so crewmembers gain experience with the variety of conditions and sites encountered in the field. A more detailed schedule for training is provided by Fellers and Freel (1995). All field personnel should have a minimum of first aid/CPR training, and preferably training in wilderness medicine (e.g., wilderness first responder) and be prepared to respond to any potential safety hazard encountered in the field.

Quality Control and Assurance

Several standard management quality objectives are discussed in Fellers and Freel (1995). The most critical elements for quality control of aquatic visual encounter surveys include (1) searches are conducted with similar effort by all surveyors (same rate of perimeter surveyed over time); (2) second visits to meadows are conducted over the same area as first visits; (3) surveyors have similar search image for amphibians and reptiles (e.g., individuals must be trained to flip over relevant cover items such as logs, bark, and rocks, and search in habitat features commonly used by amphibians and reptiles such as eddies along streams, in grassy sections of ponds, along water perimeters); (4) observers correctly identify all encountered species at a given site at all larval stages present (e.g., eggs, tadpole, metamorph/juvenile and adults); (5) abundance is estimated with adequate accuracy and similarly across observers; and (6) data are recorded completely, consistently, and legibly on all data sheets.

Field crew leaders rotate among crews, periodically working with each field crewmember to observe their field techniques and correct problems. These checks help ensure that field crews are following the standardized protocol correctly and consistently, species identification is accurate, abundance estimates are comparable between observers, and surveyors are recording data with appropriate accuracy, detail, and penmanship. Rotation of observers to sites across visits is also important to assure correct species identification at a given survey location, and occasional paired observer surveys (e.g., once every 2 weeks) will aid in survey consistency.

Data Storage and Analysis

Data analysis consists of creating species lists for each monitoring point across both visits, and estimating the proportion of all monitoring points occupied within the entire area of inference, using the probability of presence and detection probabilities as parameters in a maximum likelihood model. (See chapter 2, section 2.6.2.) The freeware program PRESENCE is available for this analysis (http://www.mbr-pwrc.usgs.gov/software.html). The species detection data from each survey are compiled to create detection histories for each site. Detection histories consist of either a “1” for the entire sample unit (regardless of the number of detections) or a “0” if no detections were made. For example for two visits, the detection history for a given species will be 00, 01, 10, 11, 1x, or x1, 0x, or x0, where x represents that either the first or second visit was not conducted.

Detections across sites within each sample unit may also be combined to generate a composite species list for the monitoring point. Sampling adequacy can be evaluated by estimating the probability of detection per unit effort, and estimating the power to detect a trend of a given magnitude and precision given the existing sample effort. Sample effort may then be adjusted if indicated by the analysis.

9.2.2 Aquatic Point Count Surveys

Point counts are an effective method for detecting aquatic-associated bird species, as well as songbirds and woodpeckers. (See chapter 3, section 3.1.1.) Point counts are a primary survey method in addition to AQVES because waterfowl and shorebirds typically forage at multiple aquatic sites, lowering their per-visit detection probabilities. The addition of point counts increases the survey time, and therefore increases the detection probability, for aquatic-associated bird species. In addition, point count surveys can be used to record all bird species detected, which provides a measure of aquatic association and increases the overall detection probabilities for all landbirds detected with point counts.

Sampling Design

Point counts are conducted along the perimeter of the aquatic site to improve detection probabilities for waterfowl and shorebirds. Count stations are located 200 m apart along the shoreline of aquatic habitats. For lakes, ponds, bogs, and wet meadows, count stations are established at or around their perimeter in locations with good visibility of the waterbody. If the perimeter is less than 400 m, then either two stations are established (if visibility is too poor to view the entire waterbody from one location) or one station is established and it is surveyed for two consecutive counts (i.e., 20 minutes).

Data Collection

Each count is conducted for 10 minutes. The minimum of two counts (visits) per waterbody results in the each waterbody being sampled a minimum of 20 minutes. The number of points for waterbodies with more than 400 m of shoreline or length will be a function of their size. Counts are conducted between 15 minutes after sunrise and no later than 4 hours after sunrise (Ralph et al. 1993). Observers minimize disturbance by approaching the site quietly. During counts, the distance of each individual detected is recorded as being within or outside a 100-m radius. Lakes over 10 ha in size occasionally require multiple observers to complete the counts in one morning and survey 100 percent of the area. Point counts can be conducted by the same individuals and on the same day as AQVES surveys, with point counts conducted first. In these cases, observers should walk some distance from the shoreline when moving between count stations to ensure that other aquatic-associated vertebrates are not disturbed prior to the AQVES survey. Any target species encountered during the point count survey, however, should be recorded and considered a detection (not an incidental sighting) given that the survey time per point count is consistent from site to site and visit to visit.

Two separate counts are conducted at each aquatic site and are separated by at least 4 days to ensure that they represent variation in environmental conditions (e.g., temperature, moisture). In addition, multiple visits to aquatic sites associated with monitoring points are required to estimate probability of detection and proportion of points occupied. Observers are rotated among aquatic sites to conduct point count surveys over the course of the survey season. Counts are not conducted during precipitation or windy conditions. (See chapter 3, table 3.2.)

The list of aquatic-associated bird species developed for AQVES serves as the target species for aquatic point count surveys. Observers record the number of individuals of each species on the target species list. Observers may be trained, however, to identify and record all bird, amphibian, and squirrel species detected as per the terrestrial point count survey method (chapter 3, section 3.1.1), which would greatly increase the amount of information gained by conducting aquatic point counts. Birds seen flying over and not landing or using the habitat within the 100-m radius are recorded as such. Observers may record the type of observation (auditory or visual), which can be particularly useful to provide additional documentation for species occurrences that are rare or unusual. Additional information recorded per visit includes date, cloud cover (chapter 3, table 3.1), wind conditions (chapter 3, table 3.2), observer, start time, and any notable events or conditions including incidental sightings of nontarget species. Observers carry tape recorders to record calls or songs that can not be identified to species in the field.

Equipment Needed

Crews should bring boots or waders with felt soles or skid-proof soles, binoculars, clipboard, stopwatch or watch with timer, field guides for individuals and sign of birds, amphibians, reptiles, and mammals (same as AQVES), tape recorder and blank tape.

Staffing, Training, and Safety

Typical bird crews consist of a mix of experienced (GS-7/9) and less experienced (GS-3/4/5) field biologists. If only aquatic-associated birds are the target of aquatic point count surveys, then inexperienced field personnel with some training in ornithology can be fully trained in a 2-week training period. The field crew leader should have at least 1 year of bird survey data collection experience and have the maturity and skill to hire, train, supervise, schedule, and oversee all data collection activities. If all bird species detected are to be recorded, however, field crewmembers must already know the majority of bird species by sight and sound based on previous experience. At least one season of training is typically required to sufficiently learn all songbird songs and calls. Crew leaders are responsible for training all crewmembers, scheduling visits, promoting safety, and ensuring data quality and organization, as well as conducting point count surveys. When screening applicants, note all birding experience whether professional, volunteer, or hobby.

Crew size is dependent on the number of points that will be sampled during the season. If point counts and AQVES surveys are conducted by the same individuals, then a crew of two can conduct point counts at two sites, and then together conduct the AQVES surveys at each site, for an average of one site fully sampled per crewmember. This scenario is very efficient and is most feasible when only aquatic-associated bird species are recorded during counts (do not need seasoned birders on crew). In this case, two aquatic sites can be surveyed per morning per crew of two. If a separate point count crew is used, then a crew of two individuals can visit 20 aquatic sites in a typical work week (2 monitoring points per day times 5 workdays times 2 observers).

Follow the training approach outlined in chapter 3, section 3.1.1, to prepare observers for quality data collection for aquatic point counts, and use the expected species list from the AQVES for training, adding the species list for terrestrial point counts if all bird species are to be recorded.

Quality Control and Assurance

Management quality objectives for terrestrial point counts (chapter 3), and AQVES apply to aquatic point counts.

Data Storage and Analysis

As with terrestrial point counts, point count data may be contributed to the USGS Bird Point Count Database (http://www.pwrc.usgs.gov/point/). The Patuxent Wildlife Research Center and American Bird Conservancy have worked together to build a repository for Partners in Flight point count data. The Web-based Bird Point Count Database can be accessed and used by anyone with point count data from North America. The database was developed to meet the following goals:

- Provide easy data entry and access to everyone over the Web.
- Accommodate count data from multiple sources, allowing for small differences in protocols, such as:
  - Counts at different times of year: breeding, winter, or migration counts.
  - Counts differing in time intervals (3 vs. 5 minutes, for example) or radii.
- Store vegetation information associated with points.
- Enforce data quality control through validation routines and through distributed responsibility.

Data analysis consists of creating species lists for each monitoring point across both visits to each site, and estimating the proportion of all monitoring points occupied within the entire area of inference, using the probability of presence and detection probabilities as parameters in a maximum likelihood model (chapter 2, section 2.6.2), as per the AQVES data.

Analysis approaches specifically applicable to point count data are available in reference to a number of specific topics: general data analysis (Thompson 2002), estimating probability of detection (Farnsworth et al. 2002, Nichols et al. 2000), species richness estimates (Boulinier et al. 1998, Cam et al. 2000, Nichols et al. 1998,), and proportion of points occupied (MacKenzie et al. 2002, MacKenzie et al. 2003). If all bird species are recorded at aquatic sites, aquatic sites can serve as additional monitoring points for landbirds, greatly increasing the sample size and power to detect change for species detected in both environments.

9.3 Supplemental Survey Methods

9.3.1 AQVES Augmentation

Additional survey effort to determine fish presence. If fish are not observed during visual observations, snorkeling (Thurow 1994) may be conducted at aquatic habitats that are more than 1 m deep to increase the probability of detection of fish presence and/or to obtain a more comprehensive species list if the presence of individual fish species is of interest. In standing water, snorkeling is conducted from an inflatable raft. To determine presence of fish, snorkeling is conducted until fish are observed, or for a maximum of 10 minutes for sites less than 0.4 ha with an additional 5 minutes per ha (for a maximum of 30 minutes) for larger sites. In streams and rivers, observers start from the downstream end of the segment (reach) and move upstream at a pace of 50 m every 10 minutes, for a total of 1 hour of survey for the 300 m segment. If the river is more than 5 m wide, two observers should conduct the survey simultaneously, moving upstream and surveying each side of the river together.

Fish species list. To obtain a more complete list of fish species present at a site, the AEUI technical guide calls for electrofishing (where it is permitted) as a national attribute at the river reach scale. (See Hixson et al. [2005] for details.) Where electrofishing is not permitted (i.e., in the range of threatened or endangered species), snorkeling is prescribed to develop a species list.

Additional sites. The primary survey methods prescribe three stream/river habitats and three other habitat types to be sampled for aquatic-associated vertebrates. Aquatic inventory and monitoring objectives at the forest or region scale may call for sampling a greater number, a set proportion, or all sites of a given type within the aquatic sample unit. In these cases, additional sites can readily be selected from the population of all sites generated to select primary survey sites for MSIM.

