The Multiple Species Inventory and Monitoring protocol: A population, community, and biodiversity monitoring solution for National Forest System lands

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Abstract

The U.S. Forest Service manages approximately 76 million ha (191 million acres) of National Forest System (NFS) lands. The National Forest Management Act (NFMA; 1976) recognizes the importance of maintaining species and ecosystem diversity on NFS lands as a critical component of our ecological and cultural heritage. Information on the condition of populations and habitats of plants and animals is a primary tool for determining desired conditions, understanding potential conflicts in multiple use objectives in the context of sustainability, and formulating management direction to achieve these objectives. To date, no consistent, nationally standardized monitoring program exists to obtain status and trend data on multiple species on NFS lands. Inconsistencies in the development and implementation of multiple species monitoring programs have resulted in inadequate or unreliable monitoring data on most species. Over the past five years, Forest Service research and management have collaborated to develop a nationally standardized protocol, the Multiple Species Inventory and Monitoring (MSIM) protocol. The MSIM protocol is designed to provide a minimum of presence/absence and habitat data for a broad suite of vertebrate and plant species. Primary survey methods are identified for each taxonomic group, including terrestrial and aquatic birds, mammals, amphibians, reptiles, and plants. The protocol uses the Forest Inventory and Analysis systematic grid to structure sampling, thus enabling a variety of options for post-stratifying the data to address various management questions. Ancillary information includes habitat relationships of many species, identification of potential causal factors associated with observed trends, and data to evaluate the validity and strength of indicators. The protocol is designed for implementation on both NFS and non-NFS lands to provide data on population and habitat conditions at multiple scales for a variety of applications.

Key words: monitoring, biological diversity, vertebrates, National Forest System, Forest Service, national protocol, indicator species, species diversity, ecosystem diversity, wilderness, invasive species

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Introduction

The U.S. Forest Service manages approximately 76 million ha (191 million acres) of National Forest System (NFS) lands. Information on the condition of populations and habitats of plants and animals is a primary tool for determining desired conditions, understanding potential conflicts in multiple use objectives in the context of sustainability, and formulating management direction to achieve these objectives. The National Forest Management Act (1976) highlights the need to maintain species and ecosystem diversity on NFS lands as essential elements of our ecological and cultural heritage, and specifies the inclusion of a monitoring strategy in each forest's Land and Resource Management Plan. Further, the U.S. Forest Service has a lead role in assessing the extent, condition, and sustainability of the nation's forests and grasslands under the guidance of legislation (for example, Forest and Rangeland Renewable Resources Planning Act 1974) and international agreements (for example, Criteria and Indicators for Sustainable Forestry – the Montreal Process; Anonymous 1995).

Development and implementation of monitoring at Forest and Regional scales has been slow. A report by the General Accounting Office (GAO 1997) documented inadequacies in the agency's monitoring, stating "the Forest Service (1) has historically given low priority to monitoring during the annual competition for scarce resources, (2) continues to approve projects without an adequate monitoring component, and (3) generally does not monitor the implementation of its plans as its regulations require." Reasons for inadequate monitoring have not been evaluated as thoroughly, but undoubtedly include lack of clear monitoring objectives in land management plans that can be readily translated into sampling design specifications, lack of capacity or commitment to fund data collection, management, and analysis, and lack of standardized monitoring protocols. Consistent, nationally standardized monitoring protocols have not been available to Forests and Regions to obtain reliable status and trend data on animal populations and habitats on NFS lands. Inconsistencies in the development and implementation of integrated species monitoring programs result in the development of various of designs and approaches that are inadequate to address population and habitat trends with sufficient rigor to support land management decisions and meet NFMA monitoring requirements (for example, GAO 1991). The need for effective monitoring programs is mounting because over the next five years most Forest Land and Resource Management Plans which guide management for the second 10 to 20 year planning period as per NFMA will be revised. Lack of credible monitoring plans is likely to create a barrier to successful plan revision.

