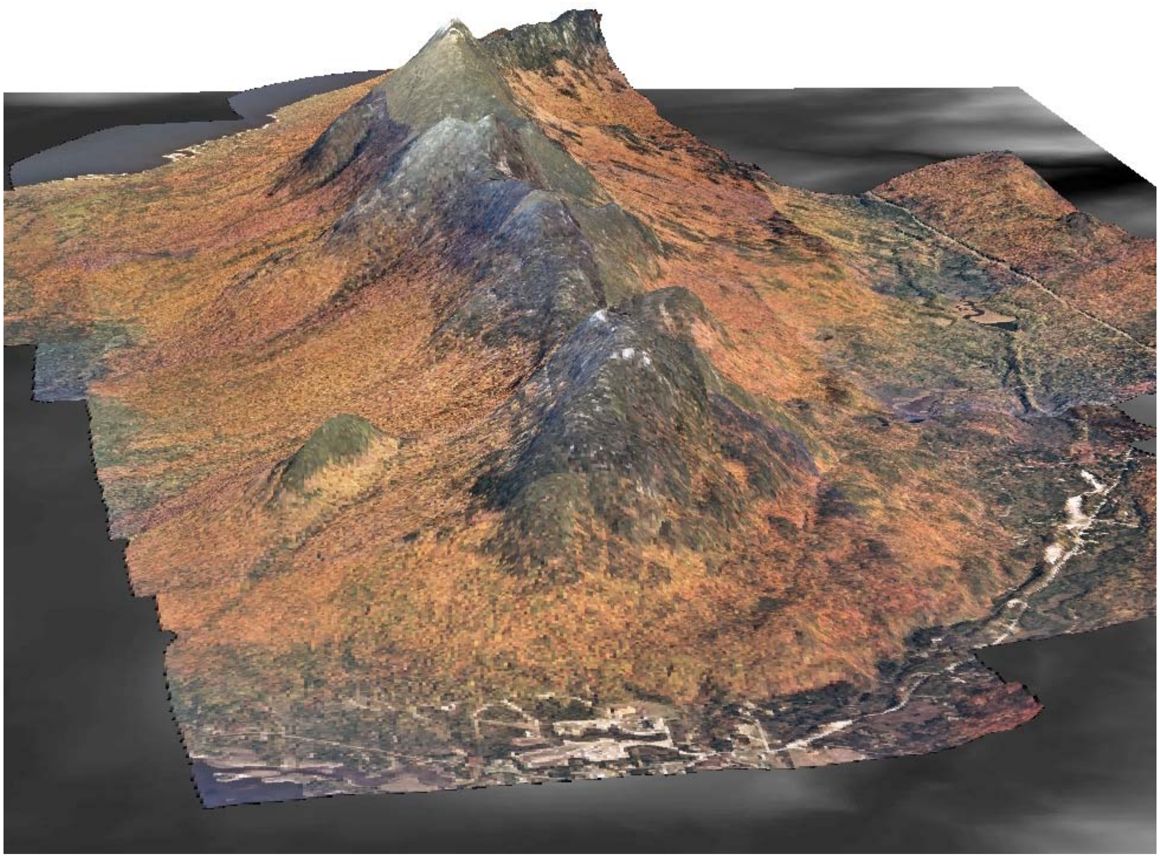
Ecological Reserves Monitoring Plan



Bigelow Reserve, color air photos enhanced through GIS

Maine Department of Conservation
Natural Areas Program
July 2003

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Acknowledgments

Funding for this project was provided to the Maine Natural Areas Program (MNAP) from the Maine Outdoor Heritage Fund and The Nature Conservancy.

Although Andy Cutko, MNAP ecologist, is the principal author of the plan, the Ecological Reserves Monitoring Committee (see Appendix 1) provided significant input and review throughout the plan's development. This committee will continue to serve in an advisory capacity regarding scientific use of the Reserves. Staff of the Bureau of Public Land's Inventory Committee (Tom Charles, Steve Swatling, Vern Labbe, Gena Denis) also provided important feedback, and other BPL staff, such as Jay Hall, assisted with various logistics including lodging and purchase of air photos. Others who reviewed the plan and provided valuable input are Linda Alverson, Jensen Bissell, Charlie Cogbill, Mike Dann, Phillip deMaynadier, Steve Sader, Bob Seymour, and Bob Unnasch.

Current and former MNAP staff and contractors assisted in a variety of capacities. Dan Coker spent countless hours designing a new Access database to accommodate Reserve plot data. Dan also created many of the original Reserve maps for distribution and helped with plot stratification. Mark Ward conducted much of the background research on monitoring programs across the country. Rick Frisina explored options for orthorectifying air photos. Field assistance during the first year's effort was provided by Mike Auger, Mark Ward, Emily Pinkham, and Gillian Brooks. Brooke Wilkerson, a UVM graduate student and MNAP summer intern in 2003, provided a critical review of the plan as part of her Master's Project.

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1. Introduction

Establishment of Ecological Reserves

In August 2000 the Maine Legislature enacted a law to create a system of Ecological Reserves on the Department of Conservation's (DOC) public lands. The purposes of the Reserves are to "maintain one or more natural community types or native ecosystem types in a natural condition and range of variation and contribute to the protection of Maine's biological diversity." Furthermore, the reserves are to be managed "as a benchmark against which biological and environmental change may be measured, as a site for ongoing scientific research, long-term environmental monitoring and education," and "to protect sufficient habitat for those species whose habitat needs are unlikely to be met on lands managed for other purposes" (Chapter 592, MSRA Section 13076).

Potential reserves on DOC lands were selected following a multi-year inventory and assessment effort by the Maine Forest Biodiversity Project (MFBP) on a much broader set of conservation lands in Maine. Using acreage guidelines established by the legislature, in 2000 nearly 70,000 acres of Ecological Reserves were subsequently designated on the Department's Public Lands. In 2002, two additional reserves totaling more than 8,000 acres (Big Spencer Mountain and Mt. Abraham) were added to the system (Figure 1). Reserves range in size from 775 acres at Wassataquoik Stream to over 11,000 acres at Nahmakanta. (A corresponding notebook produced by MNAP, entitled "Ecological Reserves Monitoring Project," contains maps and descriptions of each Reserve.) According to the legislation, the Bureau of Parks and Lands is mandated to report on the status of Ecological Reserves, including monitoring activities and research. The Maine Natural Areas Program is mandated to maintain a database of areas designated as Reserves and provide scientific review of such areas.

Establishment of Monitoring

In 2001 the Maine Natural Areas Program received a grant from the Maine Outdoor Heritage Fund to establish a protocol for long-term monitoring of the state's Ecological Reserves. The grant specified that three Reserves would be selected for initial monitoring. In addition, MNAP proposed to draft criteria to be considered when evaluating proposed research projects on Ecological Reserves.

A longer term goal is to establish baseline monitoring on each of the state's Reserves. As noted above, the initial MOHF grant enabled only the development of a monitoring protocol and establishment of monitoring on three Reserves. A desirable long-term schedule would involve the re-sampling of each Reserve approximately every ten years (i.e., one or two reserves each year). Deviation from this schedule may be necessary if a specific event occurs that is likely to have significant but ephemeral ecological effects. For instance, if a wildfire or budworm outbreak occurs, it may be useful to document these impacts immediately following the event.

As of March 2003, funding had been secured for baseline monitoring of three additional Reserves (Rocky Lake, Duck Lake, Deboullie), but reliable longer-term funding had not been identified. The maximum benefits from monitoring would be derived from a program that is consistently funded over the long term.

An Ecological Reserves Monitoring Committee was formed in 2001 to provide oversight of the monitoring effort. Members of this committee represent state agencies, private conservation groups, ecological consultants familiar with the Reserves, and the academic community (see Appendix 1). The committee met several times in 2001 and 2002 to discuss goals and methods for monitoring, and the contents of this plan largely reflect input from this committee. The committee will also serve a continuing advisory role in matters relating to analysis and use of monitoring data, and facilitation of all research on Reserves.