Nocturnal surveys. Nocturnal surveys can be employed as a supplemental approach to increase detections of nocturnally active species (Doan 2003, Downes et al. 1997, Emmons 1983, Heyer et al. 1994, Smith et al. 1997). If species of particular interest are nocturnal, one or more additional searches could be conducted within a given season to improve detectability of nocturnal species. Nocturnal searches, however, carry a greater risk of injury and should be employed with caution, particularly given that many sites will be remote and lack roads or trails. Nocturnal surveys should always be conducted by a team of two crewmembers working together.

9.3.2 Automated Data Collection

Sound recording devices capable of obtaining high-resolution recordings of amphibian calls may prove an effective means of obtaining accurate presence data without having to deploy field personnel. The automated recording of anuran vocalizations, specifically, can be a simple and effective way to determine the presence or absence of frog species. Two types of systems are commonly used: a data logger-based system that can also simultaneously measure environmental variables, and a timer-based system that is less expensive but cannot monitor environmental variables (Peterson and Dorcas 1994).

Data logger systems are programmed to periodically activate a tape recorder via a relay switch. Although this system has advantages such as accurate, precisely timed intervals, it can be expensive and require time to learn how to program. A less expensive alternative for periodically recording anuran vocalizations uses a solid state timer that can be set to activate a cassette tape recorder at specific periods or intervals, and runs on a 12-volt battery. Little expertise is needed to assemble the system and, because of the low cost, several systems can be used simultaneously to monitor several sites (Peterson and Dorcas 1994).

Recording technology is still in development that can be left out in the field for 4 weeks and be programmed to take multiple recordings over time, and the ability to decipher recordings still remains dependent on direct human interpretation. This technology is likely to develop quickly, however, and may provide a highly reliable method for monitoring anurans in the near future.

9.3.3 Aquatic Traps

Commercially available live traps for use in aquatic systems can be an effective and relatively inexpensive technique for determining the presence of turtle, amphibian, and fish species. Minnow traps are cylinders with funnels extending inward at one or both ends; animals enter through the funnels but are discouraged from leaving by the small diameter (Shaffer et al. 1994). These traps have proven to be effective for use with small fish as well as aquatic or larval stage amphibians. Larvae amphibians are generally strong swimmers that can outswim slow moving nets, or can easily hide in bottom substrates (Shaffer et al. 1994). Minnow traps allow for low impact and relatively thorough sampling, particularly when used in discrete aquatic units such as ponds, where species richness of larvae could be determined (Shaffer et al. 1994).

Several types of live traps are designed specifically to capture turtles with varying foraging habits; these traps attract turtles by either using bait or as surrogate basking substrates. Funnel traps, which must be baited, are likely to attract turtles from much greater distances than basking traps and therefore are best employed in larger waterbodies. Reese (1996) found them effective at capturing all age classes of western pond turtle (*Clemmys marmorata*) in both lacustrine and riverine habitats. Less commonly used basking traps are also effective for all age classes and are the preferred trapping method of smaller or closed waterbodies, which could be impacted by the input of bait from frequently used funnel traps (Ashton et al. 2001). Turtles are air-breathing reptiles, so regardless of trap type it is imperative that they do not sink. In areas where water levels may vary, floats are recommended to allow the trap to fluctuate with water levels (Ashton et al. 2001).

Chapter 10. Plant Species Monitoring

Plant species composition data can serve many important purposes in the Multiple Species Inventory and Monitoring (MSIM) protocol. Terrestrial ecosystems typically support three or more times as many vascular plant species as vertebrate animal species, thus plant species comprise a substantial proportion of their biological diversity (Noss and Cooperrider 1994). Concomitantly, plants typically comprise the greatest number of species of concern in most regions, both in terms of native species with populations at risk and nonnative species that pose risks. Plant species richness and composition can be strong indicators of site condition, including the richness of other species groups (e.g., Murphy and Wilcox 1986), and they are often closely correlated with the richness and composition of animal species.

Plant species monitoring is addressed in a chapter separate from measures of habitat condition (chapter 11) because, although plant species composition can be used as a measure of habitat condition for animal species, its foremost purpose is to monitor populations of individual plant species. With the exception of rare plants, plant species monitoring is not currently a common practice in most regions, and therefore it is not identified as a core survey method in the national framework. Plant monitoring, however, is highly recommended. The recommended survey methods are referred to as primary survey methods, which are equivalent to core methods in that they are the most efficient single or combined approach to detecting the majority of species. No supplemental methods are identified.

The objective of the plant composition surveys described in this chapter is to provide reliable, standardized data on status and change in the distribution and relative frequency of a large number of plant species. Overall, the MSIM protocol is intended to serve as a consistent and efficient method for obtaining spatially and temporally coincident detection/nondetection data and habitat condition data across a diversity of species. The National Framework and basic sampling design of the MSIM protocol is described in chapter 2. Survey methods for animal and plant species are described in the subsequent eight chapters. The National Framework identifies six core survey methods and three additional primary survey methods that together provide information on a representative sample of species in various taxonomic groups and at various trophic levels.

All survey methods associated with the MSIM protocol are designed to be implemented at MSIM monitoring points that are associated with, but offset from, Forest Inventory and Analysis (FIA) grid points on National Forest System lands. The scale of implementation is the national forest, but the primary planning scale is the region to ensure consistency in monitoring approaches for species and habitats shared among forests. The MSIM National Framework calls for a minimum of 50 percent of the FIA grid points to be selected to establish MSIM monitoring points. This core set of monitoring points is to be surveyed over a 3-year sample period with no more than a 5-year resample cycle. Sampling associated with most of the core and primary survey methods is contained within a 200-m radius (approximately 10-ha) sampling hexagon centered on the MSIM monitoring point. Species detections are used to estimate the proportion of monitoring points occupied by the species. For more details on the overall sampling design, see chapter 2.

10.1 Primary Survey Methods

Plant populations are characterized using a combination of FIA protocols (USDA Forest Service 2003) with some additional measures. The primary survey methods consist of fixed plots and transects.

10.1.1 Plot, Quadrat, and Transect Surveys

Current FIA protocols for characterizing plant species composition are conducted at only a small subset (6.3 percent) of FIA points. Given the small proportion of FIA points with plant species composition data, the MSIM protocol measures plant species composition at each monitoring point (offset 100 m to 150 m from the actual FIA point) so the data are spatially coincident with the animal data collected at the monitoring point.

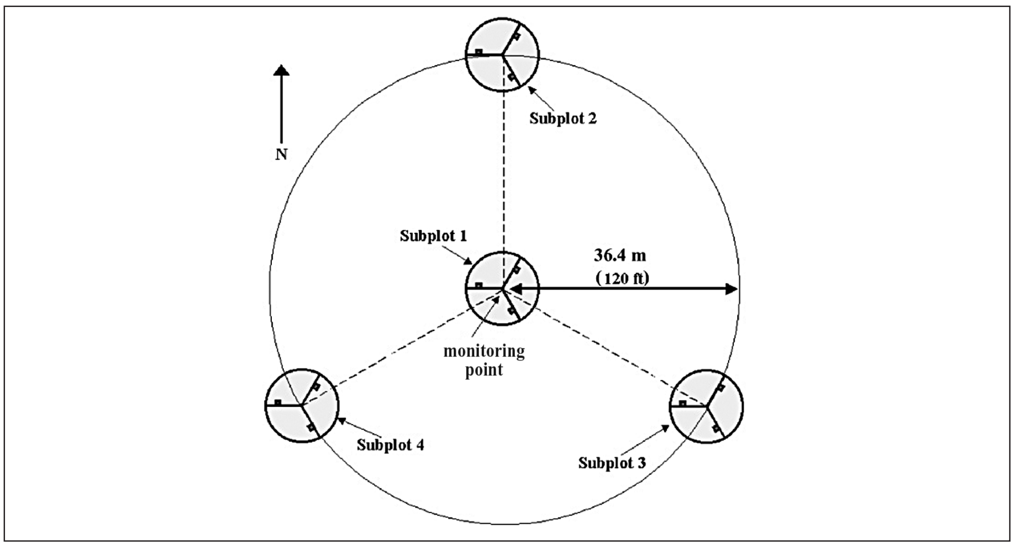
Sampling Design

FIA measures consist of 12 quadrats measuring 1 m^2, imbedded in four 7.3-m radius subplots (three quadrats per subplot) (fig. 10.1). Presence and cover are recorded for all vascular plants, identified to species within each quadrat, and presence and cover of woody plants are recorded within each subplot. In addition to the FIA-based measures, species composition of all plant species is recorded along the 36.4-m transects (dashed lines, fig. 10.1) that connect the center subplot with the other three subplots.

Data Collection

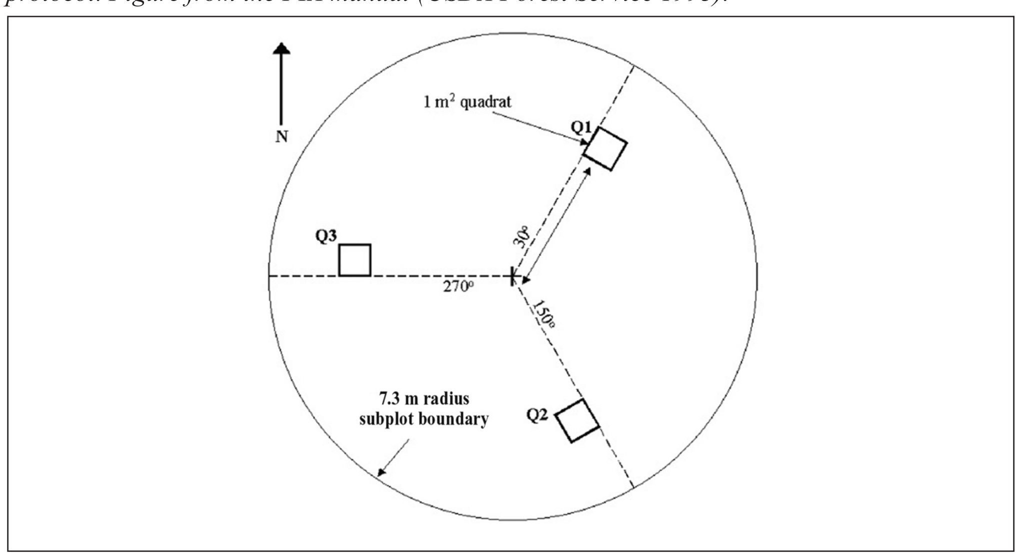
Plant species composition is sampled once at each monitoring point; half the points are then randomly selected for a second sample (visit). Sampling should occur when plants are flowering for ease of identification, which will vary across regions but typically range from spring through mid-summer. Four subplots are established at each monitoring point. (These same subplots are used for habitat measurements. See chapter 11.) Subplots are 7.3-m (24-ft) radius circles arranged in an inverted Y shape with the first subplot centered on the monitoring point, and the other three subplots placed 36.4 m (120 ft) from the center at 120°, 240°, and 360° azimuths (fig. 10.1). Within each subplot, three 1 m^2 quadrats are established (fig. 10.2). From subplot center, three quadrats are located on the right sides of lines at azimuths of 30°, 150°, and 270° for a total of 12 quadrats per monitoring point. Two corners of each quadrat are permanently marked (e.g., chaining pins or stakes) at 4.6 and 5.6 m (15 and 18.3 ft) horizontal distance from the subplot center.

Figure 10.1. *Layout of plant species composition subplots at a monitoring point within a 36.4-m (120-ft) radius circle plot for the MSIM protocol. Figure from the FIA manual (USDA Forest Service 1993).*



FIA = Forest Inventory and Analysis.

