



Quality Assurance Plan for the Northeast Temperate Network and Mid-Atlantic Network Long-term Forest Monitoring Protocol

Natural Resource Report NPS/NETN/NRR—2022/2430



ON THE COVER

Photograph of Forest Crew Member sampling diameter at breast height in Morristown National Historical Park.
NPS Photo

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Kate M. Miller¹, Aaron S. Weed², Camilla E. Seirup¹, Adam J. Kozlowski², and Mark J. Johnson³

¹ Northeast Temperate Network
Acadia National Park
P.O. Box 177
Bar Harbor, ME 04609

² Northeast Temperate Network
54 Elm Street
Woodstock, VT 05091

³ Mid-Atlantic Network
120 Chatham Lane
Fredericksburg, VA 22405

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Northeast Temperate Network and Mid-Atlantic Network Protocol Package Documents

This is one of a series of documents that collectively describe the objectives, procedures, and data quality of the Northeast Temperate Network (NETN) and Mid-Atlantic Network (MIDN) long-term forest monitoring protocol. Please visit the NETN/MIDN Forest Monitoring Program on the US NPS's Data Store ([IRMA Reference Code #2189101](#)) for links to all supporting protocol documents and products associated with this program, including but not limited to:

- Protocol Narrative
- Standard Operating Procedures (SOPs)
- Safety Plan
- Summary of Major Protocol Changes

Revision History

As part of the National Park Service (NPS) Inventory and Monitoring Program, the Northeast Temperate Network (NETN) and Mid-Atlantic Network (MIDN) long-term forest monitoring protocol consists of a narrative (Tierney et al. 2017 (NETN); Comiskey et al. 2009 (MIDN)) that describes the monitoring objectives and sampling design, Standard Operating Procedures (SOPs) that outline specific data collection details of the monitoring protocol, a Summary of Major Protocol Changes and Deviations, a Safety Plan and a Quality Assurance Plan (QAP; this document) that describes the standards and procedures used in the collection, processing, storage, analysis, and publication of monitoring data. The latest version of the narrative, SOPs, QAP, Safety Plan, Summary of Major Protocol Changes and Deviations, and additional supporting information can be accessed online at the NETN website (<https://www.nps.gov/im/netn/forest-health.htm>), the MIDN website (<https://www.nps.gov/im/midn/forest-vegetation-coastal-plain-piedmont-parks.htm>) or the NPS Data Store (<https://irma.nps.gov/Datastore/Reference/Profile/2189101>).

The narrative, each SOP, and the QAP have respective revision history logs to document changes in the protocol. The following revision history log is for the QAP. Version numbers will be incremented by a whole number (e.g., Version 1.3 to 2.0) when a change is made that significantly affects requirements or procedures. Version numbers will be incremented by decimals (e.g., Version 1.3 to Version 1.4) when there are minor modifications that do not affect requirements or procedures included in the protocol. Rows are added to the log as needed for each change or set of changes tied to an updated version number.

Revision History Log:

Version #	Date	Revised by	Changes	Justification
1.00	May 2022	–	Initial version	–

Acronyms/ List of Terms

ACAD: Acadia National Park

APCO: Appomattox Court House National Historical Park

BOWA: Booker T. Washington National Monument

COLO: Colonial National Historical Park

GEWA: George Washington Birthplace National Monument

DBH: Diameter at breast height

EISE: Eisenhower National Historic

FRSP: Fredericksburg and Spotsylvania National Military Park

GETT: Gettysburg National Military Park

GRTS: Generalized Random Tessellation Stratified

HOPE: Hopewell Furnace National Historic Site

IMD: Inventory and Monitoring Division

MABI: Marsh-Billings-Rockefeller National Historical Park

MIMA: Minute Man National Historical Park

MIDN: Mid-Atlantic Network

MORR: Morristown National Historical Park

NCBN: Northeast Coastal and Barrier Network

NETN: Northeast Temperate Network

NPS: National Park Service

PETE: Petersburg National Battlefield

QA: Quality assurance procedures – typically occurs before or during data collection.

QAP: Quality Assurance Plan – documents the quality assurance and quality control procedures for a protocol.

QA/QC Visit: Quality Assurance/Quality Control visit – involves NETN staff resampling a RAM site to assess observer bias and sampling error.

QC: Quality control procedures – typically conducted after data have been collected.

RICH: Richmond National Battlefield Park

ROVA: Roosevelt-Vanderbilt National Historic Sites

SAGA: Saint-Gaudens National Historical Park

SAHI: Sagamore Hill National Historic Site

SARA: Saratoga National Historical Park

SOP: Standard Operating Procedures – detailed descriptions of the methods used for this monitoring protocol.

THST: Thomas Stone National Historic Site

VAFO: Valley Forge National Historical Park

WEFA: Weir Farm National Historical Park

Abstract

In accordance with guidelines set forth by the National Park Service Inventory & Monitoring Division, a quality assurance plan (QAP) has been created for use by the Northeast Temperate Network (NETN), Mid-Atlantic Network (MIDN) and Northeast Coastal and Barrier Network (NCBN) in the implementation of the Long-term Forest Monitoring Protocol (Comiskey et al. 2009 (MIDN/NCBN); Tierney et al. 2017 (NETN)). This QAP documents the standards, policies, and procedures used by NETN, MIDN and NCBN for activities related to the collection, processing, storage, analysis, and publication of monitoring data. This QAP was largely adapted and greatly benefited from the Eastern Rivers and Mountains QAP for Vegetation Monitoring (Perles et. al 2018). The policies and procedures documented in this QAP are consistent with the quality assurance plans for other monitoring activities conducted by the three networks and supplement National Inventory & Monitoring Division Quality Management Plan (DeVivo in preparation).

Introduction

The National Park Service (NPS) Inventory & Monitoring Program was established by an act of Congress in 1999 to provide more than 270 national park system units a core suite of baseline scientific information (inventories) and to identify and implement long-term monitoring of high-priority measurements of resource condition in those units (Fancy et al. 2009). The overarching purpose of natural resource monitoring in parks is to develop scientifically sound information on the current status and long-term trends in the composition, structure, and function of park ecosystems, and determine whether current management practices are sustaining those ecosystems.

Policies and procedures were designed to ensure that all scientific work conducted by or for the NPS Inventory and Monitoring Division (IMD), including data, reports, and associated decision support tools, is appropriate for its intended use and of documented quality. Transparently communicating information about data quality also ensures continuity and comparability of data over time.

The IMD is responsible for developing a quality management plan (DeVivo in preparation) that documents the policies, procedures, memoranda, Director's orders, training requirements (e.g., Department of Interior Scientific Integrity Training) etc. that apply to all IMD activities Service-wide. Data quality standards and procedures for each monitoring protocol are detailed in a protocol-specific quality assurance plans (QAP).

This QAP outlines data quality standards for long-term forest monitoring in the Northeast Temperate Network (NETN), Mid-Atlantic Networks (MIDN), and Northeast Coastal and Barrier Network (NCBN) – three of the 32 ecoregional “networks” of parks that were grouped by geography and shared natural resource characteristics (Fancy et al. 2009). In addition to the QAP, this protocol consists of a narrative that describes the monitoring objectives and sampling design, a set of Standard Operating Procedures that outline specific data collection details of the monitoring protocol, a Summary of Major Protocol Changes and Deviations, and a Safety Plan. With the exception of the narratives, all protocol documents are shared by NETN, MIDN and NCBN. Additionally, MIDN and NCBN protocols are identical, with the only difference being that monitoring began in MIDN parks a year or more before monitoring began in NCBN parks. Hereafter, we refer to the combined MIDN and NCBN monitoring as MIDN for brevity, and only mention NCBN when there is a noteworthy difference to highlight. The latest version of each of these documents, can be accessed in the Long-term Forest Monitoring Project in the NPS Data Store (available at: <https://irma.nps.gov/Datastore/Reference/Profile/2189101>).

The intent of the QAP is to provide all potential end-users of protocol data with adequate information to understand what data are being collected and how, as well as what standards those data are being collected to. This allows end-users to independently determine whether or how those data may be interpreted and used. In addition, the Summary of Major Protocol Changes and Deviations document summarizes any major protocol changes that affect data comparability and/or availability across years that may influence data analysis.

This QAP outlines the quality assurance (QA) and quality control (QC) procedures implemented during all levels of data collection and processing as detailed in the protocol SOPs. Data that have undergone all QA and QC procedures and either meet stated data quality standards or are appropriately identified as not meeting the standards, are considered “certified” by the NPS. All data and reports disseminated for general (public) use will be based on certified data. Data certification and the processes entailed by that designation (as documented in this QAP) are the primary means by which data quality is communicated to end users.