An increased emphasis on monitoring on NFS lands is being generated not only by NFMA, but also by growing concerns about declines in biological diversity in the United States (Flather and others 1999) and around the world (United Nations 2002). Recent ecoregional assessments conducted in various locations around the country suggest that a consistently large proportion of all vertebrate and plant species are of concern and interest (SAMAB 1996; Stephenson and Calcorone 1999; Wisdom and others 2000; USDA 2001). For example, in a recent assessment of the Columbia River Basin, 173 of 468 vertebrate species (37 percent) were considered species of focus based on concerns for their persistence (Wisdom and others 2000). A similar scenario existed in California, where an assessment of vertebrates in the Sierra Nevada indicated that 213 of 465 species (46 percent) were considered vulnerable to population losses (USDA 2001), and the Southern California assessment found 184 of 482 vertebrates (38 percent) were considered focal species based on special interest or concern (Stephenson and Calcorone 1999). Across the country in the southern Appalachian Mountains, a comparable situation existed, where an assessment determined that 92 of their 320 vertebrate species (29 percent) were considered special interest or concern (SAMAB 1996). Similar trends existed for vascular plant species in these assessments, with proportions of species that are of concern generally ranging from 10 to 20 percent, but the absolute numbers of plant species of concern were over twice those of vertebrates of concern. Clearly, single species approaches to conservation, management, and monitoring are not feasible or effective means of dealing with the significant ecological and social consequences associated with the potential loss of 20 to 50 percent of the flora and fauna, equating to hundreds of species of plants and animals at ecoregional scales. Multiple-species, ecosystem-based monitoring strategies that provide reliable, timely, and informative measures of change are desperately needed.

Investments in monitoring by land management agencies are on the rise, particularly in the development and implementation of regionally and nationally consistent protocols for the inventory and monitoring of natural resources and land uses (for example Amphibian Research and Monitoring Initiative, Partners in Amphibian and Reptile Conservation, National Park Vital Signs Monitoring, Aldo Leopold Wilderness Research Institute Monitoring Initiative, Environmental Protection Agency's Environmental Monitoring Assessment Program, Forest Inventory and Analysis). Over the past few years, the U.S. Forest Service has launched multiple efforts to develop nationally consistent inventory and monitoring protocols for a variety of resources (e.g., wildlife, vegetation, streams, recreation use; www.fs.fed.us/emc/rig). Within the Forest Service, most wildlife monitoring approaches being developed are restricted to one species or narrow taxonomic groups, with one exception. The U.S. Forest Service has developed the Multiple Species Inventory and Monitoring (MSIM) protocol. Through collaboration between research and management, this nationally standardized protocol for monitoring a large number of plant and animal species was designed to meet the basic requirements of NFMA and provide an effective, efficient, and reliable source of information on the status and trends of populations, habitats, and biological diversity on NFS lands. The MSIM protocol was developed in response to the large and growing number of species of concern and interest (for example, Management Indicator Species, Forest Service Sensitive species, and state and federally listed species) on NFS lands and throughout the country. This paper provides an introduction to the MSIM protocol and its potential to meet a variety of information needs at a range of scales for National Forest System lands and across land ownerships throughout ecoregions.

Objectives

The MSIM protocol was designed to provide a cost effective means of generating reliable status and trend (sensu Busch and Trexler 2003) estimates based on presence/absence data that are spatially and temporally coincindent across multiple species and taxonomic groups. The MSIM protocol yields status and trend data for a breadth of levels of ecological organization (species, community, and landscape), thus enabling a comprehensive evaluation of biological diversity and ecosystem condition (Noss 1990; Gaines and others 2003). Primary survey methods provide data on species occurrence and composition, and contribute data on habitat condition at multiple scales.

The MSIM protocol is designed to answer the following inventory (status) questions (1) within an administratively defined area (for example, National Forest or Region), (2) within an ecologically defined area (for example, ecoregion or biome), and (3) throughout a species range, including diverse landscapes:

1) What is the status of populations of individual species adequately detected?
   a) Proportion of occupied monitoring sites
   b) Spatial distribution of occupancy
2) What is the status of habitat for species for which predictable habitat relationships have been determined?
   a) Habitat characteristics (at all FIA points)
3) What is the relationship between the status of species and environmental conditions?
   a) Predictive models of species presence based on environmental conditions (for example, vegetation composition and structure, logs and snags, elevation)
4) What is the pattern of co-occurrence between species adequately detected?
   a) Spatial and temporal differences in species composition

The MSIM protocol is designed to answer the following change (trend) questions (1) within an administratively defined area, (2) within an ecologically defined area, and (3) throughout a species range, including diverse land ownerships:

1) What is the direction and magnitude of change in the proportion of sites occupied by individual species that have been adequately detected?
   a) Change in the proportion of occupied points
   b) Change in the spatial distribution of probability of occupancy
   c) Change in site occupancy rates and patterns (in other words, sequence of occupancy for individual sites summarized over all points)
2) What is the change in community composition and structure?
   a) Change in species composition
3) What is direction and magnitude of change of habitat?
   a) Change in habitat characteristics (at all FIA points)
4) What is the relationship between changes in species and their habitats?
   a) Coincident change in species presence and habitat conditions

The MSIM protocol is a retrospective approach to monitoring (NRC 1995; Noon and others 1999; Noon 2003), meaning that it seeks to reflect effects or changes after they have occurred. Unlike predictive or "prospective" monitoring, it does not presume prior knowledge of key environmental stressors (anthropogenic sources of change) or make predictions about the ecological effects resulting from primary stressors. The principle objective of retrospective monitoring is to estimate parameter values at points in time and over time, and not to test hypotheses (Stewart-Oaten 1996). Alternatively, prospective monitoring targets condition indicators of stressors and ecological responses, and tests hypothesis about cause-effect relationships (Noon and others 1999; Noon 2003). It is likely that MSIM will provide status and trend data on a number of species that are considered indicators and their associated environmental conditions. Thus, the MSIM protocol may enable hypothesis testing by providing data to address one or more assumptions associated with prospective monitoring, such as population distribution and response to disturbances.

Sampling Design and Detection Methods

The MSIM protocol consists of a national framework of core design, methodological, and procedural elements (table 1; see Manley and others in prep for more details). The core design and methodological elements of the protocol are described here: sampling frame, sampling frequency, and survey methods.

Sampling Frame

The sampling frame of the MSIM protocol is the systematic grid of the Forest Inventory and Analysis (FIA) program, which is an on-going nation-wide program that monitors the composition and structure of forested ecosystems (Roesch and Reams 1999). The national FIA design consists of a single point randomly located in each systematic hexagonal 2400 ha (6000 acres) grid cell (fig.1), resulting in a grid point density of approximately 210 points per 5000 km^2 (1.25 million acres). The FIA grid was selected as the foundation of the MSIM sampling design because the density of the grid is low enough to assume independence between points for the majority of vertebrate species (in other words, different individuals detected at each point). Further, the FIA program offers a temporally and spatially reliable source of vegetation data across all land ownerships, thus it promises to provide the potential for monitoring habitat conditions at the density of the grid on NFS lands, and across all land ownerships in collaboration with other institutions and landowners. To maintain the integrity and anonymity of FIA plot locations, MSIM sampling is slightly off-set from FIA points

Sampling Frequency

Sampling every FIA grid point every year clearly would yield the greatest statistical precision and power. However, fiscal conservancy has led FIA to a serially alternating panel designs because they appear to have a high degree of statistical precision and power per unit effort to describe status and detect trends over time (Lesser and Overton 1993; Roesch and Reams 1999). In a serial alternating panel design, a systematic subset of grid points (a panel) is identified for sampling each year, thus if all sites are visited every five years, then there are five panels with 20 percent of the sites in each panel.

Sampling frequency for the MSIM protocol follows a panel design, but entails more frequent sampling than FIA in response to the dynamic and variable nature of animal population sizes and distributions, which challenge the ability to describe status and trend within the 10 to 20 year time period corresponding to LRMP plan revision schedules (as per NFMA). Given that animal populations fluctuate from year to year, the MSIM protocol has added an annual panel that is sampled every year, called an augmented serial alternating panel design, or ASAP, to improve the power to detect trends over the relatively short planning period (Urquhart and others 1993; Fuller 1999). In sum, the MSIM protocol recommends that a minimum of 50 percent of the FIA points be included in the sample, and that at least 10 percent of the selected grid points be sampled every year as part of the annual panel.