Figure 10.2. *Locations of three 1 m^2 quadrats within the subplot boundary for the MSIM protocol. Figure from the FIA manual (USDA Forest Service 1993).*



FIA = Forest Inventory and Analysis.

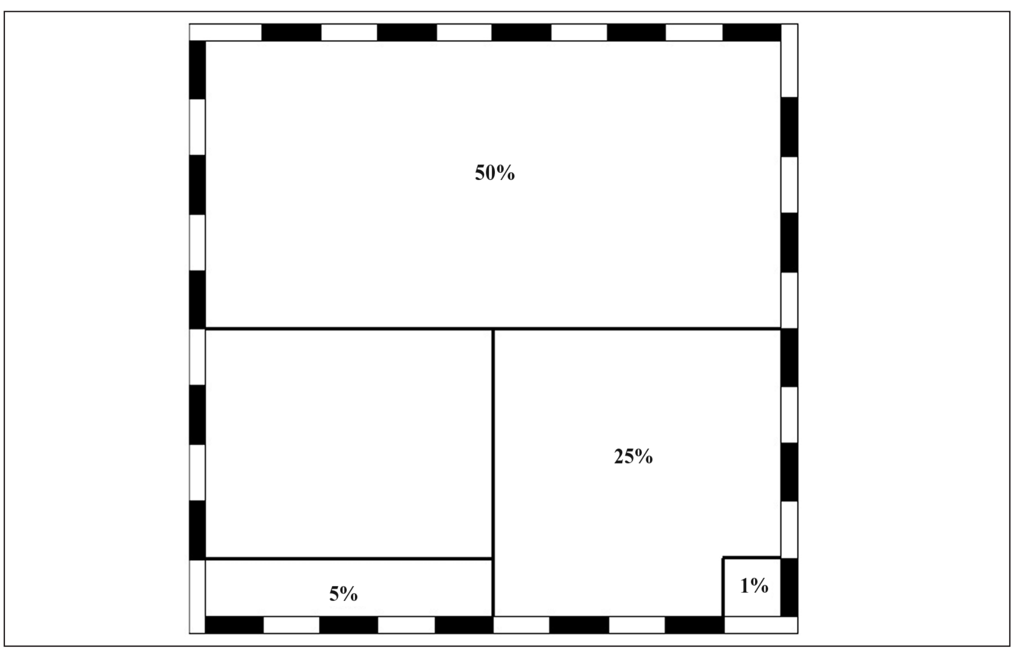
The boundary and cover estimates within the quadrats are aided by using frames calibrated in 10 cm sections (fig. 10.3) to define quadrat boundaries. Reference cover estimate examples are provided below for both quadrats (fig. 10.3) and subplots (fig. 10.4).

A lightweight quadrat frame can be crafted from polyvinyl chloride pipe and joints; epoxy is applied to join joints to one end of each of the four pipes for ease of assembly in the field. Increments can be made most permanent by scoring every other 10 cm section before coloring the section with a permanent marker. Although using colored tape is easiest for marking, it becomes sticky in hot weather.

Quadrat frames are carefully placed at each designated location along the transect. The first measurement requires the installation of permanent pins to mark the corner locations of each quadrat. Each quadrat is leveled before measurement, when necessary, by propping up the quadrat corners. When a quadrat is located on a steep slope the observers positions themselves next to or downhill from the quadrat to prevent sliding or falling into the quadrat.

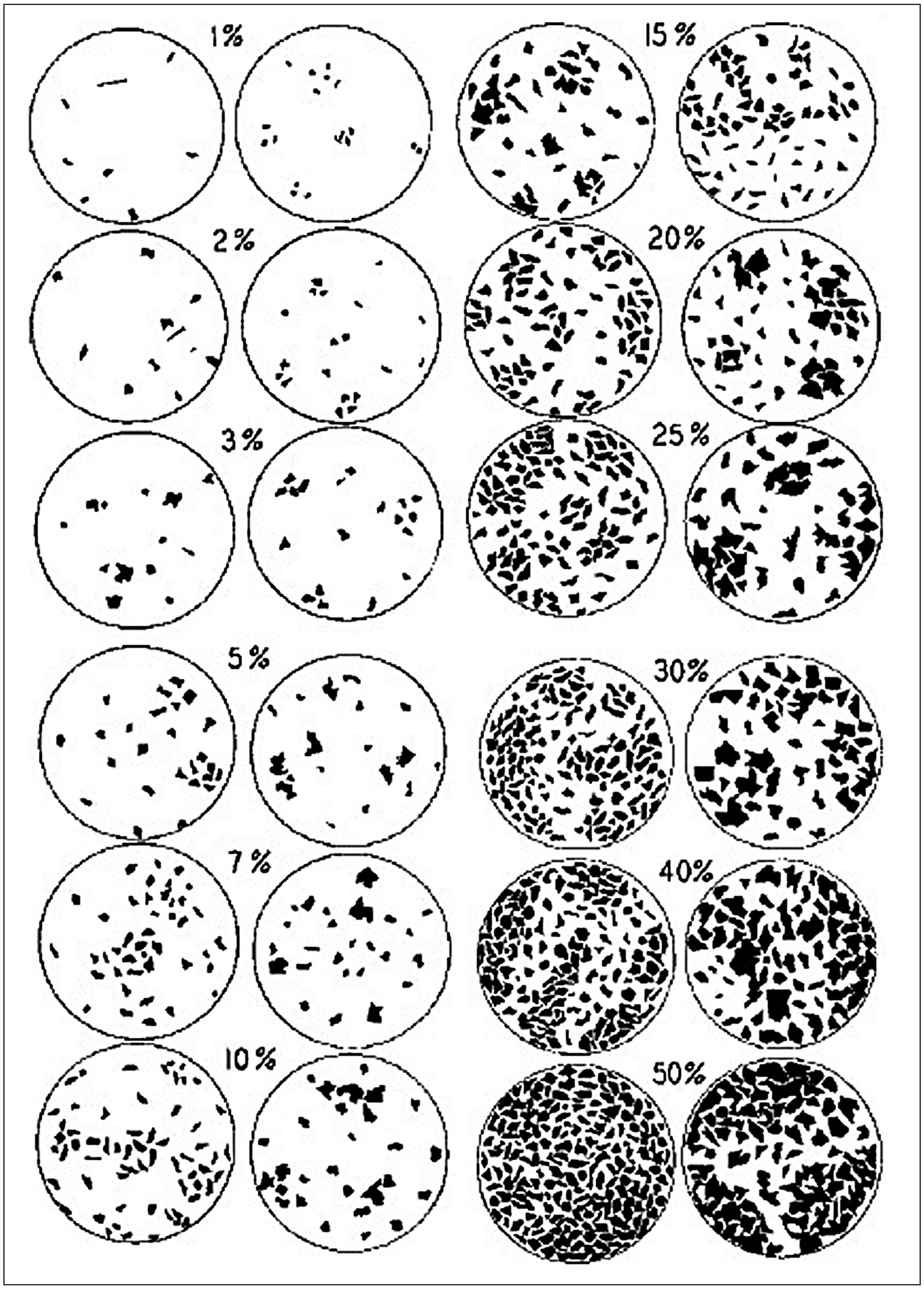
One habitat type code is assigned to each quadrat (table 10.1). When a quadrat contains more than one habitat type, the observer assigns the code for the habitat type that occupies the greatest area in the quadrat. When the quadrat is completely occupied by nonvegetative elements (e.g., water) or is too hazardous to enter (e.g., steep, unstable terrain) the corresponding habitat type number (e.g., 3 or 8, respectively) is entered and the remaining quadrat items left blank.

Figure 10.3. *Diagram of 1 by 1 m quadrat frame depicting 10 cm increments, with illustrations of various cover levels for aiding field estimates for plant species composition, MSIM protocol. Figure from the FIA manual (USDA Forest Service 2003).*



FIA = Forest Inventory and Analysis.

Figure 10.4. *Reference plots for cover estimation for plant species composition subplots and quadrats for the MSIM protocol. Figure from the FIA manual (USDA Forest Service 2003).*



FIA = Forest Inventory and Analysis.

Table 10.1. *Habitat type codes used to describe quadrats for plant composition monitoring as part of the MSIM protocol.*

Code	Habitat type
1	Forest land
2	Small water (.4–1.8 ha standing water, or 9–61 m wide flowing water)
3	Large water (standing water >1.8 ha, or flowing water > 61 m wide)
4	Agriculture (e.g., cropland, pasture, orchard, tree plantation)
5	Developed cultural (e.g., business, residential, urban buildup)
6	Developed rights-of-way (e.g., road, railroad, power line, canal)
7	Rangeland
8	Hazardous (e.g., cliff, hazardous/illegal activity)
9	Other (e.g., beach, marsh; explain in comments)

Cover of each species is estimated to the nearest 1 percent for plants or portions of all vascular plants that fall inside the quadrat frame and are less than 1.8 m (6 ft) above the ground. For each plant species, cover is estimated based on a vertically projected polygon described by the outline of each plant, ignoring any normal spaces occurring between the leaves of a plant. This best reflects the plant's above- and below-ground zone of dominance. The only exception is for species represented by plants that are rooted in the quadrat, but have canopies that do not cover the quadrat or that are more than 1.8 m above the ground; cover for these species is estimated based on their basal area. Percent cover estimates are based on the current years' growth, by including both living and dead material from the current year. Overlap of plants of the same species is ignored such that plants of the same species are grouped together into one cover estimate. Occasionally the canopy of different plant species overlaps; therefore, the total cover for a quadrat sometimes exceeded 100 percent. All trace cover estimates are recorded as 1 percent. The percent cover is recorded for the exact amount present at the time of the plot visit, and not adjusted (i.e., for immature or wilted plants) for the time of year during which the visit was made. In addition to the quadrat measurements, plant species data are collected within each subplot. The species composition and cover of woody plants is estimated to the nearest 1 percent within each subplot.

Plant species are also identified along the three 36.4-m (120-ft) transects that connect the subplots. Observers stop at every third meter, starting near the edge of the center subplot (7 m from the monitoring point), for a total of nine 1-m lengths, along which observers record all plant species that intersect the endpoint of the 1-m line at any height. Height intervals may be used in forested ecosystems, but they need to be consistently applied throughout the region or per ecosystem type (e.g., hardwood forest, grassland). The 1-m line can be represented by any straight object (e.g., fiberglass tape, Biltmore stick), as long as the placement is unbiased (objectively measured and placed on the ground) and consistent. If the line is represented by an object with any width (e.g., Biltmore stick), then one side of the object must be selected and consistently used to represent the line. Plants that cannot be confidently identified to the species level in the field are collected off plot for later identification at the office. Transect data serve two purposes: they distribute samples throughout the area around the monitoring point, and they provide data on the vertical distribution of vegetation by species, which can be an important habitat feature for some animal species (chapter 11).

A minimum of half of the monitoring points selected for plant species monitoring are visited twice, and the selection of these points for a second visit is random. The survey protocol for the second visit consists of the 1-m^2 quadrats in each of the four subplots, and the line transects. A plant species list from the first visit may help speed the identification of plants on the second visit. Species codes are used to represent each plant species found in the quadrat. Species codes used are those of the Natural Resource Conservation Service PLANTS database (http://plants.usda.gov/). The PLANTS database contains cross-references to synonyms and older species names that occur in plant identification field guides.