Protocol Overview, Objectives, and Sampling Design

Preserving the condition of park resources, including forests, unimpaired in perpetuity is the fundamental management objective of the NPS. Indeed, this “anti-degradation” or “no decline in condition” management objective captures the essence of the NPS mission and forms the underpinnings of the NPS Inventory and Monitoring Division (Fancy et al. 2009). As such, the overall goal of this protocol is to monitor status and trends in the structure, function, and condition of NETN/MIDN forested parks to inform management decisions affecting those systems. More detailed monitoring objectives shared across networks include:

1. Determine the status and trends in forest structure and composition, including canopy closure, tree regeneration, coarse woody debris and snag abundance.
2. Monitor condition of trees, including presence of pests/pathogens, along with tree growth, mortality and recruitment rates.
3. Determine status and trends in understory composition and diversity, including invasive exotic plants and species indicative of deer browse pressure.
4. Determine the status and trends in soil Ca:Al and C:N ratios to assess the extent of base cation depletion, increased aluminum availability and/or nitrogen saturation impacting forest soils.

The parks covered by this QAP are listed in Table 1. The sampling design across all networks used generalized random tessellation stratified sampling to generate a random sample of spatially balanced plot locations for each park (GRTS; Stevens and Olsen 2004). GRTS points that were located in primarily forested areas and/or areas succeeding to forest were established as forest plots, as long as they were ≥ 15 m from a road (including a carriage road), a perennial stream or water body large enough to create a canopy opening, a mowed area, or the park boundary. Plots in areas receiving management, such as logging and invasive species removal, were included in the target population as long as these plots were not specifically targeted for the management and the management objective was not forest conversion to open habitat (e.g., not cleared to restore a battlefield).

Once established, plots are sampled every 4 years using a rotating four-panel design (Table 2). Note that the 4-year rotation was disrupted by COVID-19, with no parks sampled in 2020, and only a subset of parks sampled in 2021. We will attempt to get the panel schedule back on track by the end of 2023 and will update Table 2 to indicate the timing of sampling for each panel and park once the panel schedule returns to a 4-year sampling interval.

Table 1. Parks covered by Quality Assurance Plan by network. # Plots is the number of permanent plots as of September 2021. The Year column represents the year plots were first sampled in each park. Note that ASIS only has one of four projected panels installed (i.e., 6 out of 24 plots) as of 2021.

Network	Park	Code	# Plots	Year
Mid-Atlantic Network (MIDN)	Appomattox Court House National Historical Park	APCO	28	2007
	Booker T. Washington National Monument	BOWA	8	2007
	Fredericksburg & Spotsylvania National Military Park	FRSP	104	2007
	Gettysburg National Military Park	GETT	33	2007
	Hopewell Furnace National Historic Site	HOFU	16	2007
	Petersburg National Battlefield	PETE	52	2007
	Richmond National Battlefield Park	RICH	32	2007
	Valley Forge National Historical Park	VAFO	28	2007
Northeast Coastal & Barrier (NCBN)	Assateague Island National Seashore	ASIS	24*	2019
	Colonial National Historical Park	COLO	48	2011
	George Washington Birthplace National Monument	GEWA	8	2008
	Sagamore Hill National Historic Site	SAHI	4	2008
	Thomas Stone National Historic Site	THST	8	2008
Northeast Temperate Network (NETN)	Acadia National Park	ACAD	176	2006
	Marsh-Billings-Rockefeller National Historical Park	MABI	24	2006
	Minute Man National Historical Park	MIMA	20	2006
	Morristown National Historical Park	MORR	28	2007
	Roosevelt-Vanderbilt National Historic Sites	ROVA	40	2007
	Saint-Gaudens National Historical Park	SAGA	21	2006
	Saratoga National Historical Park	SARA	32	2006
	Weir Farm National Historical Park	WEFA	10	2007

Table 2. Forest monitoring panel design by network and park. The table lists the first year that each panel was sampled in a given park. Each panel was then sampled every four years up through 2019. The panel schedule will be updated after networks catch up from canceled/reduced sampling in 2020 and 2021 due to COVID-19.

Network	Park	Panel Schedule			
		Panel 1	Panel 2	Panel 3	Panel 4
MIDN	APCO	2007	2008	2009	2010
	BOWA	2007	2008	2009	2010
	FRSP	2007	2008	2009	2010
	GETT	2007	2008	2009	2010
	HOFU	2007	2008	2009	2010
	PETE	2007	2008	2009	2010
	RICH	2007	2008	2009	2010
	VAFO	2007	2008	2009	2010
NCBN	ASIS	2019	TBD	TBD	TBD
	COLO	2011	2012	2013	2014
	GEWA	2008	2009	2010	2011
	SAHI	2009	–	–	–
	THST	2008	2009	2010	2011
NETN	ACAD	2006	2007	2008	2009
	MABI	2006	–	2008	–
	MIMA	2006	–	2008	–
	MORR	–	2007	–	2009
	ROVA	–	2007	–	2009
	SAGA	2006	–	2008	–
	SARA	2006	–	2008	–
	WEFA	–	2007	–	2009

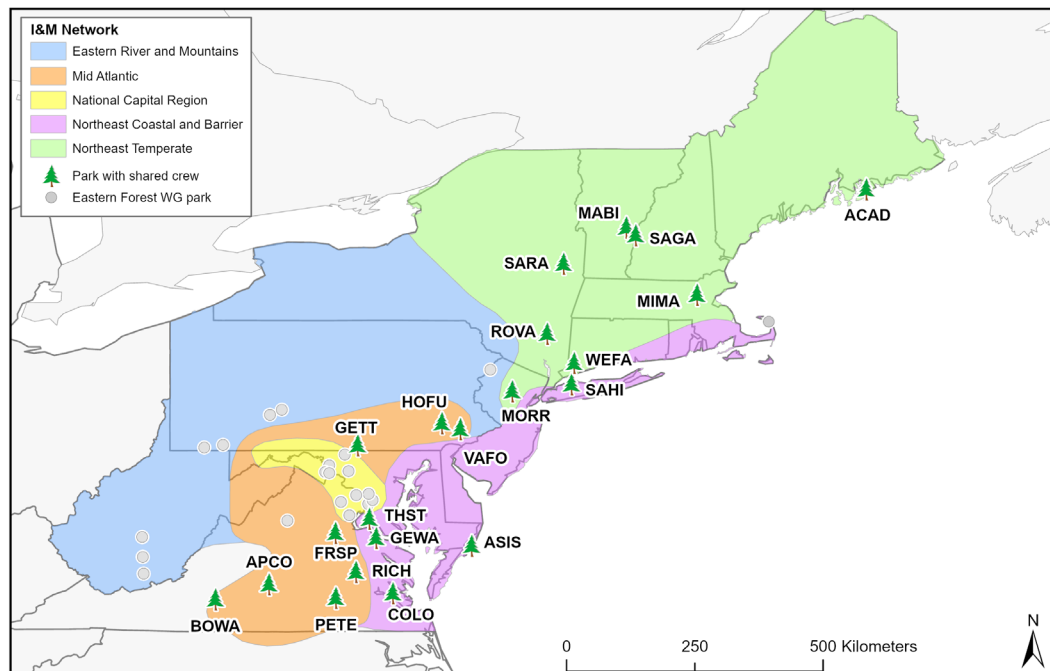


Figure 1. Map of NETN, MIDN and NCBN parks covered by this QAP (tree symbols). Grey circles indicate eastern parks with similar forest monitoring protocols implemented by other I&M networks.

Adapted from the U.S. Forest Service Forest Inventory and Analysis Program, the NETN/MIDN forest monitoring protocol monitors a representative suite of site and vegetation measures in an extensive network of randomly located permanent plots (Tierney et al. 2022; Comiskey et al. 2009). While protocols vary slightly between NETN and MIDN, each network uses a combination of fixed-area, square plots and smaller subplots to sample forests from the ground to the canopy (Figure 2). In both networks, tree and stand measurements are made within the largest square plot (15 m x 15 m at ACAD; 20 m x 20 m at the other parks), and coarse woody debris (CWD) is assessed using line intersect sampling along three 15-m transects. In NETN, seedlings, saplings and shrubs are measured within three 2-m radius circular microplots embedded within the larger square plot; understory diversity is assessed within eight 1-m² quadrats; and soil samples are obtained from a location outside of the plot. In contrast, MIDN microplots are 3-m radius circles and monitor only shrubs and saplings. MIDN saplings are also monitored more intensively, with each live sapling being tagged to track individual growth and demography over time. Tree seedlings in MIDN are monitored in twelve 1-m² quadrats, although they are tallied using the same methods as NETN. Soil samples in MIDN were collected for one cycle but followed the same procedures as NETN. Finally, MIDN monitors cover of indicator species in quadrats, rather than all vascular species. More details on NETN and MIDN protocol differences can be found in the protocol SOPs.