Survey Methods

The eight primary survey methods selected for the MSIM protocol consist of commonly employed, standardized survey methods that detect a large number and breadth of species per unit effort and, in the case of habitat, most efficiently measure habitat variables pertinent to the majority of species detected by survey methods. Primary survey methods include methods to detect species in each of the following major taxonomic groups: songbirds and woodpeckers, owls, aquatic birds, small mammals, medium and large-bodied mammals, amphibians, reptiles, and vascular plants (table 2). Point counts are used to survey songbirds and woodpeckers, and consist of standing at each of four count stations 200 m apart and recording the number of individuals of each species of vertebrate seen or heard during a 10 minute count period. Distance estimates can be added to the protocol to calculate density estimates. Broadcast calling is used to detect nocturnal birds (primarily owls) and consists of a nighttime survey conducted by driving or hiking along roads and trails throughout a 3 km radius area around the sample point and broadcasting calls of local owl species. Sherman live trapping is used to detect small mammals, and consists of quart-sized aluminum trap boxes placed around a 200 m radius hexagon around the point that are baited and checked for occupants over a four night period. Prior to release, captured individuals (primarily rodents) can be marked to estimate abundance and tissue can be collected for genetic analysis (Smith and Wayne 1996). Trackplates and cameras are used to detect medium to large sized mammals (primarily carnivores), and the array consists of six devices placed 250 m apart around the sampling point over a 10 day period. Trackplate stations consist of sooted aluminum plates that are baited with meat, and tracks created by animals walking on the sooted surface are identified to species. Devices to collect hair at trackplate stations are being developed and tested (W. Zielinski, pers. com.) that will enable more definitive species identification and could provide estimates of abundance for some species (Mills and others 2000). Associated camera stations are baited with meat and vegetables, and visitation to the bait triggers the camera to take a picture of the animal. Mistnetting is used to detect bat species, and consists of sampling aquatic sites or forest openings within a 1 km radius area around the sample point. Mistnets are lightweight nets that extend 6 to 18 m across and up to 4 meters in height. Surveys are conducted at night for three to four hours, and captured bats are identified to species. Amphibians and reptiles, as well as a smattering of specialist and larger bodied species, are detected with terrestrial and aquatic visual encounter surveys. During these surveys, observers traverse the sample unit (200 m radius hexagon for terrestrial surveys; littoral and shore zones for aquatic surveys) visually scouring and physically probing suitable habitat for individuals or their sign. Habitat measurements constitute the final primary survey method in the MSIM protocol; these measurements are conducted at the center point and repeated at some of the more remote survey locations.

Design Considerations

Land management agencies are increasingly turning to presence/absence data as an attractive measure of large-scale population trends prompted by recent advances in standardized techniques for obtaining (Ralph and others 1993; Heyer and others 1994; Wilson and others 1996) and analyzing (Azuma and others 1990; MacKenzie and others 2002; MacKenzie and others 2003) presence/absence data. The primary survey methods for the MSIM protocol provide a minimum of presence/absence and habitat data for a broad suite of animal and plant species, but in a number of cases (for example, point counts and Sherman live trapping) they also provide estimates of abundance, typically for species that occur at higher densities such as many small mammal and songbird species (Ralph and others 1993; Wilson and others 1996, respectively). However, obtaining reliable abundance estimates for larger-bodied species with large territories can be very time intensive and infeasible to accomplish for all such species of interest and concern at the ecoregional scale. Thus, occupancy serves as the basic population parameter shared by all species detected in large-scale, multiple-species monitoring efforts.

The proportion of points occupied across a region serves as an index of population abundance (Thompson and others 1998). State Atlas programs (Pearman 1997; Telfer and others 2002) and the National Lynx Survey (McKelvey and others 1999; Ruggerio and others 1999; McDaniel and others 2000) are examples of other population monitoring approaches similarly based on the extent of a species' occurrence. In many cases the areal extent of a population and its size have a positive relationship (for example, Nachman 1981; Geissler and Fuller 1986; Bart and Klosiewski 1989; Robbins and others 1989; Gaston 1994; Syrjala 1996; Thompson and others 1998). However, the proportion of points occupied can be insensitive to certain types of population decline. Specifically, species with higher densities (multiple individuals occupying a given sample unit) could experience significant declines before site occupancy begins to change. In response, standardized multiple species survey methods for higher density species (for example, small mammals and songbirds) typically yield abundance estimates that logically would be generated for these species to better elucidate their individual population trends (for example, Ralph and others 1993; Wilson and others 1996; Buckland and others 2001).