In addition to plant species composition and cover, the following information is recorded at each visit: date, observer(s), monitoring point number, subplot number (1 = Center subplot, 2 = North subplot, 3 = Southeast subplot, 4 = Southwest subplot) and quadrat number (1 = Quadrat with closest corner located 4.6 m on 30^{o} azimuth from subplot center, 2 = Quadrat with closest corner located 4.6 m on 150^{o} azimuth from subplot center, 3 = Quadrat with closest corner located 4.6 m on 270^{o} azimuth from subplot center). Data are also collected on trampling conditions. Trampling is defined as damage to plants or as disturbance of the ground layer by humans or wildlife. A trampling code is assigned to each quadrat: 1 = Low: 0 to 10% of quadrat trampled, 2 = Moderate: more than 10 to 50% of quadrat trampled, 3 = Heavy: more than 50% of quadrat trampled.

Equipment Needed

Crews will need 1-gallon sealing plastic bags for unidentified plants, 1-m^2 calibrated quadrat frame, hand lens, local flora keys and species lists, newspaper and cardboard, chaining pins or stakes to mark quadrat, countdown timer, plant press, folding hand trowel, access to dissecting scope with illuminator and associated tools (one scope per two-person team), and a PLANTS code book with cross-reference to alternative species names and codes.

Staffing, Training, and Safety

Field crews are two-person teams with complementary skills that work together to enhance the identification skills applied to each site. In general, a team of two skilled botanists can be expected to complete plant species composition and habitat data collection at 30 monitoring points per field season.

Each field crew of four individuals includes a field crew leader (GS-7/9) with the following training: (1) working knowledge of the flora of the area and at least 2 years experience collecting field data; (2) identifying plant species in the field; and (3) using plant identification keys for the area. Ideally, at least one person has expertise in graminoids and grass-like plants to assist in the identification of some of these more difficult to identify taxa (e.g., species in the genus *Carex*). Crew leaders need to be capable of effectively training and supervising field crews (e.g., good communication skills, positive attitude, attention to detail), knowledgeable of specimen collection and preservation techniques, and experience working in remote areas. Crew leaders are responsible for training all crewmembers to a common standard level of skill, setting and enforcing strict data quality and penmanship standards, maintaining equipment in good working order, setting an example of safe/efficient field working habits, and identifying questions/concerns from crew members that need to be addressed by the program supervisor. Field crew leaders are also responsible for quality data collection, field checks, and maintaining a reference collection of plants for the area; the area is determined in a regional plan and coordinated across all field crews in the area.

Crewmembers are GS-4/5 biological technicians with a minimum of academic training in general botany, knowledge of plant species of the area, and skill in using plant species keys. It is especially important that each crew member understand the importance of following the specified protocol, paying close attention to detail to avoid misidentifying plants, and taking high-quality notes in the field.

Two weeks of training are required for all employees each year. Training can consist of a variety of methods to familiarize field crews with field methods and plant identification, including (1) visiting one or more university herbarium collections to study the variability of defining characteristics of plant species in the area; (2) field trips with local plant experts to various locations to identify plants in the field (may need to schedule these at a couple of points in the field season as new plant species emerge); (3) conducting several practice surveys (with the entire field crew together and with one-on-one training of crew member by crew leaders); and (4) targeting geographic areas with representatives of the species occurring on the forest and a variety of habitat types, including aquatic, so crewmembers gain experience with the variety of conditions and sites encountered in the field. All field personnel must have a minimum of basic first aid training, and preferably training in wilderness medicine (e.g., wilderness first responder).

Quality Control and Assurance

Sources of error in detecting plant species include timing of surveys, vigilance of observer, plant identification skills of observer, accurate location of quadrat with each visit, and site disturbance by field personnel. Multiple visits (n = 2) at a subset of points are designed to minimize detection limitations based on survey timing, and having different observers collect data at each visit will help mitigate vigilance and identification weaknesses associated with individual observers. Observer vigilance and identification skills are a function of training and motivation; they are evaluated and enhanced by "hot checks" in the field, which consist of both observers simultaneously and independently recording data for one quadrat, and then comparing data after the quadrat is completed to identify differences and the actions necessary to correct them. In addition to field crewmember comparisons, the crew leader will rotate through each crewmember or team and participate in hot checks to identify problems and correct them in a timely manner.

Unidentifiable plants are assigned a unique code, and a specimen outside the quadrat is collected for later identification. Not all plants are readily identifiable to species because of growth stage, missing plant parts, or animal and human disturbance. The most complete specimen available is collected, including as much as possible of roots, stem, leaves, fruit, seeds, or cones. When an unidentified plant species is very uncommon in the plot area (i.e., fewer than five individuals found) it is not collected and the species genus is entered as the PLANT code in place of the species code when possible or the unknown code "UNRARE" is entered. When no live plants are found within the quadrat, the code "NOPLANTS" is entered and all other information pertaining to that quadrat is recorded.

Data Storage and Analysis

Data analysis consists of creating species lists for each monitoring point for each visit (half of the monitoring points have two visits), and estimating the proportion of all monitoring points occupied within the entire area of inference, using the probability of presence and detection probabilities as parameters in a maximum likelihood model. (See chapter 2, section 2.6.2.) The freeware program PRESENCE is available for this analysis (http://www.mbr-pwrc.usgs.gov/software.html). The species detection data from sampling at each monitoring point are compiled to create detection histories for each visit to each monitoring point for each species. Detection histories consist of either a "1" for the entire sample unit (regardless of the number of detections) or a "0" if no detections were made. For example for two visits, the detection history for a given species will be 00, 01, 10, 11, 1x, or x1, 0x, or x0, where x represents that a second visit was not conducted.

The number of quadrats and line transects with detections can serve as a measure of frequency of occurrence. Sampling adequacy can be evaluated by calculating species accumulation per quadrat and/or line transect, estimating the probability of detection per unit effort, and estimating the power to detect a trend of a given magnitude and precision given the existing sample effort. Sample effort may then be adjusted if indicated by the analysis.

Data sheets are checked by fellow crewmembers at the end of each day to ensure all fields are filled out correctly and legibly. This check also serves to identify discrepancies in species identification among observers and alert observers to unusual species or situations that they may encounter the next day. Field crew leaders check all data sheets at the end of each week to review species identification and quality of data recording.

Voucher specimens for each ecoregion in each region should be archived and stored at a designated national forest (or the regional office) in a climate controlled environment for training and verification. Rare species or species of special interest should be reported to U.S. Department of Agriculture, Forest Service personnel and State natural heritage programs.

Chapter 11. Habitat Monitoring

Habitat monitoring for the Multiple Species Inventory and Monitoring (MSIM) protocol consists of repeated measures of basic environmental characteristics that are strong determinants of habitat conditions for many vertebrate species. It is not essential that habitat monitoring data be collected at the same spatial or temporal scale as the plant and animal data, as long as the spatial scale and resolution of environmental measures are compatible with the key features that define habitat for individual species. Spatially and temporally coincident population and habitat data collection has multiple important advantages, however, particularly at the start of a monitoring program. For example, although environmental condition measures can be used to characterize habitat status and change based on preconceived notions of habitat associations for species, spatially and temporally coincident population and habitat data collection makes it possible to develop, validate, or improve habitat relationship models to strengthen the scientific basis of how habitat is defined and characterized for species. It also enables the analysis of coincident patterns of population and habitat change that can be used, in concert with other environmental data, to hypothesize what causal factors may be responsible for observed changes in populations or habitats.

Forest Inventory and Analysis (FIA) data can make a substantial contribution to habitat monitoring for many species (http://www.fia.fs.fed.us). The FIA point is located in close proximity to the MSIM sampling hexagon, and Phase 2 FIA protocols measure many of the basic environmental characteristics targeted by the MSIM protocol. It is unlikely, however, that FIA data alone will be sufficient to characterize habitat for many species given its emphasis on woody vegetation and longer remeasurement periods (typically 10 to 15 years) compared to MSIM (5 years). More detailed environmental measurements taken in a spatially and temporally coincident manner with population data are needed to determine the environmental characteristics most pertinent to each species, and in what manner FIA data fall short. Thus, MSIM calls for describing environmental characteristics at the same time and place as population measures *during the first sample period* (i.e., the first time monitoring points are sampled), after which the adequacy of FIA and MSIM data can be evaluated, and measurements at FIA and MSIM points can be refined to most efficiently characterize habitat conditions for species of concern and interest. Once habitat relationships are determined for monitored species, environmental condition measurements in subsequent sample periods are likely to consist of either augmented data collection at the FIA point, or standard measurements at the FIA point plus a core set of environmental condition measures at the MSIM monitoring point.

No aquatic equivalent of FIA exists in terms of an existing monitoring program being conducted consistently across National Forest System and other public lands. The Aquatic Ecological Unit Inventory (AEUI) technical guide (Hixson et al. 2005), however, specifies the key biophysical features and attributes of riverine ecosystems to measure, and standardized methods by which to measure them. The national attributes in the AEUI technical guide are included here as core environmental measures of riverine ecosystem condition, thereby implementing AEUI in the context of an integrated national monitoring program for plants and animals. No nationally standardized measures existed for lacustrine ecosystems (i.e., open standing water, such as lakes and ponds), so the measurements identified here target environmental characteristics that are typically important for aquatic vertebrates, and field methods that are commonly employed and effective.

11.1 Terrestrial Sampling Methods

A summary of environmental variables derived from field and remotely sensed data are provided in table 11.1. At monitoring points, FIA measurements (Phase 2 and some of Phase 3) serve as the primary environmental measures. In addition to FIA measurements, canopy cover, ground cover, and vegetation height profiles are measured.

The range of variables to be described at survey locations differ among taxa and detection methods. Data on species composition, vegetation structure, ground cover, and canopy cover are collected at the monitoring point (section 11.1.1), and an additional simplified set of measurements are taken at a sample of the distal survey locations (e.g., additional point count stations as in section 11.1.2). Aquatic site characteristics are measured with an additional set of field methods (section 11.2). Other data sources (i.e., weather stations, satellite imagery) are used to describe a range of environmental variables at the monitoring point (e.g., precipitation, aspect, slope, temperature) and at larger scales around the monitoring point (e.g., vegetation types). Environmental measures are described below for sampling locations associated with all core survey methods.

Table 11.1. *Environmental variables described at monitoring points.*

Environmental variable	Metric	Source	Sample sites: Center monitoring point	Sample sites: Point count stations (outer)	Sample sites: Bat sites (terrestrial)	Sample sites: Trackplate stations
Abiotic environment						
UTM coordinates		FLD	X	X	X	X
Slope	percent	GIS	X	X	X	X
Aspect	azimuth	GIS	X	X	X	X
Distance to water	m	GIS	X	X	X	X
Elevation	m	GIS	X		X	
Precipitation	cm	GIS	X		X	
Vegetation						
Tree density by size class	stems per ha	FLD	X	X		X
Tree decadence	frequency by type	FLD				
Stump density	stumps per ha	FLD	X	X		X
Canopy cover	percent	FLD	X	X	X	X
Ground cover by type	percent per type	FLD	X	X		X
Litter depth	m	FLD	X	X		
Log density	m/ha	FLD	X	X		X
Snag density	stems/ha	FLD	X	X		X
Vertical vegetation profile	frequency by ht interval	FLD	X	X		
Tree diameter	average d.b.h. and basal area	FLD	X	X		X
Tree species composition	species list	FLD	X	X		X
Shrub species composition	species list	FLD	X	X		
Shrub cover by species	percent	FLD	X	X		
Vegetation type composition	prop. area within 100, 300, and 1000 m	GIS	X	X	X	X
Disturbance						
Site disturbance	proportion of area	FLD	X	X	X	X
Surrounding disturbance	proportion of area	GIS	X	X	X	X

d.b.h. = diameter at breast height; FLD = field data; GIS = Geographic Information System data sources; UTM = Universal Transverse Mercator.

