U.S. Fish and Wildlife Service
U.S. Department of the Interior

National Wildlife Refuge System

# Rapid Ecological Assessment Methods for Forests in the Laurentian Mixed Forest-Great Lakes Coastal Biological Network, Midwest Region, National Wildlife Refuge System, US Fish & Wildlife Service

*Midwest Region - Survey Protocol Framework: First Edition (2014)*

**ON THE COVER**
Red pine stand, Seney National Wildlife Refuge
Photograph by: G. Corace (Seney NWR)

# NWRS Protocol Signature Page

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| **Protocol Title: Forest Rapid Ecological Assessment Methods, Great Lakes Biological Network (NWRS)**<br><br>**Version[1] : 1.0** | |
| **Station Name:**<br>**Horicon, Ottawa, Rice Lake, Seney, Shiawassee, Tamarac** | **Authors and Affiliations:**<br>**Greg Corace (Seney NWR) and Holly Petrillo (Univ. WI-Stevens Point)** |

**Approvals**

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| **Zone I&M[3] or equivalent Approval:** | [illegible] | Feb. 19, 2014 |
| **Regional I&M[4] Approval:** | Melinda Knutson Melinda Knutson | 2/24/2014 |
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[1] Version is a decimal number with the number left of decimal place indicating the number of times this protocol has been approved (e.g., first approved version is 1.0.; prior to first approval all versions are 0.*x*; after first approval, all minor changes are indicated as version 1. *x* until the second approval and signature, which establishes version 2.0, and so on).

[2] Signature of station representative designated lead in development of a site-specific survey protocol.

[3] Signature signifies approval of a site-specific survey protocol.

[4] Signature by Regional I&M Coordinator signifies approval of a protocol framework to be used at multiple stations within a Region.

[5] Signature by National I&M Coordinator signifies approval of a protocol used at multiple stations from two or more Regions.

## Survey Protocol Summary

During 2010 and 2011, six refuges of the Laurentian Mixed Forest—Great Lakes Coastal Biological Network (hereafter, Great Lakes Biological Network) conducted assessments of their forests using methods outlined in the original field manual. Summary documents based on these data were finalized in 2012 (for an example see Goebel and Corace 2012). On March 21, 2013 an email was sent to members of the National Wildlife Refuge System (NWRS) Division of Biological Resources (DBR) and to other NWRS colleagues requesting input and comments for improving the original field manual for use in future assessments or any other sampling done within forests of the Great Lakes Biological Network. Comments were received over the next six months, and this first edition of the regional survey protocol framework reflects those suggestions. Specifically, changes and clarifications were made in a number of areas, including the goals/objectives, sampling issues, the detail of observation in tree vigor, the dropping of damage classes, clarification with coarse woody debris (CWD) measurement and data use, how to measure saplings (midstory layer), and how to measure groundflora (groundcover). Useful comments were also received that suggested the integration of collected data into existing software such as the U.S. Forest Service Fire Effects and Monitoring and Inventory Protocol (FIREMON) and other software (e.g., T-Cruise, etc.). For copies of the detailed comments see the Appendices. These comments, and the input of other experienced professionals, will be invaluable in any future efforts to establish generalized regional or national protocols.

**Suggested citation:** Corace, RG III, Petrillo, HA. 2014. Rapid ecological assessment methods for forests in the Laurentian Mixed-Forest-Great Lakes Coastal Biological Network, Midwest Region, National Wildlife Refuge System, US Fish and Wildlife Service. Seney NWR, Seney, MI.

This protocol is available from ServCat [https://ecos.fws.gov/ServCat/]

# Acknowledgments

The first approved version of this regional survey protocol framework benefitted from the comments of Jeff Denman (White River NWR, R4), Carl Schmidt (Piedmont NWR, R4), Paige Schmidt (Zone Biologist, R2), John Simpson (Lower Mississippi River Refuge Complex, R4), and Paul Castelli (Edwin B. Forsyth NWR, R5). Their suggestions can be found at the end of this document in Supplemental Materials 3. Substantial editorial assistance was received from Ashlee Baker, Dawn Marsh, and Anthony Spencer (Applied Sciences Program, Seney NWR). The authors also appreciate the support of colleagues in the Great Lakes Biological Network who helped draft the original field methods and assisted with trials of the methods. Special thanks to Ron Huffman (Ottawa NWR), Michelle Vander Haar (Shiawassee NWR), Michelle McDowell (Rice Lake NWR), Wayne Brininger (Tamarac NWR), and Wendy Woyczik (Horicon NWR). Carl Schmidt, Jeff Denman, and Tom Lapointe (Silvio O. Conte NWR, R5) provided much needed input at the Seney NWR workshop in 2009. We would also like to thank Lindsey Shartell (Michigan Technological University), Charles Goebel (The Ohio State University), and the numerous Applied Sciences Program interns who assisted with data collection (Joe May, Dakotah Hunter, and Alina Neel). Funding for this project was received by the U.S. Department of the Interior, Fish and Wildlife Service, Midwest Region and the participating refuges, especially Seney NWR. This template was adopted from a template developed for reporting Technical Reports or Long-term Monitoring Protocols by the National Park Service. The template was initially modified and provided by Jennifer Smetzer and Bill Thompson of Region 5 of the National Wildlife Refuge System. Subsequent to drafting of the *Survey Protocol Handbook*, Sean Blomquist (Region 3 I&M) and Pat Ward (NRPC I&M) modified the template to match format suggested in that Survey Protocol Handbook. Jana Newman and Lee O'Brien (Natural Resources Program Center, I&M, National Wildlife Refuge System) provided thoughtful reviews.

# Contents

NWRS Protocol Signature Page ..... i
Survey Protocol Summary ..... ii
Acknowledgments ..... iii
Contents ..... iv
Narrative ..... 5
Element 1: Introduction ..... 5
Element 2: Sampling Design ..... 8
Element 3: Data Collection and Processing ..... 8
Element 4: Data Management and Analysis ..... 9
Element 5: Reporting ..... 9
Element 6: Personnel Requirements and Training ..... 9
Element 7: Operational Requirements ..... 10
Element 8: References ..... 10
Standard Operating Procedures ..... 13
Standard Operating Procedure 1: Sampling Design ..... 15
Standard Operating Procedure 2: Conducting Surveys ..... 18
Standard Operating Procedure 3: Data Analysis ..... 21
Standard Operating Procedure 4: Permits and Other Compliance Documents Required ..... 23
Supplemental Materials ..... 24

# Narrative

## Element 1: Introduction

### *Background*

The National Wildlife Refuge System (NWRS) attempts to conserve, preserve, and restore lands for the wildlife they support. To guide land management actions within the NWRS, the 1997 Refuge Improvement Act stipulated that managers should, "where appropriate, restore and enhance healthy populations of fish, wildlife, and plants…." (Public Law 105-57-October 9, 1997). Along with the subsequent Biological Integrity Policy (2001), land managers were encouraged to favor ecologically-based wildlife habitat management, with restoration to historic conditions where and when possible (Schroeder et al. 2004; Meretsky et al. 2006).

Of the total area comprising NWRS land units in the Lower 48 states, Scott et al. (2004) found that 11% consists of forests as indicated by National Land Cover Data (25% if woody wetlands were included). These forests provide habitat for wildlife species of many taxa, vertebrate and invertebrate, migratory and non-migratory. Consequently, in 2006 the Region 3 (Midwest) and Region 5 (Northeast) Biological Monitoring Team (BMT) held a workshop to address refuge forest management needs. An associated survey indicated 68% of refuges (63 of 92 respondents) had forests, and 86% were actively managing them. A large proportion (41%) managed >5,000 acres and 65% managed >1,000 acres. In general, refuges were concerned with the ecological integrity of their forests, and 47% considered their forests to be in poor ecological condition. However, few refuges had any data pertaining to existing forest conditions (unpub. R3/5 BMT Report, Corace et al. 2012).