Statistical power to detect a change is lowest for species present at a low proportion of points and/or with low probability of detection (for example, Manley and others 2004). Low densities can result from a variety of life history factors (for example, large home range size, habitat specialization) or from population declines. Generating abundance estimates for low density species would require additional targeted effort across an ecoregion, a level of effort that is outside the model of a broad-scale multiple-species monitoring approach. However, the probability of observation can be optimized within the confines of broad-scale multiple species monitoring approaches such as the MSIM protocol by more intensive sampling per point. Multiple sample stations and/or multiple visits per point can serve not only to increase probability of observation, but also enable estimates of probability of detection and proportion of points occupied (MacKenzie and others 2003). Large-scale monitoring efforts face the challenge of multiple concurrent observers and turnover in observers over time, emphasizing the need to estimate probability of detection each year within each ecoregion.

Empirical Testing

Manley and others (2004) conducted an evaluation of the MSIM protocol to determine its potential effectiveness in meeting agency monitoring needs for vertebrate species. They estimated the number and types of species that would be adequately detected on the approximately 6.5 million ha (16.5 million acres) of federal lands in the Sierra Nevada (SNEP 1996) if all primary survey methods were conducted at FIA points on federal lands at two points in time. They predicted that 76 percent of all vertebrate species would be adequately sampled to detect a 20 percent relative change in the proportion of grid points occupied with 80 percent precision and power. These data were reevaluated for the purposes of this paper based on the subset of points identified for sampling in the national framework for the MSIM protocol: 50 percent of the grid in the sample, 10 percent of those sampled every year, and an additional 18 percent sampled every 5 years for a total of 14 percent of the full grid sampled every year. We found that the proportion of species adequately detected dropped from 76 percent to 42 percent, which still equated to 193 species adequately detected to monitor their populations across federal lands in the Sierra Nevada ecoregion. These results indicate that the MSIM protocol, even implemented at its minimum levels, is capable of providing status and trend data for hundreds of vertebrate species, many of which are likely to be species of concern and interest for which monitoring data are required (Manley and others 2004).

The predicted effectiveness of the MSIM protocol prompted field testing to validate its results. Field testing was conducted at the scale of a National Forest in the Sierra Nevada in 2002, and consisted of 40 sample sites on the Lake Tahoe Basin Management Unit (Manley and Roth 2004). Preliminary analysis of this limited data set (few sites, small geographic area, one sample period) provides some insights into the potential performance of the MSIM protocol. The field test detected approximately 50 percent of the species potentially occurring in the study area, including a wide assortment of species, including a diversity of taxonomic groups, life history characteristics, and many management indicator species and species of concern. The field test also demonstrated that indeed it is logistically feasible and economically efficient to implement multiple primary protocols concurrently at sites over the course of a spring and summer field season. Site integrity was not compromised and survey methods were staggered throughout the season so they did not interfere with one another.

Promising Applications

In addition to MSIM's primary objectives of monitoring the status and trend of a breadth of species and communities, the protocol has the potential to yield many other substantial benefits that meet key land management information needs. In brief, species-related benefits of empirical data generated by the MSIM protocol in the first five years of monitoring could include the following (see Manley and others 2004 for more detail):

1) Identify and evaluate specific conditions of concern and interest, such as habitat thresholds beyond which populations may experience precipitous declines (for example, Fahrig 2002; Flather and Bevers 2002);
2) Provide new scientific information and understanding about community structure and dynamics under a wide variety of environmental conditions and changes over time;
3) Provide distribution data and models of suitable habitat for some species based on correlative relationships between species presence and environmental characteristics;
4) Provide basic data to empirically derive indicator species based on 1) the co-occurrence pattern among species and 2) the association between species occurrence and environmental features (for example, vegetation, disturbance); and
5) Evaluate and test existing or proposed indicator species or species groups.

Over the course of 10 or more years of implementation of the MSIM protocol, additional species-related benefits could be realized:

1) Improve the design and efficiency of population, habitat, and community monitoring programs by evaluating monitoring results;
2) Identify effects of management actions or natural disturbances on populations and habitat conditions;
3) Provide insights into the potential effects of changes in species composition on community structure and dynamics, thus providing a broad-scale context for focusing research to inform management; and
4) Validate trends indicated by other large-scale inventory and monitoring programs, such as GAP (Scott and others 1993) and Breeding Bird Survey (Droege 1990).