11.1.1 Monitoring Point Measurements

Environmental conditions are described at the MSIM monitoring point (table 11.1), where they are spatially coincident with the following core and primary survey locations: a point count station, a trackplate station, a segment of small mammal trap transect, and plant species composition quadrats and subplots. Environmental variables are described using nested circular plots and transects centered on the monitoring point. At the center point, the following basic information is recorded:

- The location of the center point using a Global Positioning System (GPS) instrument.
- Vegetation type as per the standard classification scheme used throughout the region.

The nested circular plots that are consistent with FIA protocols (USDA Forest Service 2003) are implemented at the center point to describe tree density: a 0.017-ha subplot (0.0425 ac; 7.3 m; or 24-ft radius) for small trees (same plot as used for shrub and herb cover in chapter 10), a 0.1-ha plot (0.25 ac; 17.6 m; or 58-ft radius) for larger trees, and a 1-ha plot for the largest trees (2.5 ac; 56.5 m; or 186-ft radius) (an FIA add-on). For more detailed descriptions of measurement protocols, refer to the 2003 FIA field instructions manual (USDA Forest Service 2003). The perimeter of each plot is estimated based on a few taped measurements to establish the bounds of the plots.

Within each 0.017-ha (0.0425-ac) subplot, the following information is recorded:

- An ocular estimate of percent cover of litter, vegetation (including trees), rock, and soil/sand (should add up to 100 percent).
- For each tree greater than or equal to 12.5 cm (5 in) in diameter, the species, diameter at breast height (d.b.h.), and height to the nearest meter, and all decadence features (table 11.2).
- For each snag greater than or equal to 12.5 cm (5 in) in diameter, the species, d.b.h., height estimated to the nearest meter, and decay class (table 11.3).

Within each 0.1-ha (0.25-ac) plot, the following information is recorded:

- For each tree greater than or equal to 28 cm (11 in) in diameter, the species, d.b.h., height estimated to the nearest meter, and all decadence features (table 11.2).
- For each snag greater than or equal to 12.5 cm (5 in) diameter, the species, d.b.h., height estimated to the nearest meter, and decay class (table 11.3).

Within each 1-ha (2.5 ac) plot, the following information is recorded:

- For each tree greater than or equal to 60 cm (24 in) in diameter, the species, d.b.h. (at 1.4 m or 4.5 ft as measured using a d.b.h. tape or a Biltmore stick), and decadence (table 11.2) are recorded. All decadence and damage features observed are recorded and the approximate number of each per tree.

- For each snag greater than or equal to 30.5 cm (12 in) in diameter, the species, d.b.h., height estimated to the nearest meter, and decay class (table 11.3) are recorded. A clinometer is used to measure the height of a subset of snags or trees in each height class, with the remaining heights being estimated. Snag heights are measured as the distance from the ground straight up, parallel to the line of gravity, to the top of the tree such that the height of leaning trees is not recorded as the length of the trunk.

In addition to the nested plots, a variety of environmental variables are described in the field at points and transects associated with the center point (table 11.1).

Coarse woody debris. Two coarse woody debris transects are established emanating from the center point out at 0º and a random selection of either 120º or 240º (corresponding to the transect lines used for plant monitoring as in chapter 10). Each transect is 35 m long and runs from the center of the plot outward. It is important that the transects are laid in a straight line to avoid biasing the selection of pieces and to allow the remeasurement of transect lines and tally pieces for future change detection. Along each transect, the following information is recorded for each log less than 7.6 cm (3 in) in diameter at the large end that touched the transect line: diameter at small end, diameter at large end, length to the nearest 0.5 m, and decay class (table 11.3). For logs that are broken into portions, each separate portion is considered a single log, provided that the pieces are completely separated.

Vertical diversity. If plant monitoring is not conducted (chapter 10), then the vertical diversity of vegetation is described along the coarse woody debris transects as part of habitat monitoring. Observers stop at every third meter, starting near the edge of the center subplot (7 m from the monitoring point), for a total of nine 1-m lengths. Observers record all plants that intersect the endpoint of the 1-m line at any height. Woody plants are identified to species, and herbaceous plants are recorded as graminoid if grass, and as herbaceous if herbaceous plant. The 1-m line can be

Table 11.2. *Decadence codes for live trees.*

Decadence code	Decadence feature
1	Conks
2	Cavities > 6 inches in diameter
3	Broken top
4	Large (> 12 inches in diameter) broken limb
5	Loose bark (sloughing)

Table 11.3. *Decay classes for (a) snags and (b) logs.*

(a) Snags

Decay class code	Limbs and branches	Top	Bark remaining	Sapwood presence and condition	Heartwood condition
1	All present	Pointed	100%	Intact; sound, incipient decay, hard, original color	Sound, hard, original color
2	Few limbs, no fine branches	May be broken	Variable	Sloughing; advanced decay, fibrous, firm to soft, light brown	Sound at base, incipient decay in outer edge of upper bole, hard, light to reddish brown
3	Limb stubs only	Broken	Variable	Sloughing; fibrous, soft, light to reddish brown	Incipient decay at base, advanced decay throughout upper bole, fi-brous, hard to firm, reddish brown
4	Few or no stubs	Broken	Variable	Sloughing; cubical, soft, reddish to dark brown	Advanced decay at base, sloughing from upper bole, fibrous to cubical, soft, dark reddish brown
5	None	Broken	< 20%	Gone	Sloughing, cubical, soft, dark brown, or fibrous, very soft, dark reddish brown, encased in hardened shell

(b) Logs

Decay class code	Structural integrity	Texture of rotten portions	Color of wood	Invading roots	Branches and twigs
1	Sound, freshly fallen, intact logs	Intact; no rot; conks of stem decay absent	Original color	Absent	If branches are present, fine twigs are still attached and have tight bark
2	Sound	Mostly intact; sapwood partly soft (starting to decay) but cannot be pulled apart by hand	Original color	Absent	If branches are present, many fine twigs are gone and remaining fine twigs have peeling bark
3	Heartwood sound; piece supports its own weight	Hard, large pieces; sapwood can be pulled apart by hand or sapwood absent	Reddish brown or original color	Sapwood only	Branch stubs will not pull out
4	Heartwood rotten; piece does not support its own weight, but maintains its shape	Soft, small blocky pieces; a metal pin can be pushed into heartwood	Reddish or light brown	Throughout	Branch stubs pull out
5	None; piece no longer maintains its shape; it spreads out on ground	Soft; powdery when dry	Reddish brown to dark brown	Throughout	Branch stubs and pitch pockets have usually rotted down

represented by any straight object (e.g., fiberglass tape, Biltmore stick), as long as the placement is unbiased (objectively measured and placed on the ground) and consistent. If the line is represented by an object with any width (e.g., Biltmore stick), then one side of the object must be selected and consistently used to represent the line. Height intervals may be used in forested ecosystems, but they need to be consistently applied throughout the region or per ecosystem type (e.g., hardwood forest, grassland). These data are used to calculate relative frequency of woody plant species and vertical diversity of vegetation by life form.

Ground cover. Ground cover measurements are taken along each of the vertical diversity lines. Along each 1-m line, the percentage of the 1 m length along one side of the line occupied by each of seven ground cover types is estimated: herbaceous plant, grass, shrub, tree, rock, litter, bare soil.

Litter depth. Three litter depth measurements are taken along both woody debris transects at 2.4, 4.8, and 7.3 m (8, 16, and 24 ft, respectively) from plot center. Litter depth is measured by digging a small hole through the litter (can use finger) and down into the mineral soil, with care not to compress the litter around the edge of the hole. The depth of litter at the edge of the hole is measured with a pocket ruler. Litter depth is measured perpendicular to the ground surface. Areas where litter is collected for the trapping protocol are avoided.

Canopy cover. Canopy cover estimates are taken with a densiometer, with four readings being taken in each of the four cardinal directions of the perimeter of the 0.017-ha subplots for a total of 16 measurements per plot.

Site disturbance. Disturbance is described within 30 m of the monitoring point, including the following:

- Area of each type of road (m^2)—highway, paved road, primary use dirt road, secondary dirt road.
- Area of trails (m^2).
- Additional area (m^2) of compacted soil and impermeable surfaces.

11.1.2 Point Count and Trackplate/Camera Station Measurements

Environmental conditions are described at each of the three point count stations forming the hexagon around the center (i.e., stations PC2, PC4, and PC6 as in chapter 3, fig. 3.1), as well as each of the four trackplate/camera stations surrounding the center point (i.e., trackplate stations TP2 and TP3, and camera stations TM2 and TM3 as in chapter 6, fig. 6.1). Measurements at these distal sampling locations are simplified relative to the center point in the following manner:

- Tree heights are not recorded for any live trees; however snag heights are still recorded.
- Ground cover measurements along each woody debris transect are recorded (as a check for the subplot estimates) by ground cover type, not species. The following seven ground cover types are used: herbaceous plant, grass, shrub, tree, rock, litter, bare soil. All shrubs and trees are identified to species, and other plant types are identified to species when possible.

11.2 Aquatic Ecosystem Sampling Methods

Environmental conditions are characterized at each aquatic site that is sampled by aquatic visual encounter surveys and aquatic point counts (table 11.4). Sites that are only sampled for bats are described in much less detail in the field because only a few characteristics seem to be factors in the use of sites for foraging, and it is the surrounding environment and special habitat elements (e.g., roost site substrates) within a large area that affect the presence and abundance of bats in the area.

Table 11.4. *Environmental variables described at aquatic sites associated with MSIM monitoring points.*

Environmental variable	Metric	Source	Sample sites	
			Bat mist netting sites	Aquatic sample sites
Abiotic environment				
UTM coordinates	percent	FLD	X	X
Slope	azimuth	GIS	X	X
Aspect	m	GIS	X	X
Elevation	cm	GIS	X	X
Precipitation		GIS	X	X
Lacustrine sites				
Lacustrine type		FLD	X	X
Area	ha	FLD	X	X
Perimeter	m	FLD	X	X
Maximum depth	m	FLD	X	X
Surface occlusion	percent	FLD	X	X
Canopy cover	percent	FLD	X	X

Table 11.4. *Environmental variables described at aquatic sites associated with MSIM monitoring points (continued).*

Environmental variable	Metric	Source	Sample sites	
			Bat mist netting sites	**Aquatic sample sites**
Littoral water depth	m	FLD		X
Littoral substrate frequency and cover	proportion of transects	FLD		X
Littoral log frequency	proportion of transects	FLD		X
Littoral plant frequency	proportion of transects	FLD		X
Shoreline substrate frequency and cover	proportion of transects	FLD		X
Shoreline log frequency	proportion of transects	FLD		X
Shoreline plant frequency	proportion of transects	FLD		X
Fish species presence and abundance	abundance classes	FLD		X
Site disturbance	proportion of area	FLD		X
Surrounding disturbance	proportion of area	GIS	X	X
Riverine sites				
Riverine type	category	FLD	X	X
Gradient	percent	FLD	X	X
Sinuosity	index	FLD		X
Bankfull width and depth	cm	FLD		X
Stream bed material	sediment type frequency	FLD		X
Large woody material	count	FLD		X
Length of pool habitat	m	FLD		X
Residual pool depth	cm	FLD		X
Fish species presence	presence	FLD		X
Site disturbance	proportion of area	FLD		X
Surrounding disturbance	proportion of area	GIS	X	X

FLD = field data; GIS = Geographic Information System data sources; UTM = Universal Transverse Mercator.