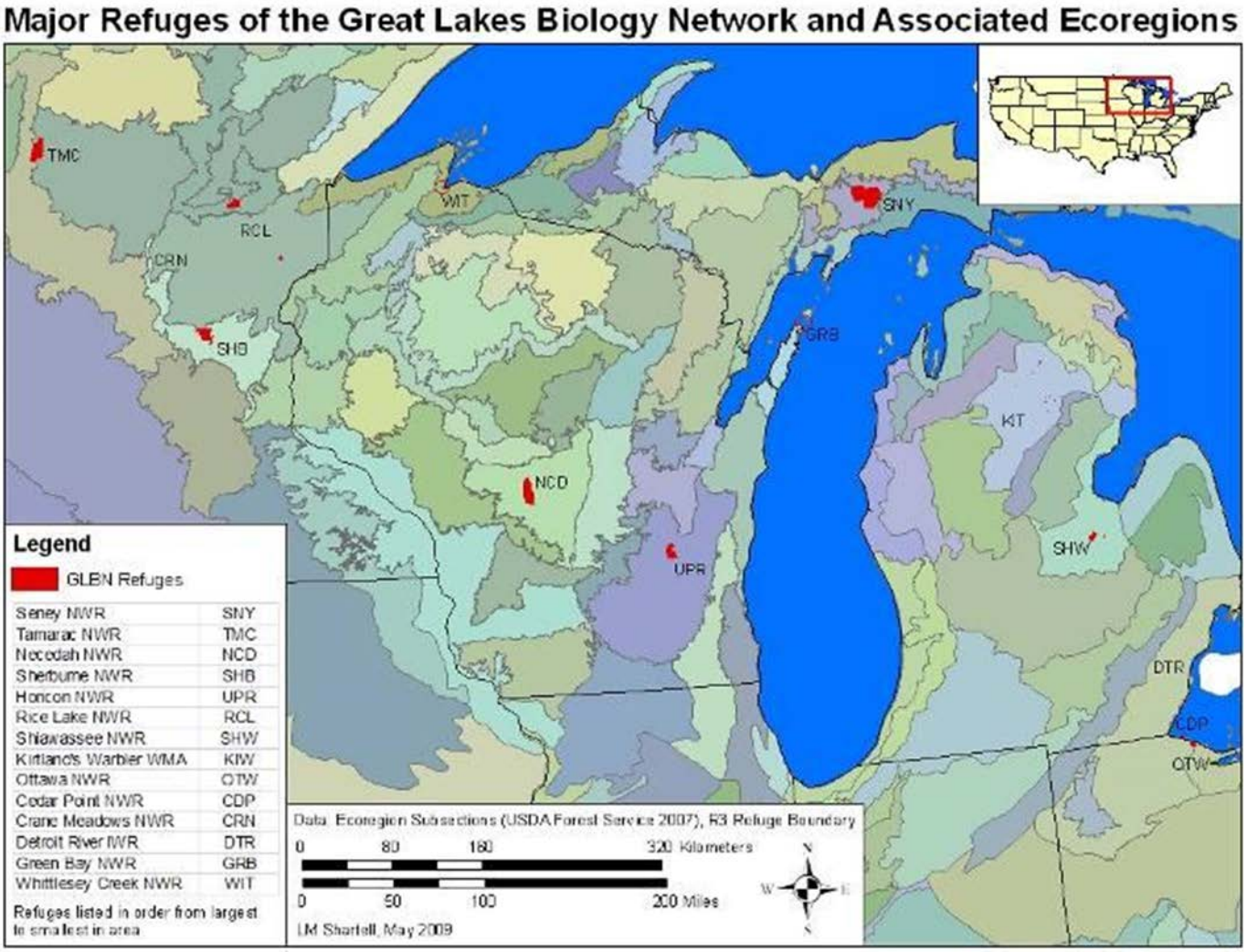
A rapid ecological assessment (REA) is a tool that can be used to investigate spatial and temporal patterns within an ecological (not necessarily wildlife) context. A protocol is developed and data are then collected from which ecological metrics are calculated. These metrics can be used to establish goals and objectives for each site. The assessment sampling methods are designed to be completed in a short time and with repeatability. Metrics chosen for a forest REA should be adapted as much as possible for specific ecosystem types as different forests develop different patterns over time.

This work provided the user values that helped facilitate further discussion and allow quantification of typical questions that might arise when thinking about the ecological condition of a forest stand: What is the dominant tree species?; How common are invasive species?; What is the mean (range) diameter?; Is browse of concern?; How much sunlight is reaching the forest floor?; How much regeneration is present by different tree species? Thus, we chose metrics that when viewed in total and with other information regarding landforms, soils, past disturbances, etc. are useful in describing the ecological condition of a forest stand. When compared with literature from benchmark stands or past data regarding historic conditions, these values may show (for instance) deviation from the natural range of variation and guide future conservation or restoration activities.

### *Objectives*

We conducted a rapid ecological assessment (REA) of refuge-prioritized forest stands of six Great Lakes Biological Network refuges: Ottawa National Wildlife Refuge (NWR), Shiawassee NWR, Seney NWR, Horicon NWR, Rice Lake NWR, and Tamarac NWR (Figure 1, below). The goal of the rapid ecological assessment was to increase understanding of existing ecological conditions of refuge forests and facilitate future monitoring and management and communication with conservation partners. Our objectives were to quantify some important compositional and structural patterns as they relate to the ecological integrity of forest stands within the refuges sampled. We did not design this REA to only quantify wildlife-related characteristics of a forest or to replace the monitoring and assessment efforts on refuges with existing programs and experienced staff. In the future, each refuge interested in using this methodology should adapt these methods as needed to meet their own specific stand-level goals and objectives and their existing forest ecosystem characteristics.

Figure 1. Refuges of the Great Lakes Biological Network (GLBN) and their associated ecoregions. A forest rapid ecological assessment (REA) was conducted for six of these refuges in 2010 and 2011: Ottawa NWR, Shiawassee NWR, Seney NWR, Horicon NWR, Rice Lake NWR, and Tamarac NWR.



## Element 2: Sampling Design

### *Sample design*

As a rapid ecological assessment (REA), this work provides baseline data typical of an inventory while also allowing future monitoring. See text above and SOP 1 for more details.

### *Sampling units, sample frame, and target universe*

The ultimate unit of interest is the forest stand, with plots being replicate sampling points within a given stand.

### *Sample selection and size*

For the work herein described, sampling was done based on management priority for the larger refuges (e.g., Seney, Tamarac) and/or the ability in the case of smaller refuges to sample nearly all existing stands (e.g., Ottawa).

### *Survey timing and schedule*

Sampling was done in this work during the May to August field season when most vegetation is active and tree identification is most easily done. If specific species of groundflora (groundcover) is of a major interest, these methods should be adapted to meet the phenology of that plant species or species group.

### *Sources of error*

Numerous sources of error can exist. Knowledge of plant identification can vary from individual to individual and from location to location. We tried to minimize this in our work by having a group conduct field measurements under the direction of a more highly skilled leader. Other errors in individual measurements include canopy opening (handled by taking four readings).

## Element 3: Data Collection and Processing

So as not to “reinvent the wheel”, literature review was first used to identify metrics of interest for characterizing vegetation and appropriate methodologies (see References), with follow-up and input by other NWRS staff at a forest ecology and management workshop at Seney NWR during the Fall of 2009 and subsequent input from reviewers and users during 2012 and 2013. On-site training was then provided so that refuge staff can collect more data in the future. We also provided each refuge with a database of collected data and associated metrics (including plot photos) and an analysis of some composition and structural patterns. This manual provides an updated and condensed methodology used in the REA, an equipment list, raw data sheets, and a list of metrics (and associated descriptions) that can be calculated based on field measurements. [For the sake of consistency and utility, English units are used (primarily) throughout this manual and in the corresponding database.]

### *Pre-survey logistics and preparation*

Prior to the field season, airphotos and GIS can be used to discern potential sampling areas.

***Establishment sampling units***
See below. Multiple methods are acceptable. If plots are to be established for long-term monitoring, rebar with flagging can be used to mark plot centers.

***Data collection procedures (field, lab)***
See SOP 2.

***Processing of collected materials***
Not applicable.

***End-of-season procedures***
Not applicable.

## Element 4: Data Management and Analysis

***Data entry, verification, and editing***
An accompanying Excel database illustrating how data can be organized and manipulated is available from the main author. No centralized database is currently available.

***Metadata***
See above.

***Data security and archiving***
See above.

***Analysis methods***
See SOP 3.

***Software***
See SOP 3.

## Element 5: Reporting

***Report content recommendations***
See SOP 3.

***Reporting schedule and distribution***
See Background and SOP 3.

## Element 6: Personnel Requirements and Training

***Roles and responsibilities***
Teams of three people are most effective at collecting these data. One person is responsible for documenting/writing, while the other two collect measurements. For precision, all should practice all measurements together and come to agreement on range of acceptable error. For

instance, all three people can collect four densitometer readings from the plot center and compare and contrast their results with one another. For consistency one person should then be assigned specific variables to be measured at each plot.

### *Qualifications*

It is critical that field personnel have comfort with the general flora of the area. This can be learned, but should be a major consideration in choosing field personnel.