Initial methods based on a draft protocol were field tested on three Reserves in 2002: Bigelow, Donnell Pond/Spring River Lake, and Salmon Brook Lake. Based on the results of this initial effort in 2002, monitoring methods were modified and are presented in this report. While the scope of monitoring and methods presented here are appropriate for the funding currently available, further modifications will likely be implemented over time as changes in scientific need and funding allow.

Monitoring Approach

As indicated in the enabling legislation, a key intent of Maine's Ecological Reserves is to protect biological diversity. Although biological diversity occurs at multiple levels (e.g., landscape, natural community, species, genetic) and dimensions (function, composition), many of these levels and functions are difficult to measure. In this monitoring program, attempts will be made to monitor:

- the *landscape* and *natural communities* through remote means.

- natural community *structure* and *composition* through plot sampling.

- selected *rare species* through population monitoring.

Natural community structure and composition will serve as the main biodiversity surrogate for several reasons. First, natural communities serve as a "coarse filter" for finer levels of biodiversity. Plants and animals adapt to specific habitats as an evolved response to structural and compositional features of the landscape. These structural and compositional features in turn reflect the state of underlying ecological functions and processes. To the extent that certain features are retained, it is assumed that natural processes are occurring and ecological integrity is maintained. Loss and fragmentation of natural communities (i.e., habitats) is considered a primary stressor in Maine's working forest, and Reserves serve as a control where these stressors have been minimized. Second, many structural and compositional features of natural communities are readily measurable, and comparable data exists for them from other sources (e.g., USFS FIA information). Third, natural communities are viewed by many as distinct entities of conservation value, and taxonomies (i.e., classifications) have been developed to recognize the rarity and distribution of natural communities.

Based on a review of similar forest monitoring plans used elsewhere, this plan will use the following approach:

1. Identification of monitoring goals and questions.
2. Description of significant stressors.

3. Clarification of suitable indicators.
4. Evaluation of methods.
5. Development of a data management system.

2. Goals

Ecological Goals:
1) To establish baseline information against which ecological changes may be measured over time.
2) To collect representative information for Reserves that can be compared with information on managed forests.

Programmatic Goals:
1) To establish a protocol for monitoring all of the state's Ecological Reserves.
2) To establish a data management system for evaluating and reporting on monitoring results.
3) To develop criteria to be considered when evaluating appropriateness of proposed research projects on Ecological Reserves.

Primary Monitoring Questions:

To further elucidate the objectives of monitoring, the Committee evaluated a wide range of monitoring questions and objectives. Questions listed below were considered to be both the most important and most feasible to monitor. Appropriate indicators are listed after each question. (See p. 10 for a more thorough discussion of indicators.) Consequently, these questions will drive the monitoring methodology. Some of the questions relate to one of the two main ecological goals (detection of change over time and comparison between reserves and managed forests), while others relate to both.

Landscape Level Questions

- What types of major natural disturbance are occurring in reserves? What is the frequency and size of long-lived natural disturbances?
  Indicators: *Canopy gap, size, shape, and distribution. Cause of disturbance.*

- What is the distribution and patch size of natural communities, and how does it change over time?
  Indicators: *Natural community size, shape, and distribution.*

- What land uses are occurring adjacent to Reserves?
  Indicator: *Adjacent land use.*

Stand or Natural Community Level Questions

- How does forest structure differ among and within natural community types? How does structure on Reserves compare to that on managed lands? How is forest structure changing over time? How does forest structure respond to natural disturbance?
  Indicators: *Various plot measures of trees, shrubs, herbs, and downed woody debris.*

- How is vegetation composition changing over time? Is the extent of alpine communities diminishing (perhaps in response to global warming)?
  Indicators: *Various plot measures of trees, shrubs, herbs, and downed woody debris. Natural community size, shape, and distribution.*

- How does the vegetation composition of natural communities within Reserves compare to similar natural communities in managed forests?
  Indicators: *Various plot measures of trees, shrubs, herbs*

<u>*Species Level Questions*</u>:

- What are the population levels and trends of selected rare plants (S1 and S2) in Reserves? Are these populations viable?
  Indicators: *Rare plant population levels and Element Occurrence ("EO") ranks.*

- To what extent do selected lichen "indicators" occur on reserves? Can selected lichens serve as indicators of undisturbed or "old growth" conditions.
  Indicators: *Frequency and distribution of old growth "indicator" lichens.*

Other Monitoring Questions Not Addressed Here

A number of other possible questions were discussed by the Committee and excluded because of their lower relative importance, difficulty in assessment, or uncertainty in generating meaningful results. Others (e.g., aquatic features) were considered important, but our assessment of them is limited by lack of funding. Some of these questions may be addressed through concurrent monitoring systems (e.g., MDIFW monitoring bald eagles, University of Maine studying water quality at Tunk Lake). Otherwise, these questions may be useful in targeting research by university scientists, conservation groups, or others. Examples of such questions include:

<u>*Landscape Level Questions*</u>

- What is the impact of climate change on vegetation composition and leafout, and how do these changes affect wildlife use and bird migration?
- What are the effects of acid rain and other types of air pollution on Reserves?

<u>*Stand or Natural Community Level Questions*</u>

- What are the impacts of current human use of Reserves?
- What is the biological composition of selected aquatic features on Reserves (e.g., composition of stream invertebrates), and how does that composition compare with similar systems within managed lands?
- How do soil conditions and nutrient cycling compare between similar sites in Reserves and in working forests?
- What soil types occur on Reserves?
- What is the physical and chemical composition of aquatic systems on Reserves, and how does that composition compare with similar systems on managed lands?

<u>*Species Level Questions*</u>:

- What are the population levels of rare animals (e.g., lynx) that use Reserves?
- How do amphibian populations within reserves compare to those on managed lands?
- What wildlife species use Reserves, and how does that list differ from that for managed lands?
- How do fish and wildlife respond to natural disturbance (e.g., what is the tolerance of raptors to disturbance)?

3. Stressors and Indicators

Stressors

Stressors are intrinsic and extrinsic drivers of change, either positive or negative, that refer to natural and human-induced disturbances that result in significant ecological effects (Mulder et al 1999). To be most effective, a monitoring program must provide insights into cause and effect relations between environmental stressors and anticipated ecosystem responses. Consequently, indicators should be chosen based on perceived links between stressors and indicators, with pathways leading to effects on ecosystem structure and function. Hemstron et al (1998) provide a general schematic model for these links for late successional and old growth forests in the northwest (Figure 2). Much of this model is relevant for Maine's ecological reserves, which are dominated by mid to late-successional forests and subject to many of the same stressors.