This broad-scale multi-taxonomic monitoring strategy can readily serve as a platform for many topic specific monitoring needs. For example, the U.S. Forest Service has identified four primary threats to the integrity and sustainability of National Forest System lands: fire and fuels, invasive species, fragmentation, and unmanaged recreation. Implementation of the MSIM protocol across all NFS lands could provide valuable data on the status and trends of these threats and their impact on plant and animal populations and biological diversity. The relationship between high fuel loads and wildlife habitat are not well understood, and the consequences of wide-spread fuel treatments on wildlife populations can only be monitored at the ecoregional scale through approaches like the MSIM protocol. Further, Fried and others (2003) demonstrated that FIA data can provide a valuable source of data to assess pre and post fuel treatment effects on residual biomass, which could be augmented with plant and animal population data if the MSIM protocol were implemented. Similarly, monitoring the distribution and frequency of occurrence of invasive species throughout their range requires a broad-scale monitoring system such as the MSIM protocol. The changing distribution and abundance of roads and trails across the landscape are important measures of fragmentation and recreational use, and the MSIM protocol provides repeated measures of these features concurrent with plant and animal population data. One important area of concern in this arena is the status of designated wilderness areas across the country. The U.S. Forest Service and others are embarking on a system-wide monitoring effort evaluate compliance with the Wilderness Act (1964) and associated agency policies in terms of the status and trend of wilderness character (Landres and others 1994; USDA 2004b). The primary threat to wilderness character is exposure to and effects of modern human impacts, including fire suppression and unmanaged recreation. Plant and animal populations and communities are a major component of the wilderness experience, and the MSIM protocol could readily provide a sound foundation of biotic and human disturbance data for evaluating wilderness character at regional, biome, and national scales.

In conclusion, the MSIM protocol holds a great deal of promise in its ability to meet a wide range of valuable and timely scientific and management-related biodiversity information needs at a range of relevant scales in a cost effective manner. Implementation of the protocol at the ecoregional scale is a logical next step toward refining and optimizing the protocol to best meet the needs of the U.S. Forest Service, other public land stewards, States, and the country in conserving and monitoring plant and animal species, communities, and biological diversity.

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Table 1. Summary of core elements of the National Framework for the MSIM protocol.

Element	Specifications
Sampling frame	• MSIM monitoring points will be established in association with FIA grid points • A minimum of 50 percent of the FIA grid points sampled
Sampling frequency	• A minimum of a five-year resample with at least 10% of sites sampled every year, which equates to 28 percent of sample sites surveyed in a given year
Survey methods	• Primary survey method are identified for each major vertebrate taxonomic group, four of which are recommended to be implemented in all regions: bird point counts, small mammal live trapping, terrestrial visual encounter surveys, and habitat measurements. • Secondary survey methods are additive, complementing primary survey methods for each taxonomic group. • Multiple visits are made to all or a subset of points for each survey method used to maximize probability of observing species that are present.
Data acquisition	• Data collection will be designed at the regional scale and coordinated within and among regions.
Data storage	• Core data (species sighting and habitat conditions) will be stored in the FAUNA module of Natural Resource Information System., • Relevant data copied to a variety of destinations, including FAUNA, TNC, and state heritage programs (via NatureServe).
Data analysis	• Data analysis will follow the minimum standards identified in the national framework, such as estimates of proportion of points occupied, probability of detection, and a quantitative description of habitat condition for each species detected. • A Regional-scale analysis guide should be developed to provide consistency and reliability to results from Regional analyses.
Reporting	• Annual reports will be produced by each Region, and they will comply with reporting standards established as part of the national framework to ensure a minimum quality and detail, as well as facilitate the examination of trends across Regions. • At 5-year intervals, a more detailed analysis will be conducted that analyzes population trends, habitat trends, habitat relationships, and any desired ancillary analyses.
Evaluation and revision	• Annual and 5-year reports will be 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 to evaluate the significance of results.

Table 2. Primary survey methods in the Multiple Species Inventory and Monitoring protocol.