### *Training*

The best training is to actually conduct test plots and to openly compare data among field personnel. A crew should be efficiently collecting data after 2 hrs of in-the-field training, assuming some initial comfort with local flora.

## Element 7: Operational Requirements

### *Budget*

The procedures described in this document were chosen with the consideration that budgets are limited. All equipment necessary to collect these data should cost <$250 (including densitometer, d-tape, field tape, etc.).

### *Staff time*

Planning to sample a stand should take 1-2 hours. Depending on the density of trees within a plot, field data should take 0.25 to 0.75 hr to collect per plot. Data input into the Excel database should take about the same amount of time, while data analysis should take a bit longer.

### *Schedule and Coordination*

See SOP 1 and 2 and Supplemental Materials.

## Element 8: References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# Standard Operating Procedures

## Background

The methods used were similar to those used by the U.S. Forest Service Forest Inventory and Analysis (FIA) Program, the National Park Service, and other researchers (see Literature Cited/References), but were modified from these intensive monitoring protocols to include measurements that were decided upon through a workshop held at Seney NWR in 2009. Some, but not all, of these metrics, their ecological value, and associated management implications are discussed below (see References, especially Lindenmayer et al. 2000, Waddell 2002, Hagan and Whitman 2006, Webster et al. 2006, Tierney et al. 2009).

- **Number of trees by species per unit area**: this metric relates to compositional heterogeneity, seral stage development, and dominance. When combined with soil data, such a metric helps to describe appropriate silvicultural treatments, help describe successional stage, and may be related to fire fuels. For refuges with significant ash (*Fraxinus* spp.) such data may help determine the severity of impact of emerald ash borer (*Agrilus planipennis* or *Agrilus marcopoli*).
- **Diameter breast height (DBH) of trees by species**: this metric relates to structural heterogeneity, seral stage identification, basal area (cross-sectional area taken up by trees), dominance, and number of cohorts. As structure often drives wildlife use (especially landbird use), this and other structural metrics can be grouped and compared to many wildlife needs.
- **Tree crown class (dominant, co-dominant, intermediate, suppressed)**: this metric relates to structural heterogeneity and future stand development. For each tree, its position in the canopy tells much about its future potential. Dominant trees already have access to a major limiting resource for growth, sunlight, and if left as is will likely continue to flourish (all things being equal). Conversely, if a given stem of many tree species is suppressed for too long in low light conditions, it will have virtually no chance to be in the overstory in the future regardless of whether or not a canopy gap is provided and more sunlight reaches its leaves.
- **Overstory percent cover**: related to the above, this metric evaluates the amount of sunlight reaching the forest floor or other layers of the forest. More open conditions are favored by many species, while other species grow better in shaded conditions (are more shade tolerant). For invasive species, light levels can be especially important as many are not tolerant of shade and do best in full sunlight or partial sunlight (Webster et al. 2006).
- **Number standing dead (snags) and size (DBH)**: this metric is another estimate of structural heterogeneity in a stand and relates very well to specific wildlife values, depending on ecosystem type. According to many authors, snags represent perhaps the most valuable category of tree form in a forest. Of all the characteristics of forest ecosystems that can be altered by past management, the size, diversity, and abundance of snags are important factors affecting bird diversity and abundance in a stand. Moreover, snag size is of interest as relatively small-diameter snags limit use by many cavity-nesting species (e.g., woodpeckers, tree nesting waterfowl, etc.). Some cavity nesters use only individual, large old snags while others prefer clumps of snags. The spatial arrangement of dead and decaying trees also influences snag usefulness to wildlife. Finally, the development of snags creates small canopy gaps that allow for the establishment of a new age class (cohort) of trees.

- **Sapling abundance by species**: this metric relates to both the successional trajectory of a stand and wildlife values. For instance, many forest passerines nest in the midstory (sapling) layer of a forest and knowing sapling abundance by species may indicate suitability for such species. The abundance or composition of a sapling layer may also indicate the effects of browse as all trees species are not browsed at the same rate.
- **Coarse woody debris (CWD) abundance**: another metric of structural heterogeneity, CWD can be related to fire fuels and wildlife use. Dead and down trees create essential habitat for many invertebrates, birds, small mammals, amphibians/reptiles, and some larger mammalian predators.
- **Groundcover (Braun-Blanquet scale) for native and non-native plants, including seedlings**: much of the composition of a forest consists of the groundcover. This metric evaluates the groundcover and, in so doing, also evaluates the abundance of existing tree seedlings. Depending on what comprises this forest layer, increased sunlight levels due to canopy gaps may promote some species over others (e.g., many non-native plants over native plants).

## Standard Operating Procedure 1: Sampling Design

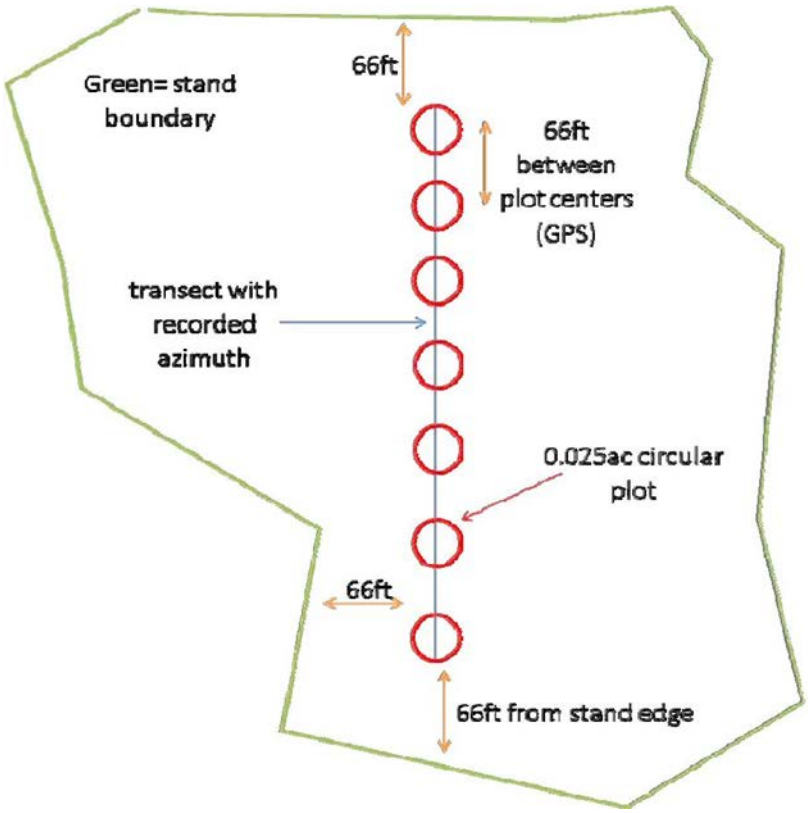
**Forest Stand Transect Layout**

Transects were established that bisected a forest stand and data were collected in fixed-radius circular plots (and associated sub-plot quadrats and transects) at fixed intervals along this transect. We defined a 'stand' as an area with a single dominant forest cover type in a contiguous area. Transects were established so as to minimize edge effect and make the most efficient use of time. The number of transects per stand (and total number of plots per stand) was determined by the total area of each stand; generally, larger stands received more transects (and plots). The number of plots established per stand should be proportional to the size of the stand. While there is no minimum or maximum number of plots per stand that we recommend, at least one transect per stand should cover a representative area, and if more time is available more transects (and plots) can be added (Figure 2). Aerial photos were used to first determine the general transect direction, with the exact azimuth measured and recorded from plot to plot.

To minimize edge effect, transects were initiated 66' (1 "chain" in surveying vernacular) from the edge of the stand (**Note:** sampling in 2010 used a distance of 132' (2 chains) between plots). Therefore the first plot center was established 66' from the edge, and then plot centers were established at 66' intervals along a specified azimuth, preferably along the longest axis (Figure 2). Plots should be established at least 66' apart but this distance may be modified based on individual circumstances in each stand (e.g., a plot landing on a road, in water, etc.). Plots should not be moved to seek nor avoid special places.

Other methods for sampling may include randomly-generated points (using GIS/GPS) or pair transects that are either parallel or orthogonal (perpendicular) to one another. Randomly-generated points have the advantage of not biasing sampling (or at least minimizing bias), but are confounded by close-canopy conditions that may make obtaining satellite signal difficult. Paired transects too may do a better job of encompassing stand heterogeneity in the sampling.