Lacustrine Site Measurements

At each lacustrine site sampled for animals other than bats, the following data are recorded in the field (table 11.4).

Location. The spatial location of the site is determined using a GPS instrument.

Habitat type. Every lacustrine site is classified by type (e.g., tarn, pond, oligotrophic lake, bog, fen) according to a published and commonly used aquatic classification for the region or ecoregion (e.g., Moyle 1996).

Unit area. Observers estimate area by estimating average length and width, and pacing the circumference (m). Field measurements are checked against digital data. Sample unit area and perimeter can be obtained from paper or digitized U.S. Geological Survey (USGS) topographic maps.

Maximum depth. Size and depth information provides a measure of the proportion of the site with suitable water depths for various species. If current data on depths are not available from other sources, depth estimates are obtained in the field. For shallow units, observers wade to the deepest part of the sample unit and measure depth to the nearest 0.1 m using a polyvinyl chloride pipe or other measuring device. For sample units up to 30 m deep, observers can use an inflatable device to get to the center of the unit and measure the depth by lowering a weighted line to the bottom. One simple option is to use a reel with a lead sinker attached to a heavy fishing line on which 1-m increments are delineated. Maximum lake depth is recorded as the greatest depth (to the nearest 0.5 m) obtained from five measurements in locations likely to be at or near the deepest part of the sample unit.

Littoral depth and substrate. A minimum of 30 littoral zone transects are established at each lacustrine site to quantify shoreline depth, substrate, woody debris, and emergent vegetation. At lakes and ponds, transect locations are determined according to paced or timed intervals as one moves around the perimeter of the lake so that a minimum of 30 transects are measured. For lakes and ponds, each transect consists of a visualized line running perpendicular to the shoreline and extending 3 m into the water from the water's edge at the time of sampling. For wet meadows and fens, a randomly determined starting point is selected for a straight line across the longest dimension of the meadow. Observers walk from that point to the opposite end of the meadow, determining transect starting points by pacing the distance between points to ensure that 30 transects are conducted per site. Transect direction is based on a random compass bearing from the observer's position. For each transect, observers record the depth at 1 m, 2 m, and 3 m (end of the transect), and the percent of transect occupied by each of 6 substrate types: silt, sand (particle size less than 2 mm), pebbles (2 to 75 mm), cobbles (greater than 75 to 300 mm), boulders (greater than 300 mm), or bedrock.

Littoral vegetation and woody debris. Along each 3-m littoral zone transect, the presence of littoral zone plant species intersecting the transect line are also recorded, including noting whether the plants are submergent, floating on surface, emergent (breaking the surface of the water), or overhanging (less than 10 cm above the water). All plants intersecting each transect are identified to species whenever possible or at a minimum to genus. Littoral zone plants are defined as rooted underwater or unattached and floating on the surface. Woody debris is also recorded along each transect. For all logs greater than or equal to 10 cm diameter at the large end that intersect the transect, the species (if possible), diameter at each end, and length of the log is recorded.

Shoreline substrate and vegetation. Shoreline substrates and vegetation are characterized along transects that extend from the water's edge to 3 m into the surrounding terrestrial zone. For each transect, observers record the percent of the transect occupied by each of six substrate types: silt, sand (particle size less than 2 mm), pebbles (2 to 75 mm), cobbles (greater than 75 to 300 mm), boulders (greater than 300 mm), or bedrock. They also record plants (to genus) intersecting the transect. If botanical expertise is limited, herbaceous plants may be recorded by groups or life forms that reflect consistent life history characteristics (e.g., rushes and sedges, willow, pond lily, grass).

Surface occlusion. The proportion of the surface of the site that is occluded by vegetation and logs is estimated.

Canopy cover. Canopy cover is taken at four locations around the site: the north, south, east, and west compass bearings. At each location, densiometer readings are taken in each cardinal direction, and then cover is recorded as the average of the four readings at each location.

Site disturbance. Disturbance is described within 30 m of the high watermark in lacustrine sites, including the following:

- Area of each type of road (m^2) within 10 m of shore and between 10 and 30 m of shore—highway, paved road, primary use dirt road, secondary dirt road.
- Area of trails (m^2) within 10 m of shore and between 10 and 30 m of shore.
- Additional area (m^2) of compacted soil and impermeable surfaces within 10 m of the shoreline.

At sites only sampled for bats, measurements taken in the field consist of only lacustrine type, area, perimeter, maximum depth, surface occlusion, and canopy cover.

Riverine Site Measurements

The AEUI technical guide (Hixson et al. 2005) provides a standard set of measurements to characterize riverine ecosystem conditions. It addresses two scales: valley segment and river reach. The AEUI guide identifies a set of national attributes that are to be applied consistently across all forests and regions. These national attributes are consistent with and identified as core survey methods in MSIM. The AEUI guide also identifies a set of regional attributes that are recommended for implementation as needed and are expected to vary in their use among regions. These regional attributes are consistent with and identified as supplemental survey methods in MSIM.

The national attributes at the reach scale are reiterated here based on Hixson et al. (2005) for the sake of completeness of the MSIM technical guide (table 11.4). More detail and references are provided in Hixson et al. (2005). Note that the most current version of the AEUI technical guide should be consulted and followed to ensure the set of attributes and their measure is consistent with AEUI. National attributes for the valley segment scale are all derived based on remotely sensed data (e.g., aerial photographs, satellite imagery, topographic maps). They are not critical to derive for the purposes of describing habitat conditions for species monitored by MSIM, but if aquatic sites are used to monitor aquatic systems as part of AEUI, then they should be generated for each sample site. The AEUI technical guide describes a large number of regional attributes that provide additional valuable data for aquatic ecosystems and associated species. The AEUI technical guide should be consulted to determine which of the regional attributes are desirable to include in regional monitoring strategies.

Sampling to describe the core environmental variables (i.e., national attributes) proceeds from the downstream end, upstream, toward the top of the reach. At each riverine reach sampled for animals other than bats, the following attributes are described:

Location. The downstream and upstream ends of the reach are determined using a GPS instrument.

Stream type. The stream type is classified according to a published and commonly used aquatic classification for the region or ecoregion (e.g., Moyle 1996).

Sinuosity. Sinuosity is an indicator of channel slope adjustment to valley slope (Rosgen 1996), and it is used to distinguish channel patterns (e.g., straight vs. meandering). Sinuosity may be measured in the field or from remotely sensed data, but gradient measurements require the length of the stream to be measured in the field.

Gradient. Gradient provides an indication of stream slope and energy and is used in reach classification. A range of instruments offering varying levels of precision are available, but for MSIM, a hand level is sufficient. The objective is to measure the difference in elevation between the upstream and downstream ends of the reach. If the reach is longer than the standard 300 m, then the gradient between the end of the reach and the 300 m mark should also be recorded. Observers measure the gradient of each length of stream with relatively consistent gradient, as indicated by the characteristics of the flow (e.g., pool, riffle, cascade). Estimate the gradient to three decimal places. The distance between measurements is determined with a tape or GPS by following the actual river length (the thalweg channel or the channel centerline).

Bankfull characteristics. Bankfull width and mean bankfull depth are used in stream channel classification (Rosgen 1996). The relationship between bankfull width and depth expressed as a width:depth ratio is an indicator of channel condition. Bankfull stage is defined as the elevation of the active floodplain. Bankfull stage is determined from visual identification using indicators such as the elevation of flat depositional surfaces adjacent to the channel, the tops of mature point bars, and breaks in slope from horizontal to vertical. Guidance on proper identification of bankfull stage is available in U.S. Department of Agriculture Forest Service training videos (USDA Forest Service 1995, 2002) and published references (e.g., Harrelson 1994). Cross-section transects are situated perpendicular to the stream flow on the first four riffles starting at the downstream end of the reach. Bankfull width and depth measurements are taken at each cross-section. Channel depths from streambed to bankfull channel height are taken at 20 locations along the cross-section. Width:depth ratios are calculated for each cross-section (Harrelson et al. 1994).

Streambed material size. Substrate size distributions can provide an indication of relative suitability of stream condition for various aquatic organisms. Changes in particle size distribution have been used to monitor the impacts of land management activities on streams (Potyondy and Hardy 1994). The Wolman Pebble Count Procedure (1954) is the most commonly used, simple, and rapid protocol for characterizing bed material size distribution (MacDonald et al. 1991). Limiting sampling to riffle habitats reduces variability between samples, has significance to aquatic species, and takes place in habitat shallow enough to be sampled. Pebble counts occur in the same four riffles used to characterize width:depth ratio (see above). A grid of 25 equally spaced measurement points is used to select particles for measurement. The width and length of the grid and the distance between its points are determined by the width of the stream bottom (grid points are restricted to the stream bottom, defined as the area of the stream that is virtually bare of vegetation) and the size of the largest particles in the riffle (adjacent grid points must not fall on the same particle). Once the dimensions of the grid are determined, observers may estimate the location of each grid point to locate its associated particle, and then the particle is measured. Measure the intermediate-sized axis of the particle (i.e., the width, as opposed to the height or the depth) to the nearest mm. Particles are then classified into the following size categories:

- < 2 mm = fines.
- ≥ 2 to < 4 mm = very fine gravel.
- ≥ 4 to < 8 mm = fine gravel.
- ≥8 to < 16 mm = medium gravel.
- ≥ 16 to < 32 mm = coarse gravel.

- ≥ 32 to < 64 mm = very coarse gravel.
- ≥ 64 to < 128 mm = small cobble.
- ≥ 128 to > 256 mm = large cobble.
- ≥ 256 to < 512 mm = small boulder.
- ≥ 512 to < 2,048 mm = medium boulder.
- ≥ 2,048 to 4,096 mm = very large boulder.
- ≥ 4,096 mm = bedrock.

Large woody material. Large, instream wood plays an important role in determining physical characteristics of stream channels (Fetherston et al. 1995, Buffington and Montgomery 1997). Its distribution affects the abundance and distribution of lotic biota (Bisson et al. 1987). The protocol suggested in the AEUI technical guide is used by the U.S. Environmental Protection Agency's Environmental Monitoring and Assessment Program (Kaufman et al. 1999). This protocol has been used across the United States, but has size classes that may be too small for the Pacific Northwest rainforest and too large for eastern streams. All woody material greater than or equal to 10 cm in diameter and greater than or equal to 1.5 m in length is recorded along the length of the stream reach, and each piece is classified into one of four diameter classes: 10 cm to 29 cm; 30 cm to 59 cm; 60 cm to 79 cm; and greater than or equal to 80 cm. Each piece is also classified into one of three length classes: 1.5 m to 4 m; 5 m to 14 m; and greater than or equal to 15 m. If the reach extends beyond 300 m, woody material occurring within the first 300 m is noted as such.