Protocol	Effort	Reference	Target taxa
Point counts	7 stations, 10 min counts, 3 visits	Ralph and others 1993, 1995	song birds and woodpeckers, some vocal small mammals and amphibians
Broadcast calling (nocturnal)	2 visits	Fuller and Mosher 1981	nocturnal and crepuscular birds
Sherman live trapping	70 traps, 4 nights	Jones and others 1996	small mammals
Trackplate stations with cameras	6 stations, 10 days	Zielinski and Kucera 1995	mid-sized carnivores
Mist netting	3 net sites, 3 visits	Jones and others 1996	bats
Terrestrial visual encounter surveys for vertebrates and their sign	10 ha area, 2 visits	Crump and Scott 1994; Wemmer and others 1996	terrestrial-phase amphibians, reptiles, large mammals, raptors
Aquatic visual encounter surveys for vertebrates	2 visits	Crump and Scott 1994; Fellers and Freel 1995	aquatic amphibians, reptiles, mammals and birds
Environmental measurements	Measurements taken in the same year and season as the species data	Forest Inventory and Analysis manual (USDA 2004a)	Habitat descriptions for all taxa

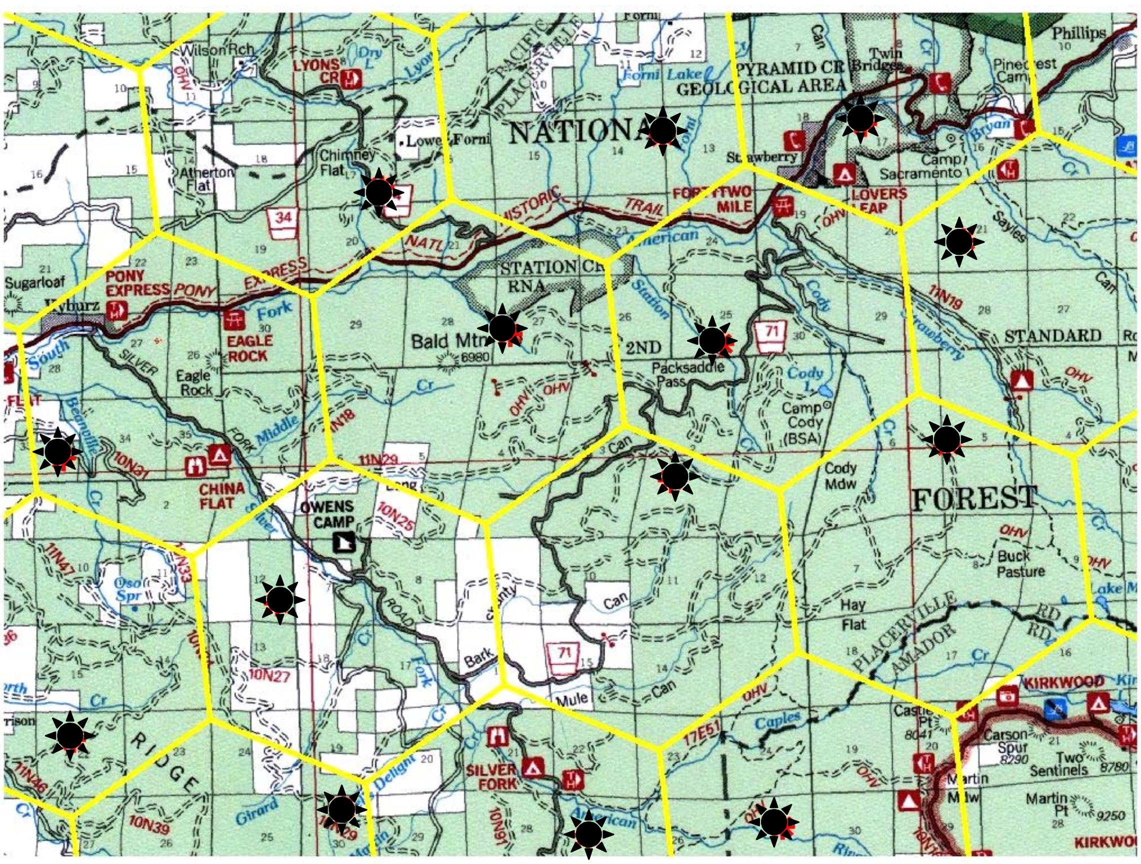

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Figure 1. Graphic representation of a Forest Inventory and Analysis hexagonal grid and sample points.