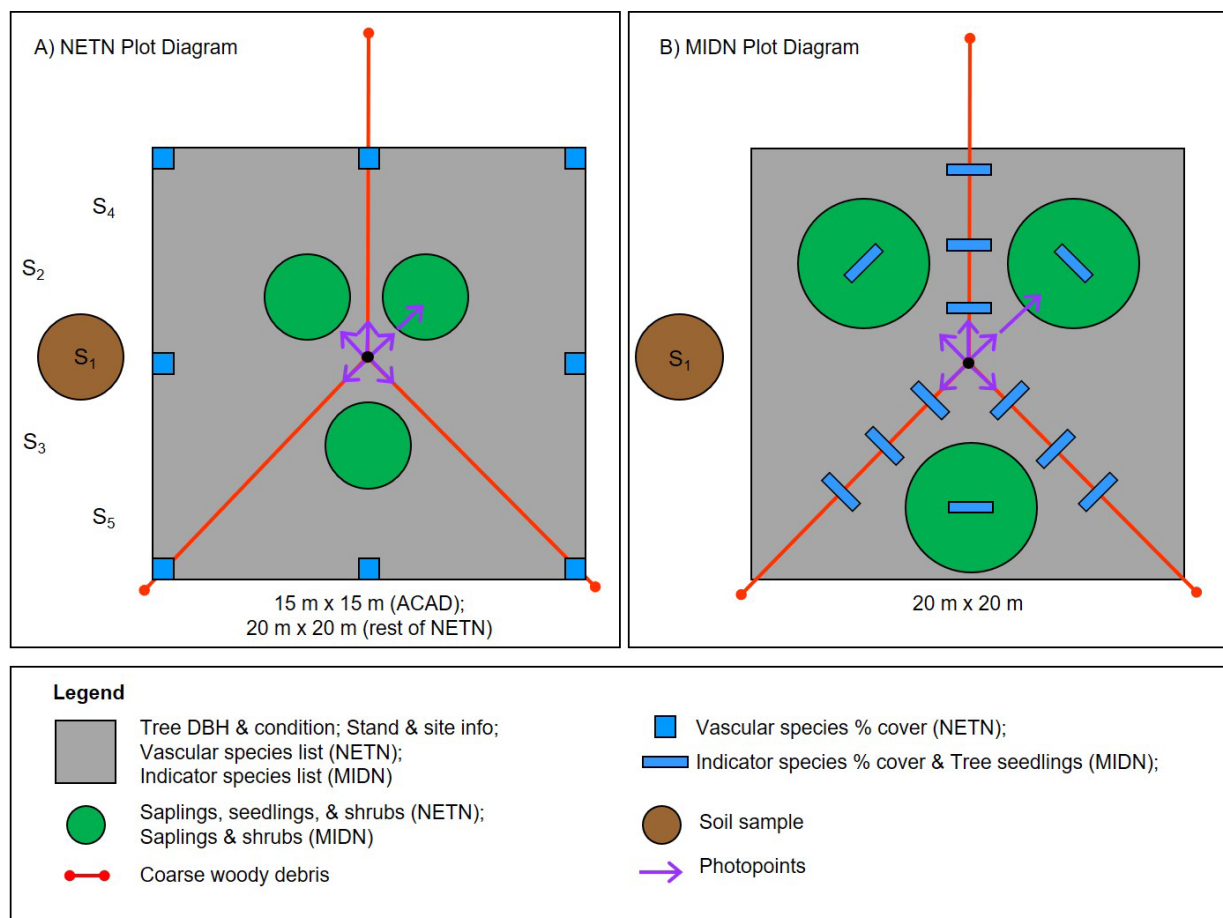


Figure 2. Forest plot diagram for A) NETN and B) MIDN. Plots are oriented upslope or North on flat land. Plots are 20 m x 20 m, except in ACAD, where plots are 15 m x 15 m. Microplots (green circles) are 2-m radius in NETN and 3-m radius in MIDN. Quadrats (blue squares/rectangles) are 1 m x 1 m in NETN and 2 m x 0.5 m in MIDN. Coarse woody debris transects are 15 m long in both networks. Soil plots are 2-m radius in both networks, although NETN collects soils periodically, whereas MIDN only collected soils during the first visit.

Protocol Activities

Data are collected or derived as a part of the NETN/MIDN forest monitoring protocol in five modules and fifteen activities (Table 3). Because protocols differ slightly between networks, activities are separated by tasks that are performed in both networks identically, or in NETN or MIDN only. The bulk of activities for this protocol consist of field observations that relate to stand and site characteristics (Stand Data), coarse woody debris (CWD Data), understory plant abundance and diversity (Quadrat and Additional Species Data), tree regeneration (Sapling and Seedling Data), shrub abundance and diversity (Shrub Data), tree condition, growth, and mortality (Tree Data), and forest soils (Soil Sampling). Processing soil samples and tree cores are the only lab-related activities.

Table 3. Project activity matrix for the NETN/MIDN forest monitoring protocol.

Activity Type	Activity	Network	Description
Plot Establishment	1 Plot Establishment	NETN/ MIDN	Install permanent plot markers (Site Selection, Plot Establishment, and Remeasurement SOP and Tree SOP)
Field Observations	2 Stand Data Collection	NETN/ MIDN	Collect data on site characteristics, stand structure, and disturbance using standard categories, cover classes, and direct measurements (Stand & Site Measurements SOP)
	3 Tree Data Collection	NETN/ MIDN	Tag trees and collect data on all individually tagged live and dead trees ≥ 10 cm DBH in 20 m x 20 m (15 m x 15 m in ACAD) square plot, including DBH, status (e.g., live, dead), canopy position, tree condition, and foliage condition (Tree Measurements SOP)
	4 Sapling Data Collection	NETN	Collect DBH of live tree saplings ≥ 1 cm and < 10 cm DBH by species in three 2-m radius microplots (Microplot SOP)
	4 Sapling Data Collection	MIDN	Collect DBH of individually tagged tree saplings ≥ 1 cm and < 10 cm DBH by species and record status in three 3-m radius microplots (Microplot SOP)
	5 Shrub Data Collection	NETN/ MIDN	Collect data on abundance and diversity of shrubs by species in three 2-m radius microplots (NETN) or three 3-m radius microplots (MIDN) using standard cover classes (Microplot SOP)
	6 Seedling Data Collection	NETN	Collect counts of tree seedlings by height category and species in three 2-m radius microplots (Microplot SOP)
	6 Seedling Data Collection	MIDN	Collect counts of tree seedlings by height category and species in twelve 1-m ² quadrats (Microplot and Quadrat Measurements SOP)
	7 Quadrat Data Collection	NETN	Collect data on substrate and composition and abundance of groundstory vascular plant species in eight 1-m ² quadrats using standard cover classes (Quadrat Measurements SOP)
	7 Quadrat Data Collection	MIDN	Collect data on substrate and abundance of indicator species in twelve 1-m ² quadrats using standard cover classes (Quadrat Measurements SOP)
	8 Additional Species Data Collection	NETN/ MIDN	Conduct 15-minute search of plot and record any new species that were not observed in other protocol activities on the plot
	9 CWD Data Collection	NETN/ MIDN	Line intercept sampling of coarse woody debris (CWD) along three 15-m transects (Coarse Woody Debris SOP)
	10 Soil Sampling	NETN	Characterize Leaf Litter, O and A soil horizon depth periodically (soil sample schedule available in the NETN forest database office app), and check for presence of exotic earthworms (every visit)
	10 Soil Sampling	MIDN	Characterize Leaf Litter, O and A soil horizon depth during plot establishment.
	11 Tree Core Collection	NETN	Collect tree cores of representative trees outside of each plot (Collecting and Aging Tree Cores SOP)

Table 3 (continued). Project activity matrix for the NETN/MIDN forest monitoring protocol.

Activity Type	Activity	Network	Description
Lab Samples	12 Soil Chemistry Lab Analysis	NETN	Characterize O and A horizon soil chemistry periodically (soil sample schedule available in the NETN forest database office app) to track impacts from atmospheric deposition
	12 Soil Chemistry Lab Analysis	MIDN	Characterize O and A horizon soil chemistry during plot establishment
	13 Tree Core Lab Analysis	NETN	Measure tree ring widths and core age at DBH
Sensor Data	14 Photopoint Collection	NETN/ MIDN	Photo-document plot conditions by taking six scenes from plot center, with one oriented portrait facing the upper center boundary, four landscape photos of the plot corners and one landscape photo focused on the microplot (Photopoint SOP).
Observer Error Data Collection	15 QA/QC Sampling	NETN/ MIDN	5% (4 plots per network) of plots are resampled each year by different observers to assess observer error and measurement quality objectives (Data Management and Quality Assurance/Quality Control SOP)

Soil samples are analyzed chemically using an external lab to track impacts of atmospheric deposition. In NETN, tree cores are measured for ring widths and number of rings using an external lab. Tree core data are used to estimate stand age as a covariate for analyses and may also be used to correlate growth with environmental and climatic variables. Photopoints, the only sensor-related activity, provide visual documentation of plot condition and change over time. Observer error is quantified as part of the Quality Assurance/Quality Control Module. For more detail on each activity, refer to the respective Standard Operating Procedure for that activity.

Data Quality Objectives

The overall data quality objectives of the NETN/MIDN forest monitoring protocol are to consistently produce: 1) data of sufficient quality to meet protocol objectives outlined in Tierney et al. (2022) and/or Comiskey et al. (2009), and 2) data of known and documented quality for all potential end-users of data and information generated by this protocol.