Length of pool. Pools are an important aquatic habitat type for aquatic organisms. They furnish deep water and cool temperatures during dry, hot periods. During drought cycles, pools may supply the only available habitat during certain seasons. For this protocol, pools are habitat types defined by the following characteristics: (1) bounded by a head crest (upstream break in slope) and a tail crest (downstream break in slope); (2) concave in profile; (3) occupy greater than half of the wetted channel width; (4) maximum pool depth is at least one and a half times the pool tail depth; and (5) pool length is greater than its width. Pools should only be considered for these calculations if they are main-channel pools (the thalweg runs through the pool) and not side-channel pools. Sampling occurs when streams are at base flow (post snow melt). The length of each identified pool is measured along the thalweg between the head crest and tail crest recorded to the nearest centimeter. The percent pool habitat is determined by adding the lengths of each pool and dividing by the river reach length.

Residual pool depth. Residual pool depth is the maximum depth of water in a pool if water was not flowing over the pool-tail crest. The maximum depth represents the deepest point in the pool and is located by probing with a depth rod until the deepest point is located. The pool tail crest depth is measured at the maximum depth along the pool tail crest. Record both maximum pool depth and pool tail crest depths to the nearest centimeter. The residual depth of a pool is calculated as the maximum depth in the pool minus the depth at the pool tail crest. River reach wide residual depth will be estimated by adding the residual pool depth of all pools in the river reach, then dividing by the number of pools.

Site disturbance. Disturbance is described within 30 m of the high watermark in lacustrine sites, including the following:

- Area of each type of road (m^2) within 10 m of shore and between 10 and 30 m of shore—highway, paved road, primary use dirt road, secondary dirt road
- Area of trails (m^2) within 10 m of shore and between 10 and 30 m of shore.
- Additional area (m^2) of compacted soil and impermeable surfaces within 10 m of the shoreline.

11.3 Map-based Data Sources

Physiographic, biological, and disturbance features of each point can be described using a variety of remotely sensed data, with some variables being duplicates of those collected in the field. The duplicity is intended to determine if remotely sensed sources are reliable for these data, and if so, can field measurements be eliminated in the future. Six features are described using remotely sensed data or interpolated data: elevation, precipitation, slope, aspect, vegetation, and disturbance (tables 11.1 and 11.4). Elevation is obtained from USGS topographic maps. Precipitation data can be obtained from PRISM data (Daly et al. 1997, Daly and Johnson 1999). A slope polygon map can be derived by interpreting topographic isoclines. The digital data for these variables represent their values as membership in value classes. Terrestrial vegetation (type and structure) and the occurrence of aquatic habitats surrounding each monitoring point can be described using existing GIS layers (interpreted satellite imagery). Vegetation type, amount, and distribution can be described at a variety of scales and using a variety of metrics to represent habitat conditions relevant to particular taxa. Care should be taken to ensure that the reliability of vegetation layers is quantified to the extent possible. Because error rates associated with map-based data are not typically available, available vegetation layers are primarily useful for habitat relationship models, but not for monitoring at these small scales. Low-altitude photography has promise for providing accurate data on vegetation types in the vicinity of monitoring points, as well as providing vegetation structure data that could relieve the need to collect some data in the field, such as tree density.

Many options exist for describing development and disturbance. Development, such as roads, houses, golf courses, and business areas can be quantified in terms of the percent of an area occupied by different types of development. Natural and human-caused disturbances are also important factors that can help identify potential causal factors for observed changes. Natural disturbances include events such as wildfire, flooding, and landslides; human-caused disturbances include activities such as timber harvest, thinning, prescribed fire, and grazing. Data sources for development and disturbance will vary among regions, but may include satellite imagery, aerial photography, digital orthophotos, fire history maps, and vegetation management history maps. Mapped data from these and other sources can be readily applied to the task of characterizing these features at a variety of scales around the monitoring point, thereby enabling the evaluation of the scale at which species may be responding to different types of disturbance.

11.4 Data Standards

Staffing, Training, and Safety

Environmental measurements are conducted soon after the biota are sampled so that the site conditions are the same. The condition of aquatic sites is particularly dynamic, with water levels and vegetation characteristics changing substantially over the course of the spring and summer. Terrestrial sites, however, can also change quickly as a result of disturbance events such as fire or management activities.

Environmental measurements at the center monitoring point are most efficiently collected by the botanists responsible for conducting plant species composition surveys. Environmental measurements at the distal terrestrial and aquatic sampling locations still must be completed. One option for staffing is to have the same individuals that collected biotic data (e.g., surveys at point count stations) also collect the environmental data at these sites. The advantages of this approach are many: (1) these individuals already know the location of the sampling sites, so no time is lost in locating them; (2) in many cases habitat data collection can be accomplished in the course of collecting the animal data, economizing on site visits throughout the field season; and (3) the work period for seasonal employees is longer (making the position more attractive to some individuals). Disadvantages of this approach are that observer variability can be substantial given that many individuals are collecting the data and individuals are not likely to be trained at the same time, so they may not all receive the same information or emphasis. Alternative staffing scenarios include (1) converting bird crews to habitat crews; they typically have a very short field season (4 to 6 weeks), and can either be converted to small mammal trapping crews or to habitat crews, giving them work for a greater proportion of the spring and summer season; or (2) hiring a separate habitat crew that works in concert with the botany crew. In either of these scenarios, a habitat crew of two individuals could collect measurements at the three point count stations around three monitoring points per week, on average.

Training is very important for collection of environmental data at aquatic sites, as well. As per the AEUI technical guide (Hixson et al. 2005), each survey crew should complete a 3- to 5-day training session. Training should be regionally coordinated. Once training is completed, individual observer quality should be tested to determine variance among teams and develop a database for predicting data accuracy and precision. Different teams will need to collect data on the same randomly selected stream segment, including an independent team to revisit an earlier site. This procedure will test variability within a team and between teams. Crews will be evaluated based on their data measurements under the same stream conditions over a 2-week period.

Crews should work in teams of two whenever possible because of the dangers of hiking cross-country. Each crew should have at least one radio, and it is recommended that each crew also have a cell phone. Cell phones facilitate rapid and efficient communication with supervisors and coworkers.

Quality Control and Assurance

Data sheets are checked by someone other than the data recorder before leaving the site to make sure that data are not missing. Data sheets are check again by a different individual in the office to ensure that writing is legible and all data fields are complete. Crew leaders check all data sheets at the end of each week to review species identification and legibility. Data recorders are recommended for these data, and data entry programs are available for data recorders for the FIA data.

Vegetation measurement standards shall follow those established by FIA (USDA Forest Service 2003). Observer care in taking measurements is a function of training and motivation; it is evaluated and enhanced by “hot checks” in the field, which consist of both observers simultaneously and independently recording data for one quadrat, and then comparing data after the quadrat is completed to identify differences and the actions necessary to correct them. In addition to field crewmember comparisons, the crew leader will rotate through each crewmember or team and participate in hot checks to identify problems and correct them in a timely manner.

Data Storage and Analysis

Data management procedures will follow those outlined in the Existing Vegetation Inventory Technical Guide, the AEUI technical guide, and the FIA manuals (USDA Forest Service 2003). No additional data management procedures are required by the MSIM protocol. All data should be directly entered into the National Resource Information System database when possible, as opposed to locally developed databases.

Many data analysis options exist for exploring habitat associations and evaluating changes in key habitat characteristics over time. Data analysis should be conducted in collaboration with research scientists with the guidance of a statistician. Habitat associations can be explored using multivariate techniques such as logistic regression (used for detection/nondetection data), where multiple environmental variables are evaluated to determine which combination of variables best differentiates where a species is present and where it is absent. The freeware program PRESENCE is available at http://www.mbr-pwrc.usgs.gov/software.html, and it can incorporate environmental variables into estimates of probability of detection and proportion of monitoring points occupied, thereby identifying those variables that are closely associated with the occurrence and detection of individual species.

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Appendix B. Example Data Forms for Core Animal Survey Methods

POINT COUNTS DATE _______________ (M/D/Y) OBS _______________

MONITORING POINT # ____________ STATION # __________ SURVEY/VISIT # ____________
TEMP (nearest 10 deg F) ____________ WIND ____________ SKY CONDITION ____________
START TIME ____________ (rating 0 - 5) (rating 0 - 5)
FINISH TIME ____________

* TALLY the number of individuals using dot count method, then write total in SUM column

		0-3 MIN				3-5 MIN				5-10 MIN			
		≤ 100 m		> 100 m		≤ 100 m		> 100 m		≤ 100 m		> 100 m	
SPECIES	**TAXACODE**	TALLY	SUM	TALLY	SUM	TALLY	SUM	TALLY	SUM	TALLY	SUM	TALLY	SUM

INCIDENTAL SIGHTINGS: what, where, when, how many

Entered by: _______________ Date entered: ______________
Checked by: _________________ Date checked: ______________

VISUAL ENCOUNTER SURVEYS

DATE _______________ (M/D/Y)

MONITORING POINT # ____________ OBS ____________ CLOUDS (%) ____________

START TIME ___________ SEARCH SIDE ____________ (W or E) PRECIPITATION _________

END TIME ___________ SURVEY/VISIT # ____________ TEMP ____________

SEARCH TIME TOTAL ___________ SEASON (circle one): Spring Summer Fall WIND ____________

* Indicate the number of individuals using dot count method (TALLY), then write total in SUM column
* WIND = none, lvs moving, twigs moving, sm branches, large branches, trees moving
* TEMP = describe temp to nearest 10 degrees F
* CLOUDS = nearest 10%
* PRECIPITATION = none, drizzle, sprinkle, rain, snow

AMPHIBIAN AND REPTILE SPECIES	TAXACODE (4-letter)	TALLY #	SUM	DETECTION	SUBSTR & LOC	SNOUT-VENT	AGE	COMMENTS

HERPETOFAUNA ONLY: Snout-Vent length (cm), Age (Adult / Subadult / Juvenile), Location along transect (nearest m) noted in Comments

VISUAL ENCOUNTER SURVEYS (CONT.)

LANDBIRD TVES: Songbirds, woodpeckers and sign; RAPTOR TVES: Raptors and rare woodpeckers (e.g. Pileated) and sign

BIRD SPECIES	TAXACODE		DETECTION	COMMENTS

MEDIUM AND LARGE MAMMAL TVES: All mammals and reptiles and their sign

MAMMAL SPECIES	TAXACODE		DETECTION	COMMENTS

INCIDENTAL SIGHTINGS: what, where, when, how many (observations outside of search time)

DETECTION: individual, scat, track, burrow, haypile, pellet , whitewash, cone pile, scratch marks, feathers, prey remains, etc.
SUBSTRATE: GR = ground, GS = grass, RK = rock, BG = bare ground, TR = tree, SH = shrub, LG = log, etc.