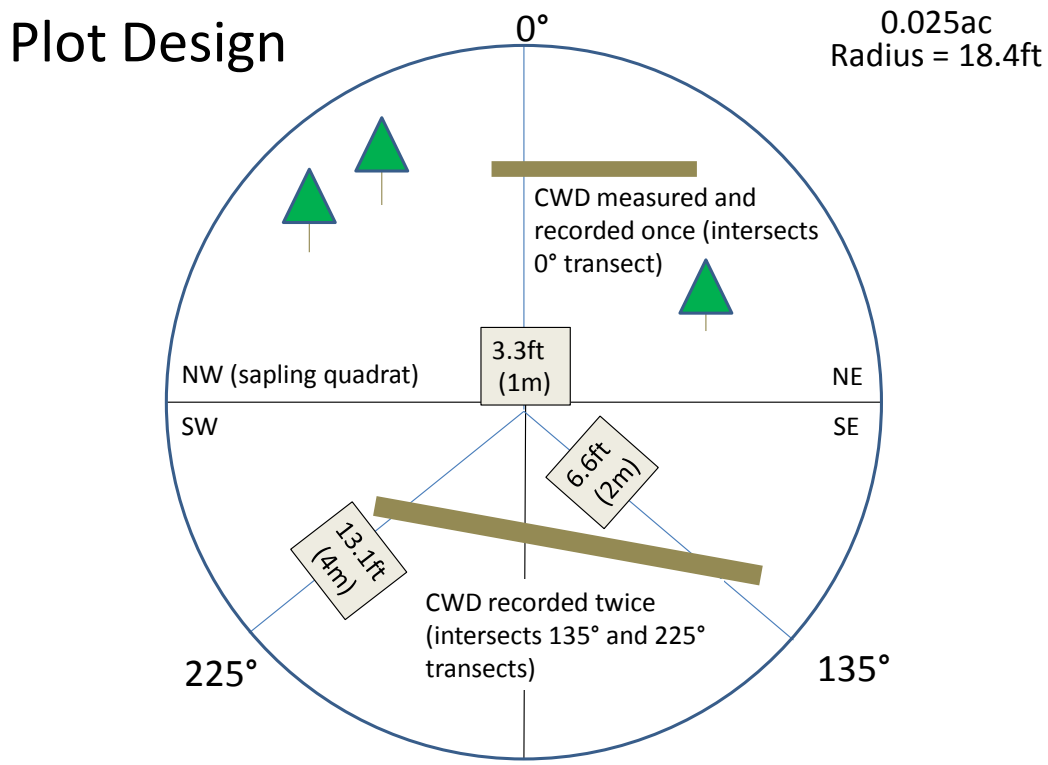
**Figure 2.** Example transect layout in respect to stand edges (green). Plot centers were established every 66', with the area contained in each plot being 0.025 ac (18.4' radius). Sampling alternatives suggested by reviewers and used in other studies include randomly-generated points and paired transects that are either parallel or orthogonal (perpendicular) to one another.




**Sampling Plot Layout and Design**

The 0.025 ac circular plots were used as a trade-off between sampling extensively and intensively and represent an approximate 2% sampling intensity (e.g., 17 plots covering 0.43 ac/25 ac). The radius of these plots was 18.4' (Figure 3). From the center of these plots, we then established three sub-plot transects for use in measuring coarse woody debris (CWD) (see Waddell 2002): one transect at 0 degrees, one transect at 135 degrees, and one transect at 225 degrees. We used one length of rope to lay out the sub-plot transects, with marks at 3.3', 6.6', and 13.1'. The center of 1 $m^2$ quadrats were placed at the mark on each piece of rope, one quadrat at 0 degrees, one quadrat at 135 degrees, and one quadrat at 225 degrees. Groundflora (groundcover) measurements were taken at these locations.

**Figure 3.** Plot design with coarse woody debris (CWD) sub-plot transects at 0, 135 and 225 degrees. CWD is measured based on intercept anywhere along the sub-plot transect and minimum diameter requirements (nothing is measured that is <5”). Sub-plot 1 $m^2$ quadrats were placed on each line: one at 3.3’ from center, one at 6.6’, and one at 13.1’.



## Standard Operating Procedure 2: Conducting Surveys

### Field Measurements

The following field measurements were taken within each plot. We used a new data sheet at the start of sampling each stand and recorded the stand name at the top of that data sheet, therefore a separate column for stand name or number was not necessary to include. Each refuge may want to add variables to address specific interests, such as stand age, physiographic class, etc.

- **Data collected from plot center or in plot overall with data recorder standing at plot center**

1. **N Coord:** GPS North Coordinate (decimal degrees, NAD83)

2. **W Coord:** GPS West Coordinate (decimal degrees, NAD83)

3. **Plot:** Numbering starts with 1 (first plot from stand edge) and proceeds in order thereafter.

4. **Pic:** The photograph number corresponding to plot center of each plot, facing **NORTH**.

5. **Densiometer (Dens N, E, S, W):** Holding the spherical densiometer as required at each plot center, four readings (percent closed canopy) are taken while facing N, E, S, and W. By averaging these four values, the vagaries of densitometer readings are reduced and this average value (with error measurement) may be used in further analyses. Readings among plots (or stands) should be taken at the same time of the year to account for patterns in foliage. That is, sample during either "leaf out" or during the dormant season where deciduous trees are present.

6. **Tree:** The tree number, in order, starting at North. Record and measure trees clockwise that fall within plot; only woody stems (i.e., trees) >5" diameter breast height (DBH) are recorded and measured. This minimum DBH was chosen based upon management considerations; trees smaller than this are usually not commercially harvested within the area covered by the Great Lakes Biological Network and thus forest treatments may not pay for themselves.

7. **Species.:** The tree species code (see Table 1 for species code).

8. **DBH:** (diameter at breast height or 4.5' measured for each tree >5" DBH). Measure to the nearest 0.1"; diameter classes can always be developed later.

9. **Status:** 1 = alive; 2 = dead (snag)

10. **Crown Class:** The crown class code (1-4) for each tree/snag is recorded (Table 2).

11. **Vigor:** The tree vigor code (1-8) for each tree/snag is recorded (Table 3).

- **Data collected within one ¼ area of each 0.025 ac plot (NE, SE, SW, NW).**

12. **Number of saplings (Midstory):** A sapling is >1" and < 5" DBH. Saplings are counted by species within ¼ of each 0.025 ac plot, rotating which ¼ area is counted from plot to plot. Each plot would have a NE, SE, SW, and NW ¼ area. Thus, if starting at Plot 1 and measuring the number of saplings in the NE ¼ area, then at Plot 5 one would be back to the NE ¼ area to measure ageain. This measures regeneration within a stand. Saplings are counted by species (FIA spp codes, Table 1).

- **Data collected based upon intersection anywhere along three sub-plot transects running at 0 degrees, 135 degrees, and 225 degrees.**

13. **CWD (CWD0, 135, 225, see Waddell 2002):** CWD is measured along each sub-plot transect **only** if: 1) the central axis of the piece intersects a transect, 2) the diameter at the small end is ≥5", 3) the piece is at least 3.3' (1 m) long, 4) the piece is in decay class 1-4, not 5 (Table 4).

If the tape cannot be wrapped around the piece of CWD, the diameter is measured by holding a tape above the log at a position perpendicular to the length. Measure both the small-end diameter (sm dia) and large-end diameter (lg dia) of CWD pieces, but no measurement should be <5" and no measurement should extend beyond the plot boundary of 18.4' from center. Large-end diameter is measured at the point that best represents the overall log volume. Identify CWD to tree species (FIA code) if possible.

If a piece of CWD extends beyond the minimum small-end diameter, the length measurement ends where the diameter tapers to 5". Length measurement ends where decay class 5 begins. Decay class recorded for a piece is the stage of decay that predominates along the length of the piece. When a tree is forked or has a very large branch attached to the main bole and both segments intersect the transect, they are tallied as two separate pieces (larger diameter fork considered main bole, smaller diameter fork measured from fork tip to point where fork joins main bole).

- **Data collected within 1 $m^2$ (10.9 $ft^2$) sub-plot quadrats along three sub-plot transects running at 0 degrees, 135 degrees, and 225 degrees. One quadrat is placed on each line: one at 3.3' from center, one at 6.6', and one at 13.1'.**

14. **Quadrat:** labeled 0, 135 or 225 corresponding to the transect degrees.

15. **Groundcover:** Percent cover of functional group or species (e.g., woody plants, herbaceous plants, and lichens/mosses) are recorded in each quadrat using ranking (Table 5). This can be adapted, however, to fit the needs of different refuges. Invasive species are also measured by percent cover, and identified by species (see below). A refuge may want to record the dominant species (not functional group) of woody or herbaceous cover if interested.