Data Quality Values

Several qualitative descriptors are used to help interpret and document the degree of acceptability or utility of the data to the user. These are variously referred to as “data quality indicators” (U.S. EPA 1997) and “data quality values” (DeVivo in preparation) and include the representativeness, completeness, comparability, and timeliness of the protocol dataset.

The concept of *representativeness* within the context of this monitoring protocol refers to the ability of the protocol to precisely estimate metrics of interest for the specified target population within forested habitats in parks monitored by this protocol. Sampling frame and target populations, along with the methodology used to specify the sampling frame and site selection (and appropriate scope of statistical inference) are summarized above and discussed in detail in the protocol narrative sections dealing with this topic. Briefly, a park-level spatially balanced random sample of permanent monitoring plots was generated to provide a representative sample of forests in each park.

Sampling *completeness* is defined following Stanley and Verner (1985) as “a measure of the amount of data collected from a measurement process compared to the amount that was expected under the conditions of measurement.” The number of sampling sites and required data measures at each site were carefully planned and piloted over a period of years to achieve a balance among protocol objectives, available budget, and field season length (phenological as well as logistical constraints). Quality assurance procedures ensure that all required data are collected in the field and entered in their corresponding database or datasheets. Where possible, all required data are entered directly into a database in the field, which ensures that all required data are checked for completeness before leaving the site. As of 2021, greater than 99% of data values required each year have been collected and entered in their associated network's database.

Data *comparability* refers to the confidence with which one data set can be compared to another. To achieve maximum utility, this protocol must yield data that are consistent and comparable from one year to the next, and to the extent possible with other NPS, state and Federal programs.

Comparability among years is achieved through strict adherence to the standard operating procedures, including thorough documentation of any changes or revisions to procedures in the revision section at the end of each SOP. Protocol changes and/or deviations from the protocol that could affect data comparability among years are also documented in the Summary of Major Protocol Changes and Deviations. To assess data comparability among years 5% of plots in each network are remeasured by different observers within the same season each year (see QA/QC Sampling section below).

Timeliness refers to the length of time required to collect, process, and certify data relative to the intended uses of the data. Because most of the forest data are collected digitally in the field, the time requirements for post-field data entry, verification, validation, and processing are relatively minimal. Forest data are therefore certified within a month of the end of field data collection, which is typically the end of August in NETN and the end of October in MIDN. In many cases, however, field data are certified within a week or two of collection. Given the relatively short turn-around for forest data certification, the use of provisional data will not routinely occur and will be limited to rare circumstances (see the Data Certification and Dissemination section below).

Data Quality Standards

To meet the data quality objectives for this protocol, four data quality standards are defined and documented below: 1) measurement quality objectives, 2) taxonomic standards, 3) accreditation standards, and 4) policy and protected data standards.

Measurement Quality Objectives

Measurement quality objectives are data quality requirements specifying the level of bias and precision (and in some cases resolution, sensitivity, etc.) of equipment, sensors, or observers to reliably measure characteristics of the target population. Bias is a systematic difference between a measured value and the true value and represents an estimate of systematic measurement error. Precision is the degree of mutual agreement among repeated measurements and represents an estimate of random measurement error. Collectively these data characteristics provide an estimate of the total uncertainty surrounding any measurement (typically referred to as accuracy). In many cases, however, assessing bias in vegetation data is not meaningful because true values are not measurable or known. Therefore, we primarily focus on measurements of precision to assess data quality for this protocol.

The measurement quality objectives for the forest monitoring protocol are presented and summarized in Table 4. Note that lab analyses for activities 12 and 13 are performed by external labs. We therefore did not define measurement quality objectives for these analyses, but rather included each lab's QAP and/or SOP documents in the reference section.

Training is conducted prior to the field season to ensure that field personnel are capable of collecting data that meet the measurement quality objectives. Field personnel are also assessed on their ability to collect data that meet the measurement quality objectives throughout the field season (see Quality Assurance Procedures below).

Table 4. Measurement quality objectives for measures collected and derived in the implementation of this protocol. Quality objectives for most measures are based on comparisons between the field crew and the QA/QC visit to calculate precision, as indicated by “QA/QC Visit” in the Method column. Quality objectives for soil and tree core lab analyses are managed by external labs and not defined here. Note that taxonomic accuracy is measured using Sorensen Similarity. See Appendix A for list of QA checks in the Field App.

Activity Type	Activity	Network	Measure	Performance standard	Method	Reference(s)
Plot Establishment	1 Plot Establishment	NETN/ MIDN	Record UTM X and Y coordinates of plot center	<5 m error for recorded location on geographic positioning system unit	Post-field check	Using the Global Positioning System (GPS) and Site Selection, Plot Establishment and Remeasurement SOPs
	1 Plot Establishment and Remeasurement	NETN/ MIDN	Distance of plot markers from plot center	Within 0.1 m of correct measurement during establishment and for replacing a missing marker; within 1 m of correct measurement during remeasurement of existing marker	Checked during every field visit	Site Selection, Plot Establishment and Remeasurement SOP
	1 Plot Establishment and Remeasurement	NETN/ MIDN	Azimuth of plot markers relative to plot center	Within 2 degrees of correct measurement during establishment and for replacing a missing marker; within 4 degrees during remeasurement of existing marker	Checked during every field visit	Site Selection, Plot Establishment and Remeasurement SOP
Field Observations	2 Stand Data Collection	NETN/ MIDN	% Crown Closure	Within 1 cover class (n = 5 classes)	QA/QC Visit	Stand and Site Measurements SOP
	2 Stand Data Collection	NETN/ MIDN	Deer Browse Impacts	Within 1 class (n = 5 classes)	QA/QC Visit	Stand and Site Measurements SOP
	2 Stand Data Collection	NETN/ MIDN	% Vascular Cover by Strata	Within 1 cover class (n = 7 classes)	QA/QC Visit	Stand and Site Measurements SOP
	2 Stand Data Collection	NETN/ MIDN	% Forest Floor Covers	Within 1 cover class (n = 7 classes)	QA/QC Visit	Stand and Site Measurements SOP
	2 Stand Data Collection	NETN/ MIDN	Stand Height	Within $\pm 20\%$ for individual trees	QA/QC Visit	Stand and Site Measurements SOP

Table 4 (continued). Measurement quality objectives for measures collected and derived in the implementation of this protocol. Quality objectives for most measures are based on comparisons between the field crew and the QA/QC visit to calculate precision, as indicated by “QA/QC Visit” in the Method column. Quality objectives for soil and tree core lab analyses are managed by external labs and not defined here. Note that taxonomic accuracy is measured using Sorensen Similarity. See Appendix A for list of QA checks in the Field App.

Activity Type	Activity	Network	Measure	Performance standard	Method	Reference(s)
Field Observations (continued)	2 Stand Data Collection	NETN/MIDN	Disturbance Presence	100% agreement between observers	QA/QC Visit	Stand and Site Measurements SOP
	2 Stand Data Collection	NETN/MIDN	Disturbance Threshold	100% agreement between observers	QA/QC Visit	–
	2 Stand Data Collection	NETN/MIDN	Disturbance % Cover	Within 1 cover class (n = 8 classes)	QA/QC Visit	–
	3 Tree Data Collection	NETN/MIDN	DBH (cm)	Within ± 0.2 cm for individual trees	QA/QC Visit	Tree Measurements SOP
	3 Tree Data Collection	NETN/MIDN	DBH Verified	100% agreement between observers	QA/QC Visit	Tree Measurements SOP
	3 Tree Data Collection	NETN/MIDN	DBH Verified	All trees that grew > 3 cm or shrank > 0.1 cm DBH between visits are remeasured	QA in Field App	Tree Measurements SOP
	3 Tree Data Collection	NETN/MIDN	Status (live vs. dead)	100% agreement between observers	QA/QC Visit	Tree Measurements SOP
	3 Tree Data Collection	NETN/MIDN	Crown Class	Within 1 crown class (n = 6 classes)	QA/QC Visit	Tree Measurements SOP
	3 Tree Data Collection	NETN/MIDN	Total % Foliage	Within 1 cover class (n = 5 classes)	QA/QC Visit	Tree Measurements SOP
	3 Tree Data Collection	NETN/MIDN	Decay Class	Within 1 decay class (n = 5 classes)	QA/QC Visit	Tree Measurements SOP
	3 Tree Data Collection	NETN/MIDN	Hemlock Woolly Adelgid Impact	Within 1 HWA class (n = 4 classes)	QA/QC Visit	Tree Measurements SOP
	3 Tree Data Collection	NETN/MIDN	Beach Bark Disease Impact	Within 1 BBD class (n = 4 classes)	QA/QC Visit	Tree Measurements SOP
	3 Tree Data Collection	NETN/MIDN	Count of Tree Conditions	Within ± 1 total count for individual trees	QA/QC Visit	Tree Measurements SOP

Table 4 (continued). Measurement quality objectives for measures collected and derived in the implementation of this protocol. Quality objectives for most measures are based on comparisons between the field crew and the QA/QC visit to calculate precision, as indicated by “QA/QC Visit” in the Method column. Quality objectives for soil and tree core lab analyses are managed by external labs and not defined here. Note that taxonomic accuracy is measured using Sorensen Similarity. See Appendix A for list of QA checks in the Field App.