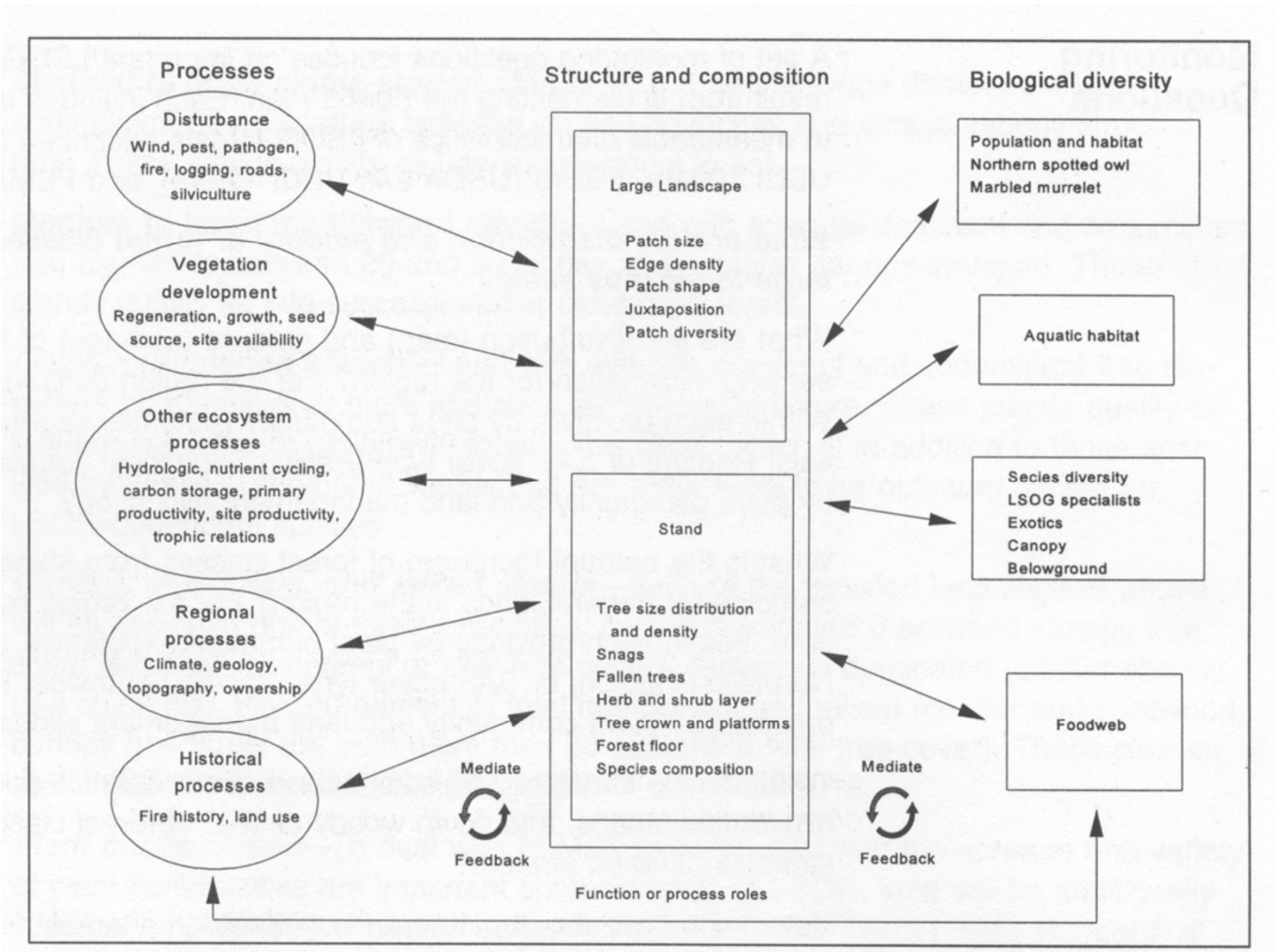

Figure 2: Conceptual model of late-successional and old growth forest (from Henstrom et al 1998).

Relevant ***stressors*** described by Henstrom et al (1998) include:

Fire

Wildfire may cause significant changes in the amount, distribution, structure, and composition of Maine's forests. Wildfire frequency and extent has been dramatically altered in the past two centuries by patterns of settlement and fuel loading and later by increased fire suppression. Some forested natural communities within Maine's ecological reserves are strongly influenced by, adapted to, or dependant on fire (i.e., red pine forests at Duck Lake or aspen forests at Spring River Lake), and many non-forested summit balds and open outcrops may have originated from fire. Although a strict "let burn" policy is not feasible within reserves, the remoteness of some reserve areas may result in the occurrence of wildfires.

Insects and Pathogens

Insect outbreaks and pathogen epidemics may have profound effects on Maine's forests. Early in the last century, the chestnut blight eliminated American chestnut (*Castanea dentata*) from a vast region of eastern North America, including southern Maine. In northern Maine, the spruce budworm (*Choristoneura fumiferana)*, a native insect, is among the more damaging of the region's landscape-level disturbance agents. The budworm alters the structure and composition of extensive softwood areas, with the degree of impact depending on the abundance of fir, which in turn is determined by the natural community type and/or past level of disturbance (i.e., more fir in areas of past heavy harvesting). (Figure 3)

Figure 3: Evidence of spruce budworm and weather damage on the north slope of Bigelow Mountain.

In hardwood and mixed wood forests, an introduced complex of *Nectria* canker (a fungus) and a scale insect (typically *Cryptococcus fagisuga*) is devastating areas with American beech (*Fagus grandifolia*). Another introduced insect, gypsy moth (*Lymantria dispar*) has periodically decimated deciduous forests in southern and central Maine. Numerous other native insects and pathogens occur in Maine's forests, and while they are damaging from an economic perspective, their ecological roles as agents of disturbance are important. Some of the impacts resulting from forest pathogens are long-lived (e.g., budworm) and likely to be captured by periodic monitoring, while others are more ephemeral and would not be captured by a periodic monitoring scheme. In such cases, it may be necessary to deviate from the standard sampling scheme and monitor the affected areas immediately

Wind and Weather
Weather events can affect forests at a variety of scales, ranging from small-scale summer down-bursts that may damage a few trees to winter ice storms that damage thousands of square miles. Weather often acts in tandem with other disturbance agents, such as prior insect damage, to alter forest structure. In such cases disturbance often results in releases of understory vegetation from shade and competition, resulting in changed canopy structure and composition over time. Such changes have direct implications for wildlife, ranging from wintering deer to insectivorous birds. As is the case with insects, impacts from wind and weather can be short or long term, depending on the severity.

Non-native Species
Some non-native species are highly competitive or pathogenic and could have long term effects on Ecological Reserves. To date, although no comprehensive inventories of such species have been completed, current impacts are thought to be minimal. Nonetheless some Reserves support habitats that are vulnerable to invasive plants (e.g., emergent wetlands susceptible to purple loosestrife), and other forested reserves may be vulnerable to non-native insects such as the hemlock woolly adelgid (*Adelges tsugae*).

Human Impacts
The most significant current and future impacts of humans on Reserves are likely to occur through recreational use. Reserves such as the Mahoosucs and Bigelow support popular hiking trails that traverse sensitive alpine habitat. Other recreational activities within Reserves include snowmobiling on designated trails, camping, fishing, and hunting. Most Reserve acres have been harvested in the past, so stand structure and composition will continue to reflect these past activities, although residual effects will diminish over time. On a broader scale, Reserves are stressed by climactic factors influence by humans, including climate change, acid raid, and other forms of air pollution.

A set of ***ecological indicators*** was selected based on the questions and stressors listed above. Indicators are intended to be measurable, to reflect the underlying ecological processes, and to represent the larger resource of which they are a structural or compositional component (Mulder et al 1999). As they relate to USFS FIA data for Maine, a number of these indicators have been discussed and analyzed by Allen and Plantinga (1999).

Indicators

Landscape Indicators:

The growth of GIS-based methods has enabled numerous landscape pattern metrics to be measured. In northwest Maine, for example, Sader et al (2002) are using LANDSAT TM imagery to detect changes in patches within the forested landscape on a large conservation easement. Nonetheless, the application and relevance of many GIS-based landscape metrics is not always well understood, and these methods are rapidly evolving (Gaines et al 1999, Hemstrom et al 1998). As an initial aim, natural community and gap patches, if captured digitally, would allow subsequent analysis by any number of means.