**Woody%C:** Ranking (0-6) as representative of percent cover of woody plants.

**Herb%C:** Ranking (0-6) as representative of percent cover of herbaceous plants.

**Moss%C:** Ranking (0-6) as representative of percent cover of lichens and mosses.

16. **Invasive Name & Invasive Cover (Inv Name1, Inv Cover1):** Name and ranking (percent cover) of invasive species are recorded in each quadrat. Space for two invasive species is provided on data sheet, add more columns if necessary.

## Standard Operating Procedure 3: Data Analysis

### Potential Forest Metric Calculations Based on Data Collected At Plot Scale (Can Pool for a Stand)

**Overstory**
Basal area of individual trees (>5”) / snags (dead tree) ($ft^2$) = $DBH^2$ * 0.005454

Basal area per acre (live and /or snag) ($ft^2$/ac) = sum basal area of all trees and/or snags in a plot * 16

Basal area per acre by species by plot ($ft^2$/ac) = sum basal area of given species * 16

Number of individuals by species (overstory trees only)

Percent trees and snags by species by plot

Average (error) percent closed canopy (densitometer readings)

Average (error) diameter at breast height, DBH (in) by all species or individual species by plot

Number of overstory trees in 2 inch diameter classes by plot and species

**Saplings**
Number of woody stems >1” and <5” DBH by species by plot = ¼ plot value * 4

Number of woody stems >1” and <5” DBH by species by ac = ¼ plot value * 4 * 16

**Groundcover**
Percent of plots with invasive species present

Average (error) percent plant cover by plot by species or functional group (for each categorical class, take midpoint of the range of percentages)

Average percent cover of lichens/moss by plot

Average percent cover by woody regeneration (<5” DBH)
**Coarse Woody Debris (CWD)**
Volume of coarse woody debris ($ft^3$/ac) (See Waddell 2002)

Number (%) of plots w/ CWD

**Per-unit Area Estimates**

| **Attribute** | **Equation (for each piece)** |
|---|---|

| | | L | V | $l$ | D | $F$ |
|---|---|---|---|---|---|---|
| Cubic feet per acre | $(\pi / 2L)(V_{ft} / l_i) f$ | Ft | $ft^3$ | ft | in | 43560 $ft^2$/acre |
| Cubic meters per hectare | $(\pi / 2L)(V_m / l_i) f$ | M | $m^3$ | m | cm | 10000 $m^2$/ha |
| Logs per acre | $(\pi / 2L)(1 / l_i) f$ | Ft | - | ft | - | 43560 $ft^2$/acre |
| Logs per hectare | $(\pi / 2L)(1 / l_i) f$ | M | - | m | - | 10000 $m^2$/ha |
| Linear feet per acre | $l_i$ x logs per acre | - | - | ft | - | - |
| Linear meters per hectare | $l_i$ x logs per hectare | - | - | m | - | - |
| Percentage of cover | $0.25\pi (D_S + D_L) / L$ | M | - | - | cm | - |

Note: 1) results of these equations must be summed to the plot level before analysis 2) L is the total length of the transect line of plot, $V_{ft}$ volume in cubic feet of individual piece, $V_m$ volume in cubic meters if the individual piece, $l_i$ length of individual piece, $D_S$ small end-diameter, $D_L$ large end-diameter, $f$ conversion factor

Volume of Individual Pieces

Cubic volume of a log: $V_{ft} = \frac{(\pi / 8)(D_S^2 + D_L^2)\, l}{144}$

where $V_{ft}$ is volume in cubic feet, $D_S$ the small-end diameter in inches, $D_L$ the large-end diameter in inches, $l$ the log length in feet. To obtain volume in cubic meters, use centimeters for diameters, meters for length. And substitute 10,000 for 144.

Total Transect Length

Total length of the transect line (L) for each plot is the sum of the entire individual transect lengths across all subplots on the plot. If multiple conditions exist (forest, field, etc.) take the sum of transect lengths within each condition

**Standard Operating Procedure 4: Permits and Other Compliance Documents Required**

N/A

# Supplemental Materials

## Supplemental Materials 1: Equipment List

Writing instrument

Field vests

Data sheets (plain and write -in-the-rain paper) Field manual (for reference)

Digital camera (for pictures of plot center, facing North)

Spherical or other densiometer

D-tape (DBH tape)

1m2 quadrat (often made from PVC, with glued “elbows”. Having one elbow not glued assists when quadrat needs to be placed around material.

Plot center set-up (typically rebar with 3 ropes attached; rebar is placed at plot center and one rope is
placed at 0, 135 and 225 degrees. Each rope also has one marking on it (one at 3.3ft from center, one at 6.6ft, and one at 13.1ft) where the quadrat is placed.

Compass

GPS Unit

Pin flags (5, with spare): one pin flag to mark 0.025 ac plot center and four to mark 18.4” boundaries of the overall plot, one at approximately each cardinal direction. This makes visualizing the plot easier and helps to determine if overstory trees are in or out of the plot.

Sharpie for marking plot center pin flag if it is to be left.

Flagging

## Supplemental Materials 2: List of Tables

**Table 1. Species codes for woody plants observed in the forest REA for six refuges of the Great Lakes Biological Network.**

**See: http://www.fia.fs.fed.us/library/field-guides-methods-proc/docs/core_ver_4-0_10_2007_p2.pdf**

| Code | Common Name | *Binomial* |
|---|---|---|
| 012 | balsam fir | *Abies balsamea* |
| 094 | white spruce | *Picea glauca* |
| 095 | black spruce | *Picea mariana* |
| 105 | jack pine | *Pinus banksiana* |
| 125 | red pine | *Pinus resinosa* |
| 129 | white pine | *Pinus strobus* |
| 130 | scotch pine | *Pinus sylvestris* |
| 241 | northern white-cedar | *Thuja occidentalis* |
| 261 | eastern hemlock | *Tsuga canadensis* |
| 310 | maple spp. | *Acer* spp. |
| 313 | Boxelder | *Acer negundo* |
| 314 | black maple | *Acer nigrum* |
| 315 | striped maple | *Acer pensylvanicum* |
| 316 | red maple | *Acer rubrum* |
| 317 | silver maple | *Acer saccharinum* |
| 318 | sugar maple | *Acer saccharum* |
| 319 | Norway maple | *Acer platanoides* |
| 356 | Serviceberry | *Amelanchier* spp. |
| 371 | yellow birch | *Betula alleghaniensis* |
| 375 | paper birch | *Betula papyrifera* |
| 391 | American hornbeam | *Carpinus caroliniana* |
| 402 | bitternut hickory | *Carya cordiformis* |
| 403 | pignut hickory | *Carya glabra* |
| 405 | shellbark hickory | *Carya laciniosa* |
| 407 | shagbark hickory | *Carya ovata* |
| 452 | Northern catalpa | *Catalpa speciosa* |
| 462 | Hackberry | *Celtis occidentalis* |
| 490 | dogwood spp. | *Cornus* spp. |
| 491 | flowering dogwood | *Cornus florida* |
| 500 | Hawthorn | *Crataegus* spp. |
| 531 | American beech | *Fagus grandifolia* |
| 541 | white ash | *Fraxinus americana* |
| 542 | black ash | *Fraxinus nigra* |
| 544 | red ash/green ash | *Fraxinus pennsylvanica* |
| 552 | Honeylocust | *Gleditsia triscanthos* |
| 480 | Mulberry | *Morus* spp. |
| 602 | black walnut | *Juglans nigra* |
| 680 | Mulberry | *Morus alba* |
| 693 | Blackgum | *Nyssa sylvatica* |
| 701 | hop-hornbeam | *Ostrya virginiana* |
| 740 | aspen spp. | *Populus* spp. |

| | | |
|---|---|---|
| 742 | Eastern cottonwood | *Populus deltoides* |
| 743 | bigtooth aspen | *Populus grandidentata* |
| 746 | trembling aspen | *Populus tremuloides* |
| 760 | cherry spp. | *Prunus* spp. |
| 762 | black cherry | *Prunus serotina* |
| 800 | oak (deciduous) | *Quercus* spp. |
| 802 | white oak | *Quercus alba* |
| 804 | swamp white oak | *Quercus bicolor* |
| 809 | northern pin oak | *Quercus ellipsoidalis* |
| 823 | bur oak | *Quercus macrocarpa* |
| 833 | northern red oak | *Quercus rubra* |
| 837 | black oak | *Quercus velutina* |
| 901 | black locust | *Robinia pseudoacacia* |
| 920 | willow spp. | *Salix* spp. |
| 931 | Sassafras | *Sassafras albidum* |
| 951 | American basswood | *Tilia americana* |
| 972 | American elm | *Ulmus americana* |
| 975 | slippery elm | *Ulmus rubra* |
| 999 | Unknown | |

**Table 2. Crown classes.**

1. **Dominant** – trees with crown extending above the general level of the crown canopy and receiving full light from above and partly from the sides. These trees are taller than the average trees in the stand and their crowns are well developed, but they could be somewhat crowded on the sides. Also, trees whose crowns have received full light from above and from all sides during early development and most of their life. Their crown form or shape appears to be free of influence from neighboring trees.