Activity Type	Activity	Network	Measure	Performance standard	Method	Reference(s)
Field Observations (continued)	3 Tree Data Collection	NETN/MIDN	% Foliage Conditions	Within 1 cover class for individual conditions	QA/QC Visit	Tree Measurements SOP
	4 Sapling Data Collection	NETN/MIDN	Sapling Count	100% agreement between observers	QA/QC Visit	Microplot SOP
	4 Sapling Data Collection	NETN	Taxonomic Accuracy	100% of species are in agreement	QA/QC Visit	Microplot SOP
	4 Sapling Data Collection	NETN	Sapling DBH (cm)	Average DBH within ± 0.2 cm	QA/QC Visit	Microplot SOP
	4 Sapling Data Collection	MIDN	Sapling DBH (cm)	Within ± 0.2 cm for individual saplings	QA/QC Visit	Microplot SOP
	5 Shrub Data Collection	NETN/MIDN	Shrub Taxonomic accuracy	100% of species $\geq 1\%$ cover are in agreement.	QA/QC Visit	Microplot SOP
	5 Shrub Data Collection	NETN/MIDN	Shrub % Cover	Within 1 cover class	QA/QC Visit	Microplot SOP
	6 Seedling Data Collection	NETN/MIDN	Seedling Tallies: 15–30cm	Tally within ± 2 stems	QA/QC Visit	Microplot SOP (NETN & MIDN) and Quadrat Measurements SOP (MIDN)
	6 Seedling Data Collection	NETN/MIDN	Seedling Tallies: ≥ 30 cm	Tally within ± 1 stems	QA/QC Visit	Microplot SOP (NETN & MIDN) and Quadrat Measurements SOP (MIDN)
	6 Seedling Data Collection	NETN/MIDN	Regeneration Summary	Within $\pm 10\%$ between observers for average seedling and sapling density, and stocking index	QA/QC Visit	Microplot SOP (NETN & MIDN) and Quadrat Measurements SOP (MIDN)

Table 4 (continued). Measurement quality objectives for measures collected and derived in the implementation of this protocol. Quality objectives for most measures are based on comparisons between the field crew and the QA/QC visit to calculate precision, as indicated by “QA/QC Visit” in the Method column. Quality objectives for soil and tree core lab analyses are managed by external labs and not defined here. Note that taxonomic accuracy is measured using Sorensen Similarity. See Appendix A for list of QA checks in the Field App.

Activity Type	Activity	Network	Measure	Performance standard	Method	Reference(s)
Field Observations (continued)	6 Seedling Data Collection	NETN/MIDN	Seedling Taxonomic Accuracy	100% of species ≥ 30 cm tall are in agreement. 90% of species < 30 cm tall are in agreement.	QA/QC Visit	Microplot SOP (NETN & MIDN) and Quadrat Measurements SOP (MIDN)
	7 Quadrat Data Collection	NETN/MIDN	Quadrat Data % Cover	Within 1 cover class (n = 10 classes)	QA/QC Visit	Quadrat Measurements SOP
	7 Quadrat Data Collection	NETN/MIDN	Quadrat Species % Cover	Within 1 cover class (n = 10 classes)	QA/QC Visit	Quadrat Measurements SOP
	7 Quadrat Data Collection	NETN/MIDN	Average % Cover	Within $\pm 10\%$ average cover for all species between observers	QA/QC Visit	Quadrat Measurements SOP
	7 Quadrat Data Collection	NETN	Taxonomic Resolution	90% of observations are identified to species	Post-field check	Quadrat Measurements SOP
	7 Quadrat Data Collection	NETN/MIDN	Taxonomic Accuracy	95% of species identified with $\geq 1\%$ cover are in agreement	QA/QC Visit	Quadrat Measurements SOP
	8 Additional Species Data Collection	NETN/MIDN	Taxonomic Resolution	90% of observations are identified to species	Post-field check	Quadrat Measurements SOP
	8 Additional Species Data Collection	NETN/MIDN	Taxonomic Accuracy	80% of species are in agreement	QA/QC Visit	Quadrat Measurements SOP
	9 Coarse Woody Debris Data Collection	NETN/MIDN	Decay Class	Within 1 decay class (n = 5 classes)	QA/QC Visit	Coarse Woody Debris SOP
	9 Coarse Woody Debris Data Collection	NETN/MIDN	Number of Pieces	100% agreement between observers	QA/QC Visit	Coarse Woody Debris SOP

Table 4 (continued). Measurement quality objectives for measures collected and derived in the implementation of this protocol. Quality objectives for most measures are based on comparisons between the field crew and the QA/QC visit to calculate precision, as indicated by “QA/QC Visit” in the Method column. Quality objectives for soil and tree core lab analyses are managed by external labs and not defined here. Note that taxonomic accuracy is measured using Sorensen Similarity. See Appendix A for list of QA checks in the Field App.

Activity Type	Activity	Network	Measure	Performance standard	Method	Reference(s)
Field Observations (continued)	9 Coarse Woody Debris Data Collection	NETN/MIDN	Total CWD Volume	Within 20% between observers	QA/QC Visit	Coarse Woody Debris SOP
	10 Soil Sampling	NETN/MIDN	Horizons	Same horizons identified	QA/QC Visit	Soil Measurements and Sampling SOP
	10 Soil Sampling	NETN	Earthworm Presence/Absence	100% agreement between observers	QA/QC Visit	Soil Measurements and Sampling SOP
	11 Tree Core Collection	NETN	Tree Core Quality	At least 3 out of 4 cores are of high quality (i.e., the pith is included or can be estimated with a pith locator).	Field Check	Collecting and Aging Tree Cores SOP
	2–10 All field observation activities	NETN/MIDN	Data Completeness	99% of all required data are entered for each plot	QA in Field App	Data Management & QA/QC SOP
Lab Samples	12 Soil Chemistry Lab Analysis	NETN/MIDN	• pH, • %Loss of Ignition, %Total C, % Total N • Ca, K, Mg, P, Al, Fe, Mn, Na, Zn (mg/kg) • Exchangeable acidity (meq/100gm) • Effective Cation Exchange Capacity (meq/100gm)	–	–	MAFES Analytical Laboratory 2016
	13 Tree Core Lab Analysis	NETN	–	–	–	Stokes and Smiley 1968

Table 4 (continued). Measurement quality objectives for measures collected and derived in the implementation of this protocol. Quality objectives for most measures are based on comparisons between the field crew and the QA/QC visit to calculate precision, as indicated by “QA/QC Visit” in the Method column. Quality objectives for soil and tree core lab analyses are managed by external labs and not defined here. Note that taxonomic accuracy is measured using Sorensen Similarity. See Appendix A for list of QA checks in the Field App.

Activity Type	Activity	Network	Measure	Performance standard	Method	Reference(s)
Sensor Data	14 Photopoint Collection	NETN/ MIDN	Photopoint scenes	Individual photopoint scenes capture 90% of the same area between observers	QA/QC Visit	Photopoint SOP
Observer Error Data Collection	15 QA/QC Sampling	NETN/ MIDN	–	–	–	Used to assess performance of measurement quality objectives as indicated by Method column

Taxonomic Standards

All plant taxa observations specify both the taxon name and the reference used for making the identification. The taxonomic standards for all species data collected by this protocol are Flora Novae Angliae (Haines 2011) for NETN parks in New England, Catalog of the Vascular Plants of New York State (Werier 2017) for parks in New York State, and Flora of the Southeastern United States (Weakley 2020) for all remaining parks. We will continue to follow these standards until updated or more appropriate standards becomes available (e.g., full coverage of Flora of North America). Plant nomenclature follows the official plant list in the backend database table (tluCOMN_Taxon), which

is based on the Integrated Taxonomic Information System (ITIS.gov). The official plant list is updated every five to ten years to be consistent with the latest ITIS nomenclature designations.

Accreditation Standards

No professional or lab accreditations are required for this protocol.

Policy and Protected Data Standards

According to federal policy, data collected by NETN and MIDN are to be made public. However, there are limited cases in which data may be withheld from release to protect park resources. Dissemination of certain information could put particular resources at risk, and some cultural and natural resource information is protected from public disclosure by resource confidentiality laws. These laws prohibit agencies from releasing protected information except in limited, specified circumstances.

The process of identifying protected data, including which data are protected, the degree of protection warranted, and if/how data will be disseminated was completed by all networks and signed by park superintendents by 2019.