Indicator	How Measured
Natural Community Size, Shape, and Distribution	Natural communities will mapped based on 1:15,840 air photos. They will be depicted on maps, and the acreage of natural communities will be calculated. Measures such as edge to area, contagion, fractal complexity, and interior area may subsequently be generated to evaluate the pattern of natural communities on the landscape
Canopy Gap Size, Shape, and Distribution	Canopy gaps greater than 1/2 acre will be noted from 1:15,840 air photos. Canopy gaps greater than 1/10 acre (i.e., gaps slightly greater than the diameter of one down tree length) will be noted during the course of plot sampling by the line-intercept method along transects. Canopy gaps are defined on p. 11.
Cause of Disturbance	When natural or human disturbance has caused canopy openings, defoliation, or other disturbance that is visible on air photos, the disturbance will be mapped and the cause of disturbance noted where possible. Field plots will also note type of disturbance. Because of the somewhat random and periodic nature of large disturbances, additional plot and remote sampling may need to be conducted on an opportunistic basis to describe the impacts of these disturbances.
Adjacent Land Use	Land uses immediately adjacent and within ½ mile of Reserves will be mapped and classified using satellite imagery or air photos, whichever is more recent. Road mileage will be calculated within ½ mile of Reserves. The *effects* of such land uses would likely require site specific investigation to the area of interest. Possible effects might include increased windthrow and spread of invasive plants.

Stand or Natural Community Indicators

A wide range of stand level indicators were initially considered, including all of those measured by Phase 2 and Phase 3 of the U.S. Forest Service Forest Inventory and Analysis (FIA) Program (See Appendix 2). Indicators listed below are considered the most relevant, measurable, and efficient of the FIA indicators (Allen and Plantinga 1999). Emphasis was placed on selecting indicators that reflect forest ***structure*** and ***composition***.

Indicator	Notes/How Measured?
	Tree Indicators
Tree diameter distribution	Diameters measured to the nearest tenth inch. All trees greater than 5 inches are tallied.
Snags (standing dead tree)	Trees assigned to one of three classes: live intact, live rough cull, or dead. Diameter and height will be tallied, and volume distribution may then be calculated.
Downed woody debris	Coarse woody debris (> 3 inches in diameter): diameter, length, and volume distribution by decay class.
Tree condition	Three conditions: Live tree, live/rough cull, dead tree
Type of damage	Numerous possible classes, e.g., live intact top, dead broken top, wounds, etc.
Vertical diversity/layering	Measured by a combination of uncompacted crown ratio, distribution of trees by crown class (four classes), tree height (measured on each tree), and stand structure (single storied vs. multi-storied).
Tree Mortality	Measured by permanently marking trees (only derived from second iteration and thereafter).
	Stand Indicators
Basal area	Calculated by prism and by plot
Tree height	ree height measured for all trees greater than 5" dbh on each plot.
Stand age	Oldest trees (dominant and co-dominant) on stand cored and aged. Stand harvest history, where available, may be used to augment this field.
Forest Floor	Measured by depth of leaf litter and depth of organic layer.
	Understory Indicators
Sapling abundance, composition	Saplings defined as greater than 1 inch and less than 5 inches dbh. Stems tallied
Shrub and herbaceous species abundance, composition	Stems tallied for shrubs, percent cover tallied for shrubs and herbs. All species identified to species level where possible, genus level otherwise.
Seedling abundance, composition	Seedlings defined by according to FIA definition: for conifers, trees less than 1 inch in diameter greater than 6" in length, and for

	hardwoods, less than one inch in diameter and greater than 12 inches in length. Individuals tallied and percent cover assigned.
Presence/absence of selected lichens	Increasing information points to the presence of certain lichen species as indicators of tree age or structure (Selva 1988, Cameron 2002, Whitman personal communication). Lichens selected for presence/absence on each tree are *Lobaria pulmonaria*, *Lobaria quercizans*, pendulous *Usnea* species, *Collema subflaciodum* and *C. nigrescens*, and *Bryoria capillaries.*

4. Sampling Design

Landscape Level

True color leaf-on air photos, flown at a scale of 1:15,840, will serve as the foundation of landscape level monitoring. Ideally photos will be taken in late spring or early fall to maximize color contrast. The date of photos that are currently available varies for each of the Reserves (see Appendix 3). Photographs will be orthorectified using ER Mapper software to enable geographically accurate polygons and to facilitate direct comparison between monitoring periods. Two types of polygons will be digitized: natural communities and gaps (canopy openings).

- Forest and woodland natural communities will be mapped and identified using the MNAP's natural community classification (Gawler, 2002). (Figure 4) The minimum mapping unit for natural communities will depend on the type. For large patch and matrix communities, the minimum mapping unit will be 3 acres; for small patch communities, the minimum mapping unit will be 1 acre. Digital stand type maps, BPL cruise plots, and reserve permanent plots will be used to "ground truth" natural community polygons.

- Non-forested areas such as the Great Heath may need to be mapped at the coarser "ecosystem" level in MNAP's classification. (Recent experience in Petit Manan National Wildlife Refuge in Maine indicates that as a mapping unit from air photos, the “alliance” level of the National Vegetation Classification is more realistic than the "association" level.)

- Canopy gaps and disturbances greater than 1/2 acre will be delineated and digitized using these photos. Canopy gaps are defined as a continuous break in the canopy strata, with no trees within 50% of the average canopy height. Gap size will be measured from the vertically-projected edge of the foliage (i.e., the dripline). For instance, if the canopy height averages 65’ tall, no trees within the ½ acre gap may be more than 33’ tall. If possible, the cause of this gap (i.e., disturbance type) will be assigned as an attribute.

- Canopy gaps larger than 1/10 acre will be noted in the field by the transect intercept method, using the plot transects. The horizontal length of the gap will be recorded.

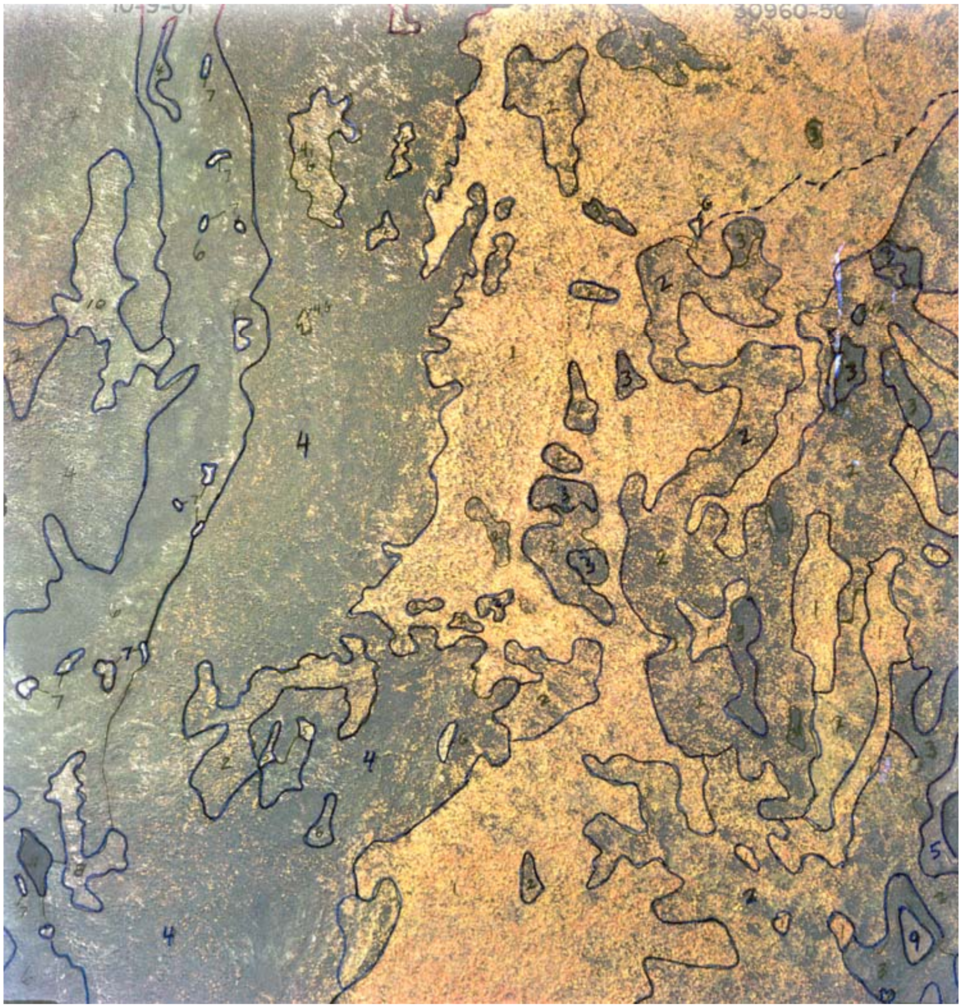

Figure 4: Preliminary natural community overlay of Bigelow Reserve

- Coarse land use/land cover within ½ mile of Ecological Reserves will be digitized using SPOT satellite imagery and air photos. The following classes will be used: clearcuts/early regenerating forest (e.g., less than 10 feet tall), young to mature forest, agricultural land, and developed. Road mileage will be calculated within ½ mile of the reserves for all drivable roads (i.e., Class 4 or better).