2. **Co-dominant** – trees with crowns at the general level of the crown canopy. Crowns receive full light from above but little direct sunlight penetrates their sides. Usually they have medium -sized crowns and are somewhat crowded from the sides. In stagnated stands, co-dominant trees have small-sized crowns and are crowded on the sides.

3. **Intermediate –** trees that are shorter than dominants and co-dominant. They receive little direct light from above and none from the sides. As a result, intermediate trees usually have small crowns and are very crowded from the sides. Intermediate trees may be short but as long as their bole is relatively straight, they will receive this designation. If the tree is crooked and has a lot of bends in the bole from trying to get light, it should be categorized as suppressed.

4. **Suppressed** -- trees with crowns entirely below the general level of the crown canopy that receive no direct sunlight either from above or the sides. Suppressed trees usually have multiple bends in the bole for the tree as the tree grows toward light, and excessive side branching as well.

**Table 3. Tree vigor/condition codes and criteria.**

| Code | Criteria |
|---|---|
| 1 | Crown with relatively few dead twigs; foliage density and color normal; occasional small dead branches in upper crown; occasional large branch stubs on upper bole |
| 2 | Crown with occasional large dead branch in upper portion; foliage density below normal; some small dead twigs at top of crown; occasional large branch stubs on upper bole |
| 3 | Crown with moderate dieback; several large dead branches; bare twigs beginning to show; several branch stubs |
| 4 | Approximately half of crown dead |
| 5 | Over half of crown dead |
| 6 | Tree dead; not cut, standing with fine twigs (less than 2.54 cm (1 in) in diameter) attached to branches |
| 7 | Tree dead (natural death); not cut; standing without fine twigs but still has some branches attached to bole of tree |
| 8 | Tree dead; standing but bole only, no branches attached to bole |

**Table 4. Coarse woody debris (CWD) decay classification.**

| Decay Class | Structural Integrity | Wood Texture | Wood Color | Presence Invading Roots | Condition of Branches and Twigs |
|---|---|---|---|---|---|
| 1 | Sound | Intact, no rot; conks on stem absent | Original color | Absent | If branches present, fine twigs still attached with tight bark |
| 2 | Heartwood sound; sapwood somewhat decayed | Mostly intact; sapwood partially soft. Wood cannot be pulled apart by hand | Original color | Absent | If branches present, many fine twigs gone; fine twigs still present have peeling bark |
| 3 | Heartwood sound; log supports its weight | Large, hard pieces sapwood can be pulled apart by hand | Red-brown or original color | Present in sapwood only | Large branch stubs will not pull out |
| 4 | Heartwood rotten; log does | Soft, small blocky pieces; metal pin can | Red-brown or light | Present throughout | Large branch stubs pull out easily |

| | | | | | |
|---|---|---|---|---|---|
| | not support its weight, but shape is maintained | push apart heartwood | brown | log | |
| 5 | No structural integrity; no longer maintains shape | Soft, powdery when dry | Red-brown to dark brown | Present throughout log | Branch stubs and pitch pockets have rotted away |

**Table 5. Rankings representing percent cover for woody plants, herbaceous plants, lichens/mosses, and invasive species. From a statistical perspective, one can take the midpoint value of the percentages during data analysis. For instance, if three quadrats are sampled in a plot and three rankings (e.g., 1, 2, 5) are recorded, one can treat these as three unique percent cover values (e.g., 3%, 15%, 85%) and obtain averages and error estimates.**

| Rank | Percent Cover |
|---|---|
| 0 | Not Present |
| T | Trace, <1% |
| 1 | 1-5% |
| 2 | 5-25% |
| 3 | 25-50% |
| 4 | 50-75% |
| 5 | 75-95% |
| 6 | >95% |

**Supplemental Materials 3: I&M Protocol Review Documentation Form and Review Comments**

**Protocol Title: Rapid Ecological Assessment Methods for Forests in the Laurentian Mixed Forest-Great Lakes Coastal Biological Network, Midwest Region, National Wildlife Refuge System, US Fish & Wildlife Service**

**Version[1]: 1.0**
**Date of First Complete Draft: 2010**
**Date of Approval: February 2014**

| **Station Name:** | **Authors and Affiliations** |
|---|---|
| **Horicon, Ottawa, Rice Lake, Seney, Shiawassee, Tamarac** | **Greg Corace (Seney NWR) and Holly Petrillo (Univ. WI-Stevens Point)** |

[1] See Survey Protocol Template instructions on assigning versions.

**Protocol Type (Select One): A) New Protocol Framework**

| Version | Date | Author | Change Made | Reason for Change |
|---|---|---|---|---|
| Original draft | 2010 | See above | | Pilot testing and application at 6 refuges |
| 1.0 | 2014 | See above | See below. | Reviewer comments |
| | | | | |

**Internal review(s):** List reviewer comments and describe how they were addressed or why they were not along with each reviewer's name, date review was completed or received, organization, and contact information. If no internal review is used, please briefly describe exemption. Attach separate sheets as necessary.

See below.

**External review(s):** List reviewer comments and describe how they were addressed or why they were not along with each reviewer's name, date review was completed or received, organization, and contact information. If no external review is used, please briefly describe exemption. Attach separate sheets as necessary.

See below.

**John Simpson**
**Lower Mississippi River Refuge Complex**

The REA protocols look good. Ya'll did a good job setting this up.

The only thing that took me some time to figure out was where cavities fit into the damage category, the category name Conks, fruiting bodies, and advanced decay is not the place most folks (or at least simple "redneck" foresters such as myself) would normally look for describing cavities. Might consider changing category name to Cavities, Conks and Fruiting Bodies.

A couple of things that I have questions about, but don't know the forest habitat factors well enough to make comments.

1. Why is the Coarse Woody Debris collected in subplots? Is there so much CWD at each plot that you need to conduct subplots?

2. Why is information about vines is only collected in the damage category? Vines are an important component of the forest and provide many benefits to wildlife, thus some information should be collected about vines other than as a component of damage. May look at how information about vines is collected by refuges in LMV using the LMVJV Desired Forest Conditions publication as a reference.

3. Since you are trying to follow established forest data collection protocols, would the tree vigor/condition categories found on the habitat data sheets in the LMVJV DFC publication work in your area?

Something that may be of interest to you in the future, is the fact that we are currently working with the Lower Gulf Coastal Plain LCC, LMVJV, USGS and some others, on developing a web-based database that will allow for us to upload our forestry habitat information. If things go the way we hope, we will have a database of forest conditions on public lands throughout the region. The database is being setup to accept input from commercially available forest inventory software such as 2Dog and T-Cruise as well as individually developed databases.

**Carl Schmidt**
**Piedmont NWR**

1) Page 7 – *Transect and Plot Layout and Design*. Plots are on a transect bisecting the stand along the longest axis. While I've seen this approach before (it's suggested in the RCW foraging habitat matrix), I don't like it. All portions of the stand are not sampled. While a stand should have some level of compositional and structural homogeneity, natural stands tend to have heterogeneity. Distributing the plots throughout the stand better captures that heterogeneity. I recommend using systematic sampling on several lines throughout the stand.

2) Page 8 – *Transect and Plot Layout and Design*. Plots are 0.025 acres. For the sake of illustration a 25 acre stand in a perfect circle has a diameter of 1178 feet. That makes 17 plots for a sampling intensity of 1.7% (17*0.025 acre plots = 0.425 acres sampled/25 acre stand). While this represents the low end of the spectrum, it's acceptable. Besides, odd shaped stands increase the ratio of area sampled to stand area. By the way, it's more than I do when conducting inventory. I use a 1% sampling intensity (approximately one 10 factor prism point per 10 acres) for inventory that may result in a timber sale. So far no one's complained that the sampling intensity is too low.