As a general rule, NETN and MIDN provide as much monitoring data as possible to the public to facilitate communication and collaboration. NETN and MIDN therefore do not generally protect location data, such as coordinates of monitoring sites. However, a number of species that are rare in the region and/or vulnerable to poaching could potentially occur in forest plots. The locations of these species, if found, are redacted from all publicly available datasets. The redacted data are available upon request, but all requests must be reviewed by network and the affected park staff to ensure that providing these data will not result in unwanted resource impacts. Personally identifiable information, along with other data that would require legal protection, are not collected or stored in any databases as part of this protocol.

Quality Assurance Procedures

This section describes the quality assurance (QA) procedures implemented during all levels of data collection and processing for the NETN/MIDN forest monitoring protocol. QA procedures are employed prior to or during data collection to minimize errors and to ensure that the data collected for this protocol meet the established data quality objectives to the greatest extent possible. Quality assurance is a continuous process that follows an annual cycle and includes hiring, training, oversight and communication, data collection, data entry, data verification, QA/QC sampling, and operational review.

Hiring

The experience, dedication, and temperament of field staff are one of the most important factors in obtaining quality field data. This protocol is implemented primarily by a protocol lead/Plant Ecologist, Forest Crew Leader, and 3–4 seasonal Forest Crew Members. Collectively, we refer to the forest crew and/or forest crew members as any of the above field personnel who are permitted to sample for the protocol. The protocol lead/Plant Ecologist provides oversight, co-leads training with the Forest Crew Leader, samples with the crew as needed, merges field .baks and adjudicates records, performs weekly QC checks, and generates QA/QC summary reports. The Plant Ecologist is a permanent position that must be filled by a person with a strong background in forest ecology and sampling and advanced plant identification skills. The Forest Crew Leader samples with one of the two teams each day, ensures crews are collecting data according to the protocol, coordinates daily logistics, and updates the local database instance with the merged field .bak for each team at the beginning of each week. The Forest Crew Leader is also a permanent position and should have a solid background in forest ecology and advanced plant identification skills. In addition, a contract botanist may be needed for the more diverse parks to help with plant identification.

The Forest Crew Member positions must be filled by candidates who have demonstrated experience with vegetation data collection and in the identification of woody plants in the Northeastern and/or mid-Atlantic region. As part of the interview process, all applicants take a plant identification quiz to assess their identification proficiency with a variety of northeastern plant species ranging from trees to forbs. There is no minimum score required to be considered for hiring, rather the intent is to provide information to the protocol lead on applicants' observation skills, interest in plant identification, and strengths/weaknesses with different taxonomic groups.

Training

Prior to the field season, Forest Crew Members participate in a mandatory week-long training that covers the protocol's safety plan and each of the field-based SOPs as individual training modules. Each SOP training module includes a powerpoint presentation that introduces the methods and discusses common pitfalls (e.g., forking rules for trees) and tolerance limits (e.g., within 1 cover class for quadrat species) for each metric. Each training module includes hands-on demonstrations and practice by all Forest Crew Members. The field-based SOPs are also reviewed for each module. To facilitate adherence to the protocol, crews are also provided laminated Field Notes that document key definitions, rules, and procedures for each SOP, and these are frequently referenced during training to

ensure crew members are comfortable finding information for specific SOPs (available at: <https://irma.nps.gov/Datastore/Reference/Profile/2189101>). Plant identification, particularly identifying and keying out woody species, is also covered throughout training.

The final training module involves new Forest Crew Members resampling a test plot that the Plant Ecologist and/or Forest Crew Leader sampled prior to training. Results between trained staff and new crew members are then compared using QA/QC summary reports for [NETN](#) and [MIDN](#) to determine if there are any SOPs or measurements that require further training before Forest Crew Members can sample real plots. Once results of the QA/QC sampling are satisfactory, Forest Crew Members are certified to sample plots for this protocol. Finally, after the first week of pre-season training, the Plant Ecologist and Forest Crew Leader each lead one of the two teams for another week of hands-on training while sampling permanent plots. This second week of training is necessary to ensure new Forest Crew Members understand how the SOPs fit together, learn the most efficient ways to sample plots, and ensure that any questions or deviations from the protocol are identified and resolved early.

Oversight and Communication

Maintaining oversight and fostering open communication between Forest Crew Members, the Forest Crew Leader and the Plant Ecologist are key to obtaining quality field data, particularly during the extended periods when the crew is on travel. The main strategies for oversight are 1) regular check-ins between Plant Ecologist and Forest Crew Leader, 2) continual communication between the Forest Crew Members and Forest Crew leader, and 3) frequent checking of the data in the form of weekly QC checks and periodic QA/QC visits. Oftentimes, the regular check-ins between the Plant Ecologist and Forest Crew Leader are to discuss results of the QC checks and/or QA/QC visits, and whether anyone on the Forest Crew needs a reminder or more guidance.

Database Design

Digital data collection in the field is central to this protocol for ensuring data quality. Digital data collection allows quality assurance checks to occur as data are being collected and has dramatically reduced occurrence of errors and omissions in the data since implementation (2010 in NETN; 2012 in MIDN). Digital data collection also allows additional quality control checks to be performed within days of being collected while plots are still fresh in crews' minds and/or crews may be able to perform a field check (i.e., revisit the plot to resolve the issue) if needed. In addition, forest health issues, such as invasive species early detections, can be quickly identified and parks can promptly be notified.

For digital data collection to be feasible, the user interface for data entry must be easy to use, flow with the typical progression of sampling a plot (e.g. database tab order follows the usual order of data collection), and include comprehensive quality assurance checks that ensure all required fields are complete and within acceptable ranges (where definable). Because this protocol is typically implemented by two or more teams on separate plots, the database for this protocol must also have a merge function that can accurately pull the data collected by each team into the official database.

To accommodate the need for a user-friendly field application and a merge tool, database functions for this protocol are divided between two Microsoft Access front ends, namely the Office App and

the Field App, and two SQL Server instances, namely the Production SQL Server database and a local SQL Server Express instance that connects to the Field app (Figure 3). The Office App is where data management tasks primarily occur, including generating field .bak files, merging field .bak files, adjudicating editable historic records, updating lookup tables, and modifying historic records. Note that the Office App was not optimized for data entry and cannot accommodate new records being added. The Production SQL Server database (hereafter Production Database) is a cloud-based SQL Server database and is the official backend database for the protocol. Access to the Production Database must be granted through a user's Active Directory account and requires a NPS network connection. To permit data collection in the field, a field .bak file is created using the Office App. The field .bak is an exact copy of the database elements necessary for field data collection from the Production Database at the time it is generated. Field .baks allow a user to have a local instance of the backend database without requiring the special permissions and network connection needed to access the Production Database.

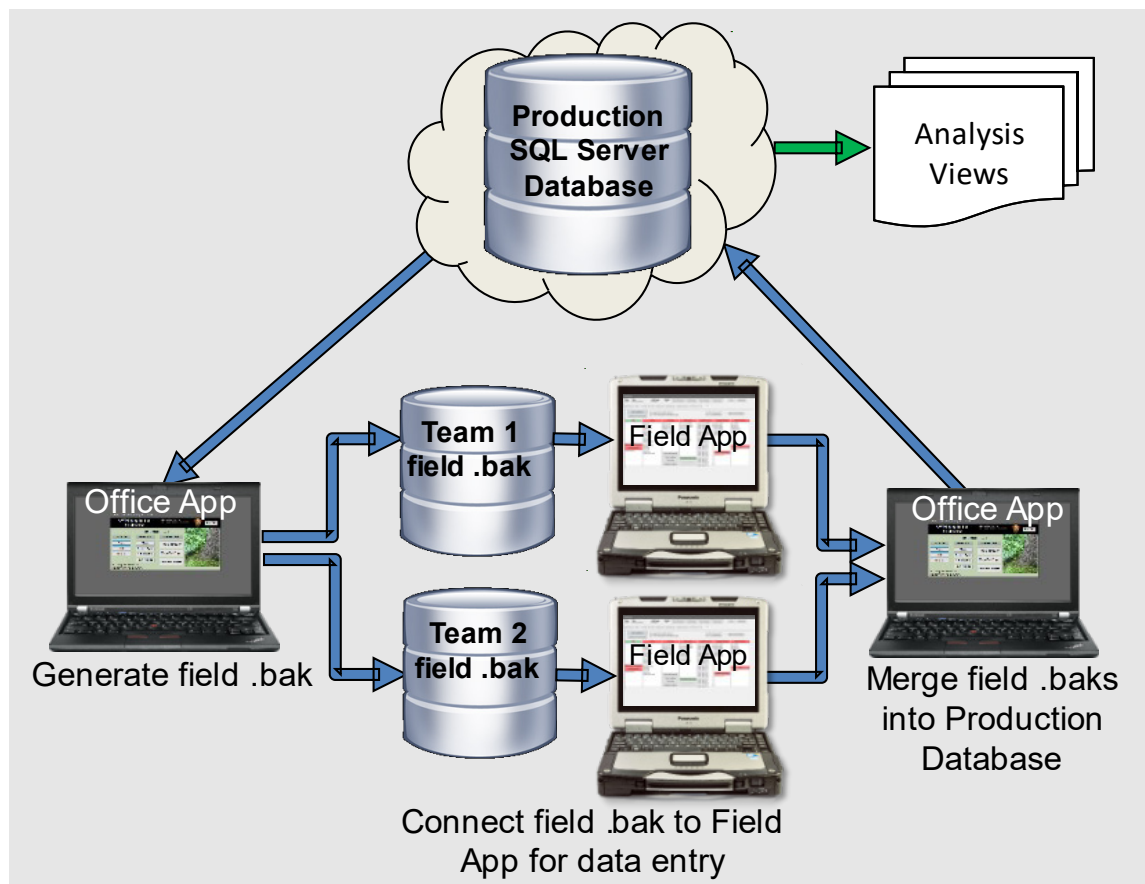


Figure 3. Overview of database design and workflow performed on a weekly basis during the field season for the NETN/MIDN forest monitoring protocol. The Production SQL Server Database is a cloud-based backend, whereas the field .baks are used to update local SQL Server Express installations of the backend. Field .baks are generated by the Office App, then restored to the local instance and linked to the Field Apps for data entry. At the end of each week, field .baks are generated then merged into the Production Database and a new field .bak is generated by the Office App. After data are merged into the Production Database, all further QC, summary, and analysis occur with the Analysis Views.