To enable the natural community mapping process to be accurate, polygons will first be drawn on acetate overlaid onto the original air photos. Next, these polygons will be geo-rectified to eliminate distortion caused by topography and variation in flight altitude. The geo-rectified polygons will then be digitized and transformed into an ARC-VIEW data layer, with relevant attributes attached.

Stand or Natural Community Level

The sampling design will seek to balance several competing factors: sample size, sample variance, representation of the Reserve, and cost (i.e., time availability). Based on these factors, a design has been developed to capture the indicators listed previously. Much of the methodology for forests and woodlands is adapted from FIA protocol, but FIA plots include many additional measures not included here. Because FIA methods are described elsewhere in exhaustive detail (*http://fia.fs.fed.us/library.htm#manuals*), many of the specific notes are omitted here (e.g., definitions of decay classes for coarse woody debris.)

Plot Stratification:

For all **forest and woodland natural communities**, a stratified random approach will be employed. Statification guidelines will be as follows:

- Three forest type strata will be used: softwood-dominated stands, hardwood-dominated stands, and mixed-wood stands. BPL stand type data will be used to delineate these three strata prior to sampling, and plots will be allocated according to the percentage of each strata. For example, if a reserve is 40% hardwood, 40% mixed wood, and 20% softwood, an attempt will be made to place 40% of the plots in hardwood, 40% in mixed wood, and 20% in softwood. Where the size of the Reserve allows, attempts will be made to place 20 plots in each strata (see Appendix 4 for discussion of minimum sample size.) Where stand type maps and funding for plots allow, finer strata may be used such as pine vs. spruce-fir, tolerant hardwoods vs. intolerant hardwoods, etc.
- Attempts will be made to make sure plots capture significant ecological differences within the reserve (e.g., north facing slope of Bigelow vs. south-facing slope.)
- To ensure adequate spatial representation of each reserve, transect selection will be conducted without replacement. That is, UTM grid cells (the same cells shown on USGS quad maps) will be used to randomly select the transect beginning points. Each new transect can not begin within a UTM grid cell that already has a transect originating in it.

For **non-forested natural communities**, the primary monitoring goal is to detect change over time, rather than to compare with other sites (many non-forested communities have been previously sampled, characterized, and classified). At a minimum, each non-forested area documented as a rare or exemplary natural community will be monitored. Some other non-forested natural communities may be monitored, depending on the Reserve (i.e., if a Reserve has no open habitats mapped as exemplary natural communities). Non-forested natural communities within Reserves are often small and patchy and do not lend themselves to stratified or random sampling. As a result, these communities will be monitored with a systematic approach involving permanent plots (likely a series of $1M^2$ plots) along a transect that is arbitrarily selected to represent the natural community.

Plot Placement for Forest and Woodland Communities:

- Plots will be placed along a transect, with five to six plots per transect (depending on terrain) and each plot spaced twelve chains (792') apart. (Figure 5) This design is intended to allow one transect to be completed in a day; it is estimated that each plot will take approximately one hour.

- Transect origins will be randomly selected by UTN grid cell, and transect bearings will be chosen to allow the transect to traverse across (perpendicular to) the topography. In cases where the bearing would take the transect outside of the reserve, the transect will return to the original plot and head in the opposite direction (180^0). This design should meet many of the statistical requirements of random sampling while providing a representative sample of each reserve.

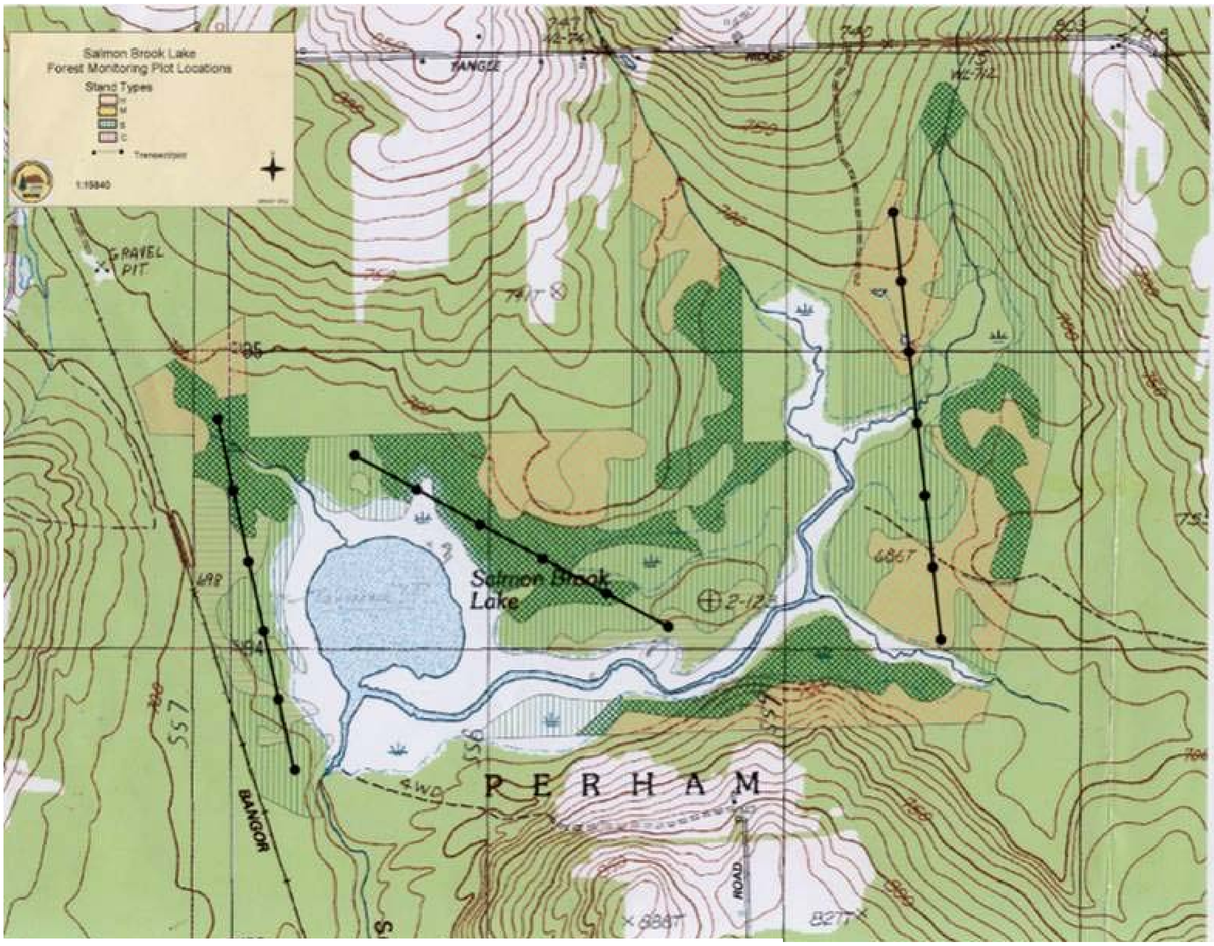

Figure 5: Provisional plot layout for Salmon Brook Lake Bog

- Latitude and longitude coordinates will be pre-determined for all plots. The first plot on each transect will be found using a GPS, and subsequent plots will be placed using a hip chain and compass. GPS readings will be taken for all plot centers. If, upon arrival at the plot center, the plot center is not within 100 feet of where it should be based on the pre-determined coordinates, it will be moved to be within 100 feet. In cases where an obstacle (water body, cliff) prevents hip chaining to subsequent plots, the next plot center will be found with a GPS.