3) Pages 8-10 – *Field Measurements*. Numbers 5 to 17 are fairly standard forest inventory measurements. I would consider changing vigor to crown ratio, since it's more commonly used and understood. I would also consider collecting these data in such a manner that they can be input into the Forest Vegetation Simulator (FVS). This Forest Service program is national in scope, is free, and has tech support. FVS can be used for detailed analysis. It's a complex program, however, so training is necessary. One detail about this program – it uses species/diameter relationships to calculate crown diameter, and thus canopy closure, negating the need for the densitometer reading. Also, it can handle the midstory measured at the sub-plots. I use FVS for compartment inventory at Piedmont (FYI – compartment inventory is misleading. Compartment is an administrative unit. The inventory really occurs at the stand level, encompassing all stands within a given compartment).

4) Pages 8-10 – *Field Measurements*. The other numbers address CWD (which is basically synonymous with large fuels), ground cover and midstory. I would look into the software package FFI: Ecological Monitoring Utilities, available at http://www.frames.gov/partner-sites/ffi/ffi-home/. This program is the integration of the NPS Fire Ecology Assessment Tool (FEAT) and the USDA Forest Service Fire Effects Monitoring and Inventory Protocol (FIREMON) http://www.frames.gov/partner-sites/firemon/firemon-home/. In other words, it's an acronym of acronyms. Anyway, this is another program that is national in scope, is free, and has tech support. While using FFI standardizes data collection, it has numerous default protocols, allowing an individual refuge to select those appropriate for their objectives and communities. FFI can export tree data and fuel data into FVS for more detailed analysis. This is what Piedmont is doing for long term monitoring. We have several hundred plots across the refuge. Ten percent are measured each year, using the FIREMON tree data protocol. They are exported into FVS for further analysis, especially with respect to red-cockaded woodpecker foraging habitat. Also, a subset of these plots has extra fire effects

monitoring such as fuel loading and fire severity. This approach integrates the forestry, fire and wildlife programs. Long term monitoring is different than rapid ecological assessment, but I don't see why FFI couldn't be used for both. It's worth investigating.

5) The BLM and The Nature Conservancy each have programs called rapid ecological assessment. Information on the BLM program is available at http://www.blm.gov/wo/st/en/prog/more/Landscape_Approach/reas.html. A book detailing the TNC program is available on Amazon at http://www.amazon.com/Nature-Focus-Rapid-Ecological-Assessment/dp/1559637544.

**Jeff Denman**
**White River NWR**

Pg. 5, The explanation of many of these metrics seem focused more on the trees rather than wildlife response to the metrics. Likely for Refuges that some of both would be good to have. For Tree vigor codes, I suggest the following, with my edits in *italics:*

**Tree vigor codes:** this metric is useful for determining future potential of a stand based upon the stated goals and objectives. *Trees of high vigor are prone to eventually dominate the site, achieve a dominant crown position, produce abundant mast, and contribute to the habitat and stand for a longer period of time.* Trees of low vigor *often are in decline and becoming a living snag prior to mortality. They* have less likelihood of becoming dominant in the overstory, putting on size, and thus becoming (over time) large snags. In other words, trees of low vigor have less likelihood of attaining all life history stages of a tree.

In southern forests, ornithologists have emphasized the importance of midstory cover as structure (cover) for fledgling silviculous birds. Foresters also recognize the shading effect of midstory cover has on lower vegetation, including tree regeneration. Defined as The middle layer of the forest, generally between 10 – 60% of canopy height. Measure of the degree of horizontal occupancy of cover (volume in space noted as midstory) within forest cover (LMVJV Forest Resource Conservation Working Group. 2007. Restoration, Management, and Monitoring of Forest Resources in the Mississippi Alluvial Valley: Recommendations for Enhancing Wildlife Habitat. Edited by R. Wilson, K. Ribbeck, S. King., and D. Twedt.) Thus, I suggest adding:

**Midstory cover:** much of the structure of a forest consists of the midsory. This metric evaluates that structure and its contribution to the shading of the understory and regeneration of trees.

Some may think the lack of Basal Area would leave the data lacking. However, it should be able to be calculated from the tree data of species & dbh taken in the plots. Your use of Overstory percent cover is the over-riding limit of sunlight available to the lower layers of habitat is the proper metric to estimate. BA is often used as a surrogate for overstory canopy closure, but differences between species of crown size & structure have to be kept in mind.

Pg. 7, **IV. Transect and Plot Layout and Design**, 2nd ¶ about # of transects & plots.
Fully concur with first 2 sentences and first half of 3rd sentence. Based on my experience, there is another way to plan sampling that differs from the 2nd half and rest of the ¶. For efficiency, sampling rates can be based upon variability instead of a standard sample rate. Homogenous stands can have reliable estimates with few samples, while heterogonous stands require more samples to achieve similar statistical reliability. Also, larger areas can have a lower sample rate than small areas. It is recognized that taking the time to sample & analyze the variability can take more time that would be spent using a standard sample scheme such as proposed. I think there are a minimum number of plots to have a reliable sample. To get reliable BA of southern hardwoods common to the Mississippi Alluvial Valley, a test of existing 1/5th acre plot data revealed that clustered plots reduced error and that 4 clusters of 5 plots each were the cost efficient sample rate. Adding a 5th cluster did not significantly increase precision for that primary metric (R. Wilson, unpublished report). My mentor was taught timber cruising with variable radius plots by Grosenbaugh of the US Forest Service in the 1950's. Their rule of thumb was 20 prism points provided reliable BA regardless of stand size, taking 30 – 50 points

gave precise volume estimates, and that taking any more points was a waste of time. Other metrics with much more variability would require more samples to achieve similar precision. For the 1/40th acre plots, I expect less than 100 will be too low in precision for highly variable metrics, such as the stand table built with # of trees by species and dbh. While no maximum number, the point of diminishing returns arrives rather quickly in large stands.
I suggest consideration to using prism sampling rather than fixed radius plots. Small fixed radius plots are often used due to difficulty of access to each tree on a plot or desire to spend less time per plot so that more areas in a stand can be sampled. Larger plots are common where low vegetation doesn't restrict visibility or access to trees in the plot. Fixed radius plots samples trees proportional to their frequency of occurrence. This often oversamples smaller, more numerous trees, while undersampling larger, less frequent trees. Variable radius plots samples trees based on their size, rather than frequency, providing higher precision of larger diameter classes which some think is a better balance of use of resources. In the south, 1/5th acre plots are often compared to 10 BAF prism points. For 1/40th acre plots, perhaps a 25 or 30 BAF prism would limit the distance to trees sampled sufficiently, while greatly reducing time spent counting trees in the smallest diameter classes.

I am an advocate of using resources (time, legs, etc.) efficiently to obtain information sufficient for planning purposes, which appears to be designed into the sample scheme described. One method we adopted to increase efficiency was to reduce dead heading by having 2 transects or if more transects desired, then a parallelogram shape of transects so that staff ends up near the beginning point, nearly eliminating dead heading back from a one-way in transect. Thus, I suggest having at least 2 transects per stand and a rectangle-shaped set of transects.

Direction of the transects should be across the elevational gradient if at all possible. Otherwise, samples may be made along a contour and not capture different sites. A topographic map, particularly laid over current imagery to show current conditions and/or obstacles is most valuable to plan an efficient transect layout.

3rd ¶, Land measurement uses "chains", forestry adopted it. Thus "chain" in land surveying vernacular…

Last line, "Plots should be …but this distance may be modified based on … circumstances … road, water, etc.)." This implies the cruiser may modify plot location due to plot landing in an area different from most of the forest. This can lead to inaccurate sampling. If the plot planner locates the plot in a forest instead of on a road, then only because the forest acreage does not include those roads, water, open spot, etc. Perhaps clarify that plot should be taken where it falls within the forest and not moved in the field to seek nor avoid special places.

Pg. 8. OK to have true random assignment of rope lengths to azimuths, but very tempting for field folks to play favorites, even unconsciously, to sample areas that look interesting or to avoid problem areas. Better to use a fixed pattern or rotating pattern, don't leave too much to varying location in the field or your sample will not be unbiased.

Pg 9, #5. Densiometer. Good effort to reduce variations in readings. If forest has any deciduous trees, sample during full leaf-out or account for during readings so as to not undersample when trees are partly dormant.

Tree: Consider starting at direction of travel rather than having to find north before starting. Being temporary plots, the trees are not to be later located for re-measuring the exact same tree.

DBH: Consider defining whether trees are grouped into 2" even-numbered classes or if measured to 0.1" accuracy.

Status: Consider incorporating into the Vigor classes, so that the extreme low vigor has dead next. Can be further divided into 2 dead classes of standing or down dead.

Damage, location, & severity: These were not any of the metrics described in the beginning. Thus these should be optional for those areas that seek the info. Likely that unless sample rate is pretty high, the value of this information may be limited unless the damage is so frequent to be commonly detected.