The Field App is optimized for user-friendly data entry and quality assurance, and data entry is typically performed on ruggedized field laptops that are connected to a local instance of the backend database. Within the Field App, field constraints and logic checks assure data quality as the data are being entered (See Data Entry and Verification section for more detail). Note that while the Field App is connected to the local instance, only new records can be entered along with a small number of editable historic records that can be modified (e.g., Tree tag number). Connecting the Field App to the Production Database, on the other hand, allows all historic data to be modified and new records to be added, but requires the same permissions and NPS network access as the Office App.

The Production Database is composed of many tables and hundreds of fields, requiring thorough knowledge of the schema to correctly compile and query the data. To avoid the challenges of working with such a complex database schema for data summary and analysis, an Analysis schema was developed that contains flattened views of the major data types, with at least one view per data tab in the Field App. The Analysis Views have been validated as accurate representations of the data and every required field in the database can be found in at least one of the views. After data have been merged into the Production Database, all further QC, summary, and analysis are conducted on the Analysis Views, rather than the backend tables. The views can be accessed directly in the Analysis schema of the Production Database and/or the local database instance. Machine readable versions of the views are also exported from the Analysis schema as comma separated values (CSV) after data are certified for a given year and included as part of the data package that is stored on IRMA. In addition, two R packages, [forestNETN](#) and [forestMIDN](#), were developed to work directly with the Analyses Views. These packages can import the Analysis views from the Production Database or the local database instance directly into R. The R packages can also import the Analysis Views by downloading and importing the CSVs in the data package posted to the NPS Data Store. The R packages can also export the Analysis Views and eventually the metadata that make up the data package, and include multiple functions for querying, summarizing and visualizing data from these views. The views and data contained in each view are defined in the data package metadata (available at: <https://irma.nps.gov/Datastore/Reference/Profile/2189103?Inv=true>), which is generated directly from the Analysis schema and thus is seamlessly integrated with the current database.

While both the Office and Field Apps are very similar for NETN and MIDN, they are network-specific to better accommodate protocol differences. The backend schemas and Analysis Datasets are also specific to each network due to protocol differences, although table and field names are identical for methods that are the same across both networks. All of the files and associated code for both networks are contained in a single project and version controlled using Azure DevOps Server. Quality assurance and quality control procedures related to the databases and/or data entry are explained in more detail in their respective sections below.

Data Collection

The procedures listed in Table 5 highlight important practices that assure data quality for each protocol activity conducted during a plot visit. For all protocol activities, training, oversight, and communication in the field are essential practices for quality assurance, as noted above. Providing

crews with data from the previous visit also helps ensure crews are consistently interpreting characteristics over time, such as stand characteristics, tree crown class, and tree status across visits and aids with plant identification. Crews are trained to review the data from the previous visit while sampling a plot. If they don't agree with the previous visit's data, they are instructed to make a note of the discrepancy and suggest any changes to the historic data. The Plant Ecologist and/or Forest Crew Leader then review these notes at the end of each week and determine whether to change and/or flag any historic values. Periodic QA/QC visits also ensure crews are following the protocol and identify areas for improvement (see QA/QC Sampling section below).

Most notably, crews are required to enter data using the Field App whenever possible to take advantage of the thorough QA checks performed on nearly every datapoint in the Field App (see Data Entry and Verification below). When the Field App is not available, datasheets must be thoroughly reviewed by crews to ensure they are complete and accurate. In addition, the crew member reviewing the datasheet must be different than the crew member who recorded the data. Reviewers must also record their initials in the Field Check box on each datasheet to confirm that the datasheet was reviewed before leaving the plot.

Table 5. QA procedures implemented when collecting and entering data for the NETN/MIDN forest monitoring protocol. For all activities listed below, training, oversight, and communication in the field are essential practices for quality assurance. This includes emphasizing the need for strict adherence to the SOPs during training and periodic assessment through QA/QC visits. Crews are also required to use the Field App for data entry when possible to take advantage of the QA checks performed by the Field App. This includes checking that all required fields are complete (See Appendix A for list of QA checks in the Field App). The QA procedures listed below are in addition to these practices.

Activity Type	Activity	Network	Measures	QA Procedures	When implemented	Reference(s)
Plot Establishment	1 Plot Establishment	NETN/MIDN	Permanent plot markers installed	Checking distance and azimuth of plot markers and resetting markers that are missing or outside thresholds defined in SOPs. Thresholds for new plots or replacing missing markers are within 2 degrees and 0.1 m. Thresholds for moving markers in established plots are > 4 degrees and > 1 m.	All plot visits	Site Selection, Plot Establishment & Remeasurement SOP
Field Observations	2 Stand Data Collection	NETN/MIDN	Site characteristics, stand structure, strata and forest floor cover and stand height.	Providing crew with previous visit's stand data to ensure consistent interpretation of site characteristics and to flag potential errors from the previous visit.	All plot visits	Stand & Site Measurements SOP
	3 Tree Data Collection	NETN/MIDN	Species identification, tree and foliage conditions, status, crown class, and snag decay class	- Providing crews with previous visit's tree data for comparison with current visit. - Tree species pick list controlled by Field App. - Tree form options and pick lists controlled by tree status.	All plot visits	Tree Measurements SOP
	3 Tree Data Collection	NETN/MIDN	Species identification and number of trees on a given plot	Autofilling tag number, species, distance, azimuth and fork in Field App for all trees sampled during the previous visit to ensure all trees are accounted for and consistently IDed in the current visit.	All plot visits	Tree Measurements SOP
	3 Tree Data Collection	NETN/MIDN	Tree distance and azimuth	Providing crew with map of tree locations color coded by status from the previous visit for comparison/ validation. Map also helps identify trees with missing tags.	All plot visits	Tree Measurements SOP

Table 5 (continued). QA procedures implemented when collecting and entering data for the NETN/MIDN forest monitoring protocol. For all activities listed below, training, oversight, and communication in the field are essential practices for quality assurance. This includes emphasizing the need for strict adherence to the SOPs during training and periodic assessment through QA/QC visits. Crews are also required to use the Field App for data entry when possible to take advantage of the QA checks performed by the Field App. This includes checking that all required fields are complete (See Appendix A for list of QA checks in the Field App). The QA procedures listed below are in addition to these practices.

Activity Type	Activity	Network	Measures	QA Procedures	When implemented	Reference(s)
Field Observations (continued)	3 Tree Data Collection	NETN/MIDN	Status and crown class	Providing crew with previous visit's tree data to ensure consistent definition of supercanopy, canopy and subcanopy layers, and to catch impossible status changes (e.g., live trees that were classified as dead in the previous visit).	All plot visits	Tree Measurements SOP
	3 Tree Data Collection	NETN/MIDN	Diameter at breast height (DBH)	- Field App check that prompts if current DBH is outside of tolerance compared to previous visit and requires a "DBH Verified" box be checked to indicate current measurement is correct. - Paintmarking location of DBH on each tree to ensure measurement is always taken at the same location. Additionally, tags are 10 cm above (MIDN) or below (NETN) DBH.	All plot visits	Tree Measurements SOP
	4 Sapling Data Collection	NETN/MIDN	Species identification and sapling count	- Providing crews with previous visit's data, including Tag (MIDN-only), species and DBH so that saplings from previous visit are all accounted for and correctly IDed. - Sapling species pick list controlled by Field App to prevent non-sapling species from being entered.	All plot visits	Microplot SOP
	4 Sapling Data Collection	NETN/MIDN	DBH	Paintmarking location of DBH on each sapling to ensure measurement is always taken at the same location.	All plot visits	Microplot SOP

Table 5 (continued). QA procedures implemented when collecting and entering data for the NETN/MIDN forest monitoring protocol. For all activities listed below, training, oversight, and communication in the field are essential practices for quality assurance. This includes emphasizing the need for strict adherence to the SOPs during training and periodic assessment through QA/QC visits. Crews are also required to use the Field App for data entry when possible to take advantage of the QA checks performed by the Field App. This includes checking that all required fields are complete (See Appendix A for list of QA checks in the Field App). The QA procedures listed below are in addition to these practices.