Sampling Intensity

As noted previously, the number of plots to be sampled will be determined by available funding, data needs, size and heterogeneity of the Reserves, and desired statistical precision. Based on the above considerations, in large Reserves (e.g., over 8,000 acres) attempts will be made to place a minimum of twenty plots in any stratification (e.g., softwood, hardwood, mixed wood, non-forested). This intensity roughly equates to roughly 1 plot per 100 acres but may range from 1 plot/50 acres to 1 plot/250 acres. Where fewer than twenty plots are used per strata, for data analysis purposes plots for each type may need to be aggregated among multiple reserves (preferably within the same ecological subsection or BPL region) to achieve a minimum sampling size. For example, rather than assessing hardwood stands just with the Duck Lake Reserve, for analysis purposes all hardwood plots may need to be aggregated within the Eastern Region to achieve the desired statistical precision. Appendix 4 provides some mathematical background for calculating a desired sampling intensity on reserves based on previous BPL cruise data.

Marking Plot Locations:

Plots will be marked in a manner similar to FIA plots. A GPS reading will be taken for each plot center. A plastic stake will mark each plot. Witness trees will be scribed and painted, and distance and azimuth from plot center will be noted (Figure 6).

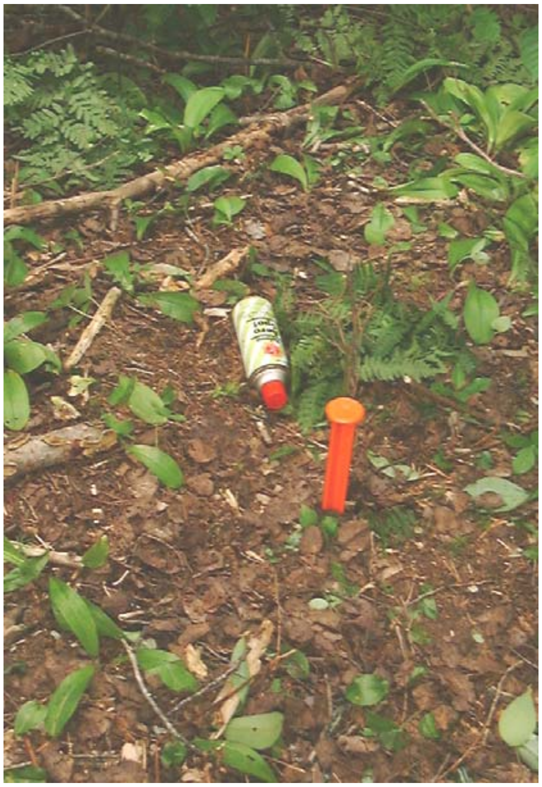

Figure 6: Plot marking: plot center (left) and witness tree (right)

For all non-forested areas at least one photo point will be taken per natural community. Position and direction will be noted for this photo point. Transect beginning and end points will be permanently marked.

Plot Size: For **forest and woodland communities**, nested plots will be used with plot sizes as follows (see Figure 1; adapted from FIA):

- 24' radius "plot": tally all standing trees (live and dead) greater than 5 inches dbh. .

- 6.8' radius "sub-plot:" 1 sub-plot per plot. Tally all saplings (between 1" and 5" dbh) and all seedlings less than 1" diameter (and greater than 12" tall for hardwoods and 6" tall for softwoods). Tally per cent cover for all vascular plants less than 6 feet tall. Cover classes will be: 0%, <1%, 1-5%, 6-10%, 11-20%, and 10% classes thereafter.

- 1 meter squared quadrat: 3 quadrats per plot; per cent cover for a all vascular plants less than 6' tall according to cover classes above; count tree seedlings (as defined above).

- Two transects for downed woody debris will be measured on every plot**.** Transects will extend for 58.9' at 30^0 and 150^0 from plot center. Each downed stem greater than 3 inches in diameter at the transect crossing will be measured if it crosses the transect. Middle diameter and total length will be measured for each stem, and a decay class will be assigned. Species will be noted where possible.

- The thickness of leaf litter, thickness of organic layer (leaf litter plus O horizon), soil type, and drainage class will be assigned. One sample per plot.

- A list will be created of all vascular plant species in the 24' radius plot (i.e., any species present in the 24' plot and not already tallied in the smaller plots will be added to the overall plot list.)

For **non-forested plots**, at least 20 meter squared plots will be used, and per cent cover will be noted for all species using the cover classes above (fewer than 20 plots may be used if the community type is homogeneous). Plot spacing will depend on the size of the natural community sampled. Plots will be permanently marked with metal stakes, PVC stakes, or paint.

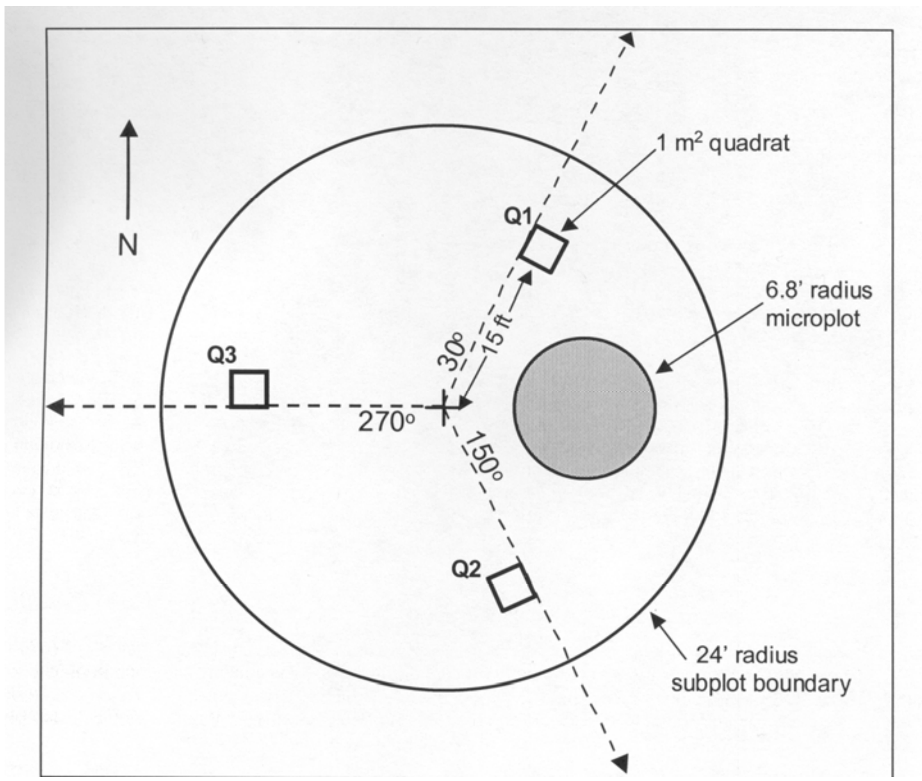

Figure 7: Plot diagram for forests & woodlands*: Source: USFS FIA Phase 3 Field Guide, Draft February 2001*

More specific stand level monitoring may occur, on an opportunistic basis, outside of this stratified random sampling plan. For instance, additional stand level monitoring may be needed

Rare Species

Rare Plant Species:

Forty-nine populations of rare plants are currently considered extant (i.e., verified within the last twenty years) on Ecological Reserves, with several others historic. In a few cases, precise locations and good baseline data exist on population levels and habitat for these species, but for many species the information is rudimentary.