Entered by: ________________ Date entered: _______________
Checked by: __________________ Date checked: _______________

NOCTURNAL BROADCAST SURVEYS

Page ____ of ____

MONITORING POINT # ____________
SURVEY START TIME ___________
SURVEY END TIME ___________
TOTAL SURVEY TIME___________

OBS ______________________
SURVEY/VISIT # ____________
SEASON (circle one): Spring Summer
MOON PHASE (circle one): Quarter Half Full

DATE ________________ (M/D/Y)
CLOUDS ____________ (nearest 10%)
TEMP ____________ (nearest 10º F)
WIND ____________ (none, low, moderate, high)

TOTAL NUMBER OF NIGHTS TO COMPLETE MONITORING POINT: ____________

	Call Station Time			DETECTION DURING TAPE SERIES						
Call Station #	**Start**	**Stop**	**First 2-min** (4-letter code)	**Time**	**Species** (4-letter code)	**Sex** (if known)	**Species on tape at time of/previous to detection** (4-letter code)	**Visual Detection?** (Y/N)	**OR Bird location mapped?** (Note Angle 1 / 2 / 3)	**5-min listen/ spotlight** (4-letter code)
									/ /	
									/ /	
									/ /	
									/ /	
Call Station #	**Start**	**Stop**	**First 2-min** (4-letter code)	**Time**	**Species** (4-letter code)	**Sex** (if known)	**Species on tape at time of/previous to detection** (4-letter code)	**Visual Detection?** (Y/N)	**OR Bird location mapped?** (Note Angle 1 / 2 / 3)	**5-min listen/ spotlight** (4-letter code)
									/ /	
									/ /	
									/ /	
									/ /	
Call Station #	**Start**	**Stop**	**First 2-min** (4-letter code)	**Time**	**Species** (4-letter code)	**Sex** (if known)	**Species on tape at time of/previous to detection** (4-letter code)	**Visual Detection?** (Y/N)	**OR Bird location mapped?** (Note Angle 1 / 2 / 3)	**5-min listen/ spotlight** (4-letter code)
									/ /	
									/ /	
									/ /	
									/ /	
Call Station #	**Start**	**Stop**	**First 2-min** (4-letter code)	**Time**	**Species** (4-letter code)	**Sex** (if known)	**Species on tape at time of/previous to detection** (4-letter code)	**Visual Detection?** (Y/N)	**OR Bird location mapped?** (Note Angle 1 / 2 / 3)	**5-min listen/ spotlight** (4-letter code)
									/ /	
									/ /	
									/ /	
									/ /	

SHERMAN LIVE TRAPPING OBS _______ DAY (1-3) ______ VISIT (morn/aft) _________ START TIME ________ END TIME _______

MON POINT # _______ DATE __________(m/d/y) START TEMP(C)_____ END TEMP(C) _____ % CLOUDS _______ PRECIP? _____

REQUIRED: trap #, **species** = scientific name, **age**: 1 = adult, 2 = subadult, 3 = juvenile, **sex**: 1 = female, 2 = male, 3 = unk,
breed: 1 = non-breeding, 2 = pregnant, 3 = lactating, 4 = testes enlarged, 5 = unk, **recap** = is it a recapture?, **mark =** did you mark it?
OPTIONAL: weight to nearest 0.1 gram, record for new captures and uncertain IDs, **length** to nearest mm, record for distinguishing features of tricky sp, etc.

Trap number check: **101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 201, 202, 203, 204, 205, 206, 207, 208, 209, 210**
301, 302, 303, 304, 305, 306, 307, 308, 309, 310, 401, 402, 403, 404, 405, 406, 407, 408, 409, 410,
501, 502, 503, 504, 505, 506, 507, 508, 509, 510, 601, 602, 603, 604, 605, 606, 607, 608, 609, 610,
701, 702, 703, 704, 705, 706, 707, 708, 709, 710, 801, 802, 803, 804, 805, 806, 807, 808, 809, 810

page _____ of _____

INCIDENTAL SIGHTINGS (latin name) ____

TRAP #	SPECIES (latin name)	TAXA	AGE	SEX	BREED	RECAP	MARK ?	Total Weight	Bag Weight	Head/ Body Length	Tail Length	Total Length	Hind Foot	Ear Length	COMMENTS

Track Plate and Trail Master Camera Survey Setup

				MONITORING POINT: __________		
				START DATE (M/D/Y): __________		
				FINISH DATE (M/D/Y): __________		
TP1:	UTM E:	INITIALS:				
	UTM N:			ZONE:		
	GUSTO APPLIED?	Y	N			
	CAMERA?	Y	N	CAMERA ID:		
	CAMERA BEARING:					
	CAMERA DISTANCE:			CAMERA UTM	E:	
	# TEST SHOTS:				N:	
	GUSTO APPLIED?	Y	N			
	NOTES:					
TP2:	UTM E:					
	UTM N:					
	GUSTO APPLIED?	Y	N			
	CAMERA?	Y	N	CAMERA ID:		
	CAMERA BEARING:					
	CAMERA DISTANCE:			CAMERA UTM	E:	
	# TEST SHOTS:				N:	
	GUSTO APPLIED?	Y	N			
	NOTES:					
TP3:	UTM E:					
	UTM N:					
	GUSTO APPLIED?	Y	N			
	CAMERA?	Y	N	CAMERA ID:		
	CAMERA BEARING:					
	CAMERA DISTANCE:			CAMERA UTM	E:	
	# TEST SHOTS:				N:	
	GUSTO APPLIED?	Y	N			
	NOTES:					

TRACKPLATE STATION CHECK SHEET

DATE __ __ / __ __ / __ __ BOX TYPE ______ PRECIPITATION ______

OBSERVER(S) ____________________ LURE TYPE ______ QUAD NAME(S) ____

SAMPLE UNIT NO. (Monitoring Point)	STA. NO.	VISIT NO.	INT.	BOX COND	BAIT	ANTS	NEW BAIT	NEW TP	SPECIES DETECTED -- PAPER / SOOT						COMMENTS
	TP1														
	TP2														
	TP3														

<u>CODES</u>

BOX TYPE : Plastic [P] or Wood [W]
STATION # : TP1, TP2, TP3
BOX CONDITION : Intact [OK] or Inoperable [I]
ANTS (conspicuous): Yes [Y] or No [N]
NEW TP (track plate replaced?): Yes [Y] or No [N]

PRECIPITATION: Yes [Y] or No [N] in the last 48 hours
LURE TYPE: Gusto [G], Other [O] or Absent [A]
INT. (INTERVAL): Number of nights since last visit
BAIT : Present [P] or Absent [A]
NEW BAIT (old bait removed and replaced with fresh bait?): Yes [Y] or No [N]
COMMENTS : bait dessicated, added lure, box collapsed, tracks on soot only (lifted), etc.

CAMERA STATION CHECK SHEET

MONITORING POINT # ____________ QUAD NAME: __________________________________

CAMERA SET-UP DATE: __ __ / __ __ / __ __ MONITORING DATE: __ __ / __ __ / __ __

CAMERA TYPE: ________ FILM TYPE: ___ / ______ ROLL PULL DATE: __ __ / __ __ __ / __ __

TM 1500: PULSES _____ CAMERA DELAY ____ ACTIVITY: ON ______ OFF______ FLASH: ________

BAIT USED: ______________ LURE USED: _____________ **ROLL NO: _____ OF _____ AT THIS SITE**

OBS: ___________ ARRIVAL TIME: _______ ENTRY TEST PHOTO:___________________

EVENTS: _______ # CAMERA EXP: _________ REPLACED: FILM[1] BATTERIES CABLE NONE
(circle)

CONFIRM TIME / DATE: RECEIVER: ______ CAMERA STA. NO. _______ (comment below if necessary)

REPLACE BAIT / LURE (describe): ____

*** Before leaving, confirm station operational: receiver and transmitter work, camera takes photo with flash.**

EXIT TEST PHOTO: _______ CAMERA EXP # : _______ EVENT # :______ DEPARTURE TIME: _______

COMMENTS: ____

RESULTS:

DATE	EVENT NO.	FRAME NO.	TIME	DESCRIPTION
				Set-up; test shot

CODES:

CAMERA TYPE: Passive [P], Yashica active [Y], Olympus active [O], Canon active [C]

FILM TYPE: Print [P] or Slide [S] / ISO (film speed)

PULSES : 1 - 30 (default = 5)

CAMERA DELAY : 0.1 - 98 min (default = 2.0)

ACTIVITY: Time on, off, or [24hr] in ON box for continuous.

FLASH: On, Off, AUTO

LURE : Gusto [G], Visual [V], Other [O] or Absent [A]

FILM[1]: Label roll with site, date, and roll #

CAMERA STA.NO.: TM1, TM2, TM3

TRACKPLATE STATION SPECIES IDENTIFICATION

Date: _______________ (M/D/Y) **Monitoring Point # :** _______________
Observers: _______________ **Trackplate Station # :** ______________

Track #1

Front **Hind**

Measurements (mm)

A	
B	
C	
D	
E	
F	

ID (species code):

Initials:
ID Confirmed By:

Track #2

Front **Hind**

Measurements (mm)

A	
B	
C	
D	
E	
F	

ID (species code):

Initials:
ID Confirmed By:

Track #3

Front **Hind**

Measurements (mm)

A	
B	
C	
D	
E	
F	

ID (species code):

Initials:
ID Confirmed By:

Track #4

Front **Hind**

Measurements (mm)

A	
B	
C	
D	
E	
F	

ID (species code):

Initials:
ID Confirmed By:

CAMERA STATION SPECIES IDENTIFICATION

Date: _______________ (M/D/Y) **Monitoring Point # :** _______________

Observers: _______________ **Trackplate Station # :** ______________

TP/Camera Number	Species ID	Date of Photo	Photo Album #	Initial	Conf. Intial

NOTE: Photo Album Number should appear with the proper ID'd photo in the photo album

CAMERA STATION SPECIES IDENTIFICATION (CONT.)

Mammals with 4 toes on forefeet and hindfeet	
CAFA	domestic dog
CALA	coyote
CASP	unknown canid
FECA	domestic house cat
FECO	mountain lion
FERU	bobcat
FESP	unknown felid
LESP	rabbit or hare
URCI	gray fox
VUMA	kit fox
VUVU	red fox

Mammals with 5 toes on forefeet and hindfeet	
BAAS	ringtail
DIVI	Virginia opossum
ERDO	porcupine
GUGU	wolverine
LUCA	river otter
MAAM	American marten
MAPE	fisher
MASP	fisher or marten
MEME	striped skunk
MUER	ermine
MUFR	long-tailed weasel
MUSP	unknown weasel
MUVI	mink
PRLO	raccoon
SPGR	western spotted skunk
URAM	black bear

Mammals with 4 toes on forefeet and 5 toes on hindfeet	
GLSA	northern flying squirrel
MICE	unknown small rodents
NEFU	dusky-footed woodrat
SCSP	unknown squirrel-like rodent
SCGR	western gray squirrel
SPBE	California ground squirrel
SPLA	golden-mantled ground squirrel
TADO	Douglas squirrel
TASP	unknown chipmunk
TATA	badger

Non-mammalian tracks	
BIRD	bird
LIZD	lizard
SALA	salamander
FROG	frog or toad
SNAK	snake

UNK	any unknown track