CWD: Discusses measuring diameter with tape… a Biltmore stick is just as accurate on down wood as it is standing trees, much quicker than tape, but lacks ability to classify much less than 1" diameter classes. For this rapid assessment, it is not likely to need precision higher than 2" diameter classes. Which renders dbh tape as slow and inefficient, and Biltmore or caliper quicker and accurate enough. Further, CWD can be calced in cubic feet by taking the middle diameter and length instead of small & large ends and trying to figure taper. Consider sampling CWD within the fixed radius plot instead of intersecting with a transect. By calculating cu. Ft. that falls within fixed radius plot, the vol/ac can be easily calced.

Percent cover ground layer: Sampling simplified by grouping percent cover, but makes analysis more difficult in that hard to get a mean or variance. It's a balance between effort applied for results gained. I'm willing to group to simplify sampling for these type rapid assessments.

MidStory: Aha! It is in there, but as a species and number inventory, not as the structure provided.

Table 1. Spp codes. Add a code for Dead, being unidentifiable CWD. Looks like codes expected for this Biological Network. Perhaps codes for other trees are available from the listed pdf.

Table 2., 4= Suppressed, last line. "…multiple bends in the bole for the tree as the tree looks for light,…" Trees have eyes to look with? Might be better to word: "…as the tree has grown toward areas light passed through, …"

Figure 4. The color image in the middle of the black & white doesn't fit well, may be a 2nd image that has gotten overlaid of the primary. Or perhaps it is to show that a narrow crowned tree could be classed as Intermediate even without crowding from others?

Table 3. Your 1st code is better than what we devised for Desired Forest Conditions for Wildlife in southern hardwoods. We said no dead limbs, but about 2 days of implementation showed that we had no trees that did not have a dead limb at least at the base of the crown. Your descriptions seem to focus on the growing part of the crown, almost ignoring the bottom, naturally dying part, with is again, well done. Lots of gradation from codes 1 – 5. If these fine gradations are 1) pertinent to wildlife being addressed and 2) this rapid assessment has enough plots to sufficiently

detect the different classes.  I suggest combining 2 & 3 and combing 4 & 5 to get 1 = healthy crown, 2 = some dieback, 3 = most of crown dead, 4 = dead still with twigs, 5 = dead with only large branches and/or bole, 6 = fresh down wood (your CWD classes 1 & 2), 7 = decaying down wood (your CWD 3 & 4), 8 = rotted down wood (your CWD 5).

Tables 4 – 6 and Figures 5 – 33. Pardon my southern, but whoooooeeeeee. This level of detail of damage could be of value for a research project, either tracking specific trees over time or with a jillion trees inventoried to get adequate sample of all the various combinations. However, for a planning inventory such as this REA, this level of detail is way too much effort that I don't see contributing significantly to the wildlife being considered. If cavities of certain characteristics are thought to be important for bats, bears, woodpeckers, tree ducks or other specific wildlife, then note those. But the cruiser will have to spend an inordinate amount of plot time to correctly characterize the exact damage codes.

## Supplemental Materials 4: Sample Data Sheet

**Refuge_____ Azimuth from plot-to-plot_____**

| Plot | Photo | Dens | Tree | Spp | DBH | Status | Class | | CWD 0 | CWD 135 | CWD 225 | Quadrat | Woody %C | Herb %C | Moss %C | Sap. Quart. | Spp. | Number of Sap. | Invasives |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | N | | | | | | Spp. | | | | | | | | | | | |
| | | E | | | | | | Sm. Dia | | | | | | | | | | | |
| | | S | | | | | | Lg. Dia | | | | | | | | | | | |
| | | W | | | | | | Decay | | | | | | | | | | | |
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*Dens N, E, S & W have to be added (written in) at the beginning of each plot; they cannot be typed in ahead of time since we don't know how many trees will be in each plot, therefore we don't know how many rows each plot will take up on the data sheet. This is the same with CWD; we don't know how many pieces of CWD will be in each plot, so the spp, sm dia, etc will have to be added in each time there is CWD measured in each plot.

| REFUGE: | | | | | | AZIMUTH PLOT-TO-PLOT: | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Plot | Photo | Dens | Tree | Spp | DBH | Status | Class | | CWD0 | CWD135 | CWD225 | Quadrat | Woody%C | Herb%C | Moss%C | Sap. Quarter | Sap. Spp. | Number of Saplings | Invasives |
| | | N | | | | | | spp | | | | | | | | | | | |
| | | E | | | | | | sm dia | | | | | | | | | | | |
| | | S | | | | | | lg dia | | | | | | | | | | | |
| | | W | | | | | | decay | | | | | | | | | | | |
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| 1. **Plot**.: Numbering starts with 1 (first plot from stand edge) and proceeds in order thereafter. | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| 2. **Photo:** The photograph corresponding to plot center of each plot, facing north. Taken Yes or No? | | | | | | | | | | | | | | | | | | | |
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| 3. **Densiometer**: Holding the spherical densiometer as required at each plot center, four densiometer readings (percent closed canopy) are taken while facing N, E, S, and W. By averaging these four | | | | | | | | | | | | | | | | | | | |
| | values, the vagaries of densitometer readings are reduced and this average value (with standard deviation) may be used in further analyses. | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| 4. **Tree**: The tree number, in order, starting at north and recording and measuring trees clockwise within | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| 5. **Spp**.: The tree species code (see Table 1 for species code). | | | | | | | | | | | | | | | | | | | |
| | plot; only woody stems (i.e., trees) >5" diameter breast height (DBH) are measured. | | | | | | | | | | | | | | | | | | |
| 6. **DBH**: (diameter at breast height measured for each tree > 5" DBH) | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| 7. **Status:** 1 = alive; 2 = dead | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| 8. **Class**: The crown class for each tree recorded and measured (Class 1 = dominant, Class 2 = co- | | | | | | | | | | | | | | | | | | | |
| | dominant, Class 3 = intermediate, Class 4 = suppressed, see Table 3 and Figure 4 for | | | | | | | | | | | | | | | | | | |
| | descriptions and diagram for each crown class). | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| 9-12. **CWD (CWD0, 135, 225)**: Measure only pieces of CWD that are >5" diameter (at the largest end) (see Tables 4-6 and Figures 6-33 for descriptions and diagrams for damage). | | | | | | | | | | | | | | | | | | | |
| | and below Decay Class 5 at the point of intersection with the transect. Diameter is measured by holding a tape above the log at a position perpendicular to the length, if the tape cannot be | | | | | | | | | | | | | | | | | | |
| | wrapped around the log. Measure both the small-end diameter (sm dia) and large-end diameter (lg dia) of the CWD pieces. Small-end diameter is measured at the end of the log (5" minimum). | | | | | | | | | | | | | | | | | | |
| | Large-end diameter is measured at the point that best represents the overall log volume. Identify CWD to tree species (by species code) if possible. Determine decay class (decay) (see Table 8 | | | | | | | | | | | | | | | | | | |
| | for descriptions and diagrams). Decay class of the log is recorded as the decay class of the piece of wood that intersects the transect. Record data in the column of the sub-plot transect that | | | | | | | | | | | | | | | | | | |
| | is intersected. | | | | | | | | | | | | | | | | | | |

**Data collected within quadrats along sub-plot transects: One 1m$^2$ (10.9ft$^2$) quadrat is placed on each line, one at 3.3ft from center, one at 6.6ft, and one at 13.1ft.**

and > 4' length and that intersect one of the sub-plot transects. The wood must be >5" diameter

13. **Quadrat**: labeled 0, 135 or 225 corresponding to the transect degrees.

14-16. **Percent cover of woody plants, herbaceous plants, and lichens/mosses** are recorded in each quadrat (see table 8 for rankings). Invasive species are also measured by % cover, and identified by species (see below). A Refuge may want to record the dominant species of woody or herbaceous cover if interested.

14. **Woody% C**: Percent cover of woody plants are recorded in each quadrat (T= trace, 1-25%, 26-50%, 51-75%, > 75%).

15. **Herb% C**: Percent cover herbaceous plants are recorded in each quadrat (T= trace, 1-25%, 26-50%, 51-75%, > 75%).

16. **Moss % C**: Percent cover of lichens & mosses are recorded in each quadrat (T= trace, 1-25%, 26-50%, 51-75%, > 75%).

17. **Sap. Quarter:** The quarter of the plot (rotated clockwise each plot) that the number of saplings are identified and recorded.

18. **Spp:** Sapling species

19. **Number of Saplings:** Number of saplings of the species recorded in **18. Spp.**

20. **Invasives:** Any invasives within the plot are identified