A subset of rare plants will be monitored including any globally rare species and species ranked S1 and S2. (Currently no globally rare plants are known within Ecological Reserves, and of the 33 rare plant populations that are ranked S1 or S2, 21 are in the Mahoosuc Reserve). Locations will be recorded using a global positioning system (GPS) and population estimates will be established. Plants will be assigned ranks from A to D, based on the perceived viability (viability is based on population size, quality of habitat, and stressors).

Rare Animal Species

Only eight populations of rare animal species are considered extant on Ecological Reserves: four nesting locations of bald eagles and four lakes in the Deboullie Reserve with landlocked arctic charr (*Salvelinus alpinus*). Bald eagles are monitored annually by MDIFW.

5. Data Compilation and Analysis

All monitoring data collected on Ecological Reserves will reside with the Maine Natural Areas Program. Data will be entered into an MS Access database specifically adapted for this purpose from MNAP's plots database. Protocols for calculating various metrics (e.g., coarse woody debris per acre) will be adapted from FIA methodology. Summary statistics (means, standard deviations, confidence intervals) may be computed based on these data. Data may be aggregated several ways:

- by stand type
- by natural community type
- by Reserve
- by BPL Planning Unit
- by Biophysical Region

Production and reporting of summary statistics will occur as the need and funding allow. To examine differences between Reserves and managed lands, statistical analyses may be coupled with vegetation classification techniques such as TWINSPAN, DECORANA, and CONOCO.

A specific reporting format has not been determined. All data will be considered public and available to universities, conservation groups, and other researchers.

All information on rare species and exemplary natural communities collected in the field will be processed in MNAP's Biotics Database.

Landscape Monitoring

Natural community and gap polygons will be digitized and ARCVIEW shape files created and stored at MNAP. Land use and roads within ½ mile of Reserve boundaries will be digitized and stored at MNAP.

Field Collection

Reserve monitoring field forms will be used (see Appendix 6) for plot sampling. Standard natural heritage field forms will be used for rare plant monitoring. GPS use will allow rare species and plot locations to be downloaded into an ARC-VIEW GIS coverage.

6. References

Allen, T.G., and A. Plantinga. 1999. Investigations into the Potential of Measuring Biodiversity in Maine's Forests with Forest Inventory and Analysis (FIA) Data. Maine Agricultural and Forest Experiment Station Technical Bulletin 171. University of Maine. Orono.

Cameron, R.P. 2002. Habitat Associations of Epiphytic Lichens in Managed and Unmanaged Forest Stands in Nova Scotia. Northeastern Naturalist 9(1):27-46.

Gaines, W., R. Harrod, and J. Lehmkuhl. Monitoring Biodiversity: Quantification and Interpretation. USDA Forest Service. Pacific Northwest Research Station. Technical Report PNW-GTR-443. Portland, Oregon.

Gawler, S. 2002. Natural Communities of Maine: A Classification of Vegetated Natural Communities and Ecosystems. Maine Natural Areas Program, Department of Conservation. Draft October 2001.

Hemstrom, M., T. Spies, C. Palmer, R. Kiester, J. Teply, P. McDonald, and R. Warbington. 1999. Late Successional and Old Growth Forest Effectiveness Monitoring Plan for the Northwest Forest Plan. USDA Forest Service. Pacific Northwest Research Station. Technical Report PNW-GTR-438. Portland, Oregon.

Mulder, B. Barry R. Noon, Thomas A. Spies, Martin G. Raphael, Craig J. Palmer, Anthony R. Olsen, Gordon H. Reeves, and Hartwell H. Welsh. 1999. The Strategy and Design of the Effectiveness Monitoring Program for the Northwest Forest Plan. USDA Forest Service. Pacific Northwest Research Station. Technical Report PNW-GTR-437. Portland, Oregon.

Selva, S. 1998. Lichens as Indicators of Old Growth. Prepared for The Nature Conservancy and Appalachian Mountain Club. University of Maine at Fort Kent.

Appendix 1:

Ecological Reserves Monitoring Committee

Name	**Affiliation**
Dave Courtemanch	Maine Department of Environmental Protection
Molly Docherty	Maine Natural Areas Program
Ken Elowe	Maine Department of Inland Fisheries and Wildlife
Sue Gawler	Gawler Conservation Sciences
John Hagan	Manomet Conservation Sciences
Mac Hunter	University of Maine at Orono
Ken Laustsen	Maine Forest Service
Janet McMahon	Private Consultant
Dave Publicover	Appalachian Mountain Club
Nancy Sferra	The Nature Conservancy
Barbara Vickery	The Nature Conservancy
Joe Wiley	Maine Department of Inland Fisheries and Wildlife

Appendix 2:

Background on the
US Forest Service Forest Inventory and Analysis (FIA) Program

The Forest Inventory and Analysis (FIA) has 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" (USFS FIA web page). FIA reports on the status and trends in forest area and location; in the species, size, and health of trees; in total tree growth, mortality, and removals by harvest; in wood production and utilization rates by various products; and in forest land ownership. In Maine, the Maine Forest Service works cooperatively with the US Forest Service to implement the FIA program. It is the most widely used and available source of information on forest conditions in the country.

In recent years there has been increasing focus on the utility of FIA data to assess biodiversity. For example, Plantinga and Allen (1998) explored the appropriateness of FIA data to gauge the status of biodiversity in Maine. Consequently, the FIA program is currently expanding the scope of its data collection to include non-timber attributes.

The basic sample design (Phase 2 plots) involves one sample location (FIA plot) for every 6,000 acres. Forested sample locations are visited by field crews who collect a variety of forest ecosystem data. Phase 3 consists of a subset of the phase two plots (approximately 1 every 96,000 acres) which are visited during the growing season in order to collect an extended suite of ecological data including full vascular vegetation inventory, tree and crown condition, soil data, lichen diversity, coarse woody debris, and ozone damage.

Use of FIA Data

FIA data will serve as the basis for comparing conditions on Ecological Reserves to those on managed lands.

- Of the ~3,000 or so FIA plots scattered throughout Maine, there are only a handful of plots on Ecological Reserves. For a variety of reasons this information is kept highly confidential by the USFS, and MFS is obliged to honor that confidentiality.

- Landowners can request data from FIA plots on their lands, but even landowners are not given plot locations.

- FIA plots have been sampled in Maine since 1956. Half of the plots sampled in 1995 are not being re-sampled, due largely to changes in methodology. A few years ago MFS moved from a periodic survey to a five year annual rotation, sampling ~700 plots each year.

- As an additional consideration, there are about 340,000 acres within Maine (not including Eco-reserves) that fall within lands classed by USFS as “Reserve Timberland” -- that is, legislated as off limits to harvesting. There are 48 permanent FIA plots on these lands. Data could be derived for reserve timberland plots and compared to data from managed lands. (One must recognize, however, that much of this “reserve timberland” land may be higher elevation or inoperable, so direct comparisons to managed lands may have limitations.) This information does not relate to Ecological Reserves *per se* but it is relevant to the broader issue of comparing managed to un-managed lands.

FIA Sampling Methodology

- FIA plots are fixed-radius, nested plots with different plot sizes for different strata (i.e., larger plot for trees, smaller plot for tree seedlings, etc.). Detailed data are collected on trees, shrubs, tree seedlings, and snags and dead trees.

- As noted above, a subset ($1/16^{th}$) of FIA plots are also sampled using Forest Health Monitoring (FHM) methodology. FHM protocol continues to evolve, but currently the major added values of FHM are: (1) additional attributes of tree health and vertical structure – specifically crown characteristics, (2) collection and documentation of vascular plant diversity, (3) collection of lichens – for species richness indices, (4) more detailed data on fine and coarse woody debris, and (5) assessment of soil properties. More detailed floristic sampling of non-woody species was field tested in 2001 and is expected to be operational by 2002 or 2003. Bryophytes are not sampled.

- There are clearly major trade-offs between amount of data collected per plot, the geographic extent/representation of plots, and the time (cost) of sampling. For FIA plots, MFS two-person crews are able to complete an average of one plot a day, at a cost of $850 per plot. Collection of FHM data adds at least another person-day.

Conclusion

Based on the need for Ecological Reserve monitoring data to be comparable with data from the rest of Maine, the Committee resolved to use a modified FIA sampling protocol as a base for sampling design. FIA, BPL, and MNAP sampling methods are similar enough so that much of the data generated from Reserve sampling can be compared with both FIA-generated data and MNAP-generated data.

Appendix 3:

A Review of Existing Data for Ecological Reserves

Ecological Reserve Inventories

- The Maine Forest Biodiversity Project orchestrated field inventories of all ecological reserves in the mid 1990s. Written reports summarizing this field work reside with the Bureau of Parks and Lands and The Nature Conservancy, and field forms and data reside with the Maine Natural Areas Program.

Stand Type Maps

- Hard copy stand type maps are available for all Ecological Reserves. Digital maps are available for most reserves, but there are complications for some reserves (Nahmakanta).

- Maps show stands in the basic format of S1A, H2B, M3C, etc. Cedar is typed out separately. Most of the type maps are based on photography from 1992 to 1995.

Air Photos

- Availability of air photos for each of the reserves is shown in the table below. Unless otherwise specified, photos are true color at a scale of 1:15,840 (1 inch = 20 chains). Reserves shown in ***bold italics*** are those selected for initial monitoring in 2002.

Reserve	Photo Date	# 1999 Cruise Plots within the Reserve	Comments
Rocky Lake	Fall 2001	20	
Great Heath	1996		
Cutler	1997	31	
Donnell Pond	Fall 2001	21	
Spring River	1994, 1998*	29	* ice storm, 1:9,000 leaf-off,
Duck Lake	Spring 2001	52	
Nahmakanta	1990	25	Some copies missing, negatives not available. Will be flown again in the fall 2002
Chamberlain Lake	Fall 2001	51	
Gero Island	1994	100	
Wassataquoik	1985	0	
Salmon Brook Lake	Fall 2001	0	
Deboullie	1996	42	
Bigelow	Fall 2001	72	
Mahoosucs	1995	10	

Timber Inventory Information

- BPL timber inventory information is in INFORM3, a DOS program that is spatially linked to MAPINFO. MAPINFO is compatible with ARC-VIEW.

- Data were derived from 1999 cruises, conducted by Sewall under contract to BPL, at a sampling intensity of approximately 1 plot per 50 acres. Plots were placed every eight chains along a transect, with transect starting points and bearings randomly selected. Plots coverage is variable for reserves. Some areas previously allocated as inoperable (e.g., krummholz, designated back-country no-cut) were not sampled.

- Plot locations were not permanently marked, and for the most part, stand type maps were not revised based on cruise data. For each plot the following information was gathered:
  - basal area (10 factor prism) by species,
  - estimated diameter in 2" classes for all trees > 1" tallied by the prism. Standing dead trees were tallied.
  - soundness for each tree (3 grades)
  - log grade for each tree (5 classes for hardwood, fewer for softwood)
  - quality of regeneration (two values – good or poor)
  - age class of stand (***this was estimated, trees were not cored***); older categories were 81-120 and 120+
  - "den" trees – live trees with cavities.
  - slope, aspect
  - height class of stand

Other Reports and Studies

A variety of other studies and reports, ranging from BPL-sponsored Natural Resource Inventories to Unit Management Plans, are noted in the Ecological Reserves Monitoring Notebook.

Appendix 4:

Discussion of the Sampling Intensity Calculation

A mathematical formula is commonly used to guide the number of plots needed for a given statistical precision:

$$n = \left(\frac{t*s}{E} \right)^2$$

Where n = sample size
t = value used for establishing confidence limits (2 for large samples)
s = standard deviation
E = desired half-width of the confedence interval

This formula can also be expressed in an alternate version:

$$n = \left(\frac{t*CV}{A} \right)^2$$

Where CV = coefficient of variation expressed as a percent of the mean, and
A = allowable error, expressed as a percent of the mean.

This formula relies on a previous estimate of standard deviation (or coefficient of variation). The standard deviation will differ for each of the numerous attributes measured (e.g., basal area, number of stems, tree diamater). For the purposes of determining appropriate sampling sizes for Ecological Reserves, prior sampling statistics were obtained from two sources:

- Timber cruises conducted for BPL in 1999. Statistics were obtained for the Tunk Lake Unit (Donnell Pond and Spring River Lake) and the Bigelow Reserve.

- US Forest Service FIA plots sampled in 1995. Plots were downloaded from the web.

Previous samples were stratified in a variety of ways to deduce a range of coeffecients of variation that might represent forested lands on Ecological Reserves. For example, using basal area as a measure, hardwood plots in the Bigelow Reserve produce a CV of 42.6%. FIA plots on "reserve land" (i.e., timber harvesting prohibited) from the1995 produce a C.V. of 52.3%. Most of the other C.V.'s for relevant stratifications ranged between 30% and 65%.

For the purposes of determining an appropriate number of plots, a C.V. of 45% seems reasonable based on the statistics of previous samples. The formula above can now be used to estimate sampling intensity for a desired level of sampling precision. For example, *To estimate the mean basal area to within ±10% at a probability level of 90%, 58 plots would be needed:*

$$n = \left(\frac{1.68*45}{10}\right)^2 = 57.1$$

Using the C.V. estimate of 45% from previous sampling, another useful way to apply this formula is to calculate the allowable error (A), or half-width of the confidence level, that would result from a given number of plots. For example,

If 25 plots are used, one would be able to estimate the mean basal area to within 11.8% at a probability level of 80%:

$$25 = \left(\frac{1.341*45}{A}\right)^2$$

A = 11.8

Using the CV of 45%, the following allowable errors are produced at the 80% and 95% confidence level:

Number of plots	**95% conf.**	**80% conf.**
5	51.7%	29.7%
10	31.7%	19.5%
15	24.6%	15.6%
20	21.0%	13.3%
25	18.5%	11.8%
30	16.8%	10.8%
40	14.4%	9.3%
60	11.5%	7.5%

As this table indicates, there are diminishing returns for increased precision as the sample size increases -- particularly below 20 plots. Thus, given other factors of sample cost and desired attributes to measure, the suggested minimum sample size for Reserves will be 20.

Appendix 5:

Criteria for Evaluating Research Projects on Ecological Reserves

In general, the Department of Conservation encourages non-manipulative research that does not significantly impact the ecological composition, structure, or function of an area. The state will generally not allow research that involves removal or destruction of geological specimens or features, alteration of terrain, or removal, destruction, or loss of plants and animals. The level of acceptable use varies by reserve, depending on the rarity of the taxa, fragility or resilience of the ecosystems, and cumulative impacts of use.

Final decisions on research will be made by the Bureau of Parks and Lands with review by the Ecological Reserves Monitoring Committee.

Specific criteria for evaluating research projects have been adapted from those for Baxter State Park:

1) Impact to the Park:

2) Relevance of the Research.

Applications:
Applications to conduct research must be no more than five pages in length and contain the following:

1. Title
2. Name of Principal Investigator and supervising professor (if appropriate)
3. Researcher's credentials (resume or c.v.)
4. Description of research, including goals, methods, and relevance.
5. Reserve(s) and areas of reserve proposed for research
6. Impact on the Reserve
7. Budget
8. Schedule for research and completion of the project.

Applications should be submitted to the Bureau of Parks and Lands at least three months prior to the initiation of research,

Collections
Collection of any plant or animal will require prior approval from the Ecological Reserves Monitoring Committee. Collection of birds, mammals, or state-listed wildlife species will require an additional permit from the Maine Department of Inland Fisheries and Wildlife.