Activity Type	Activity	Network	Measures	QA Procedures	When implemented	Reference(s)
Field Observations (continued)	4 Sapling Data Collection	MIDN	DBH	Field App check that prompts if current DBH is outside of tolerance compared to previous visit and requires a "DBH Verified" box to be checked to indicate current measurement is correct.	All plot visits	Microplot SOP
	4 Sapling Data Collection	MIDN	Species identification, sapling status, and count	Autofilling tag, species, and microplot for all saplings sampled in the previous visit in Field App to ensure all saplings from previous visit are accounted for in the current visit.	All plot visits	Microplot SOP
	5 Shrub Data Collection	NETN/MIDN	Species identification and cover class	Shrub species pick list controlled by Field App to prevent non-shrub species (e.g., herbs or trees) from being recorded.	All plot visits	Microplot SOP
	6 Seedling Data Collection	NETN/MIDN	Species identification, seedling counts, and height class	Seedling species pick list controlled by Field App to prevent non-seedling species (e.g., shrubs) from being recorded.	All plot visits	Microplot SOP (NETN); Quadrat SOP (MIDN)
	7 Quadrat Data Collection	NETN/MIDN	Cover classes	- Painting 10-cm increments on quadrats to help visualize cover class breaks. - Requiring 2 people sample quadrats and for both to agree on cover classes.	All plot visits	Quadrat SOP
	7 Quadrat Data Collection	NETN	Species identification	Hiring qualified Crew Leader with strong plant ID skills and providing contract botanist for more diverse parks.	All plot visits	Quadrat SOP

Table 5 (continued). QA procedures implemented when collecting and entering data for the NETN/MIDN forest monitoring protocol. For all activities listed below, training, oversight, and communication in the field are essential practices for quality assurance. This includes emphasizing the need for strict adherence to the SOPs during training and periodic assessment through QA/QC visits. Crews are also required to use the Field App for data entry when possible to take advantage of the QA checks performed by the Field App. This includes checking that all required fields are complete (See Appendix A for list of QA checks in the Field App). The QA procedures listed below are in addition to these practices.

Activity Type	Activity	Network	Measures	QA Procedures	When implemented	Reference(s)
Field Observations (continued)	7 Quadrat Data Collection	MIDN	Species identification	• Additional training on quadrat indicator species during MIDN training. • Providing crews with laminated indicator species ID cards. • Indicator species pick list controlled by Field App to prevent non-indicator species from being entered.	All plot visits	Quadrat SOP
	7 Quadrat Data Collection	NETN/MIDN	Species identification	• Providing crews with previous visit's quadrat species data to aid with plant ID. • Requiring 2 people to sample quadrats to reduce chances of missing species. • Using waterproof unknown species labels to ensure samples include the necessary information to relate each specimen to its record in the database. • Field App identifies duplicate species and/or species missing a non-zero cover.	All plot visits	Quadrat SOP
	8 Additional Species Data Collection	NETN/MIDN	Species identification	• Field App identifies duplicate species. • Providing crews with previous visit's additional species data to aid with plant ID. • Using waterproof unknown species labels to ensure samples include the necessary information to relate each specimen to its record in the database.	All plot visits	Quadrat SOP

Table 5 (continued). QA procedures implemented when collecting and entering data for the NETN/MIDN forest monitoring protocol. For all activities listed below, training, oversight, and communication in the field are essential practices for quality assurance. This includes emphasizing the need for strict adherence to the SOPs during training and periodic assessment through QA/QC visits. Crews are also required to use the Field App for data entry when possible to take advantage of the QA checks performed by the Field App. This includes checking that all required fields are complete (See Appendix A for list of QA checks in the Field App). The QA procedures listed below are in addition to these practices.

Activity Type	Activity	Network	Measures	QA Procedures	When implemented	Reference(s)
Field Observations (continued)	9 Coarse Woody Debris Data Collection	NETN/MIDN	Diameter, decay class, and transect intersections	Paintmarking CWD intersection with transect to ensure transects are laid out consistently across visits and avoid overlooking pieces sampled previously. This also helps ensure consistent quadrat placement in MIDN.	All plot visits	Coarse Woody Debris SOP
	10 Soil Sampling	NETN	Soil sample labels	Using waterproof labels with required information to ensure each soil sample can be associated with its plot and visit in the database.	All plot visits where soils are collected	Soil Measurements & Sampling SOP
	11 Tree Core Collection	NETN	Core labels and data collection	Requiring crews to verify that all cores are properly labeled and that the labels match on the cores and the datasheets.	All plot visits where cores are collected	Collecting and Aging Tree Cores
	12 Photopoint Collection	NETN/MIDN	Collection and file naming	- Requiring crews to view and count the number of photos taken to ensure they're in focus and all photos were taken. - Requiring crews to download and verify all photopoints were taken at the end of each day. - Using bulk rename utility to rename photos to ensure consistent file names.	All plot visits	Photopoint SOP
	3, 5, 6 Trees, Saplings, Seedlings & Shrubs	NETN/MIDN	Species identification	Hiring crew members with woody plant ID skills, and providing additional training on woody plant ID, and requiring crew members to agree on plant ID while sampling.	All plot visits	Preparation and Equipment List SOP
	2–10 Data entry	NETN/MIDN	All number fields with a measurer and recorder	Measurer will call out value and recorder will repeat the value before entering.	All plot visits	Data Management and QA/QC SOP

Table 5 (continued). QA procedures implemented when collecting and entering data for the NETN/MIDN forest monitoring protocol. For all activities listed below, training, oversight, and communication in the field are essential practices for quality assurance. This includes emphasizing the need for strict adherence to the SOPs during training and periodic assessment through QA/QC visits. Crews are also required to use the Field App for data entry when possible to take advantage of the QA checks performed by the Field App. This includes checking that all required fields are complete (See Appendix A for list of QA checks in the Field App). The QA procedures listed below are in addition to these practices.

Activity Type	Activity	Network	Measures	QA Procedures	When implemented	Reference(s)
Field Observations (continued)	2–10 Data entry in Field App	NETN/MIDN	All required fields in Field App	Requiring crews to enter data directly into the Field App when possible to take advantage of the built-in QA checks.	All plot visits where Field App can be used	Data Management and QA/QC SOP
	2–10 Data entry on datasheets	NETN/MIDN	All required fields	Crew members must thoroughly review datasheets to ensure all fields are complete and no obvious errors exist; initials indicate QA is complete	All plot visits where Field App cannot be used	Data Management and QA/QC SOP

Data Entry and Verification

The data workflow in Figure 4 summarizes the primary steps from data entry and quality assurance through to quality control and data certification. Whenever possible data are entered directly into the Field App in the field to take advantage of the thorough QA checks that are performed as data are being collected. QA procedures in the Field App include ensuring that all required fields are completed by either prompting the user to enter a value before moving to another section of the app or flagging a required field as missing in the checker. The checker is a tab in the Field App that performs dozens of QA checks on each tab in the database and returns any potential issues (e.g., missing or illogical values) in the data. The crew must review and correct these issues before leaving the plot, referred to as “clearing the checker”. Refer to Appendix A for a full list of QA checks performed by the Field App and in the checker tab. Where possible in the Field App, fields are standardized, such that numeric measurements only accept numeric values, rounding rules and acceptable ranges are enforced, and standardized pick lists only allow acceptable values. In addition, Sample Qualifiers denote the sampling status of a given protocol activity so that database users are always clear about whether a protocol activity was successfully sampled (SS), successfully sampled but nothing was present (NP), or not sampled (NS). Protocol activities denoted as NS require notes to indicate the reason for not sampling. Form-specific QA uses dynamic data entry forms that limit the available data entry fields to only those required based on user input. For example, the tree form is controlled by the tree status, since live trees require different fields than dead trees. Trees and saplings (MIDN-only) that were sampled in the previous visit are auto-filled for the current visit to ensure all individuals are accounted for and consistently recorded in the current visit. Tree and sapling (MIDN-only) diameter at breast height (DBH) measurements are also compared with the previous visit's measurement, and crews are prompted if a current measurement is $> 3\text{cm DBH}$ or $< -0.1\text{cm DBH}$ from the previous visit for a tree and $> 2\text{cm DBH}$ or $< -0.1\text{cm}$ for a sapling (MIDN only). The Field App also prevents duplicate species from being entered in quadrat species and quadrat seedling tabs and prompts the user if a quadrat species does not have a non-zero cover recorded. Finally, the Field App has a checker tab that thoroughly checks each data tab for logic errors and missing data. Crews must clear this checker before they can leave the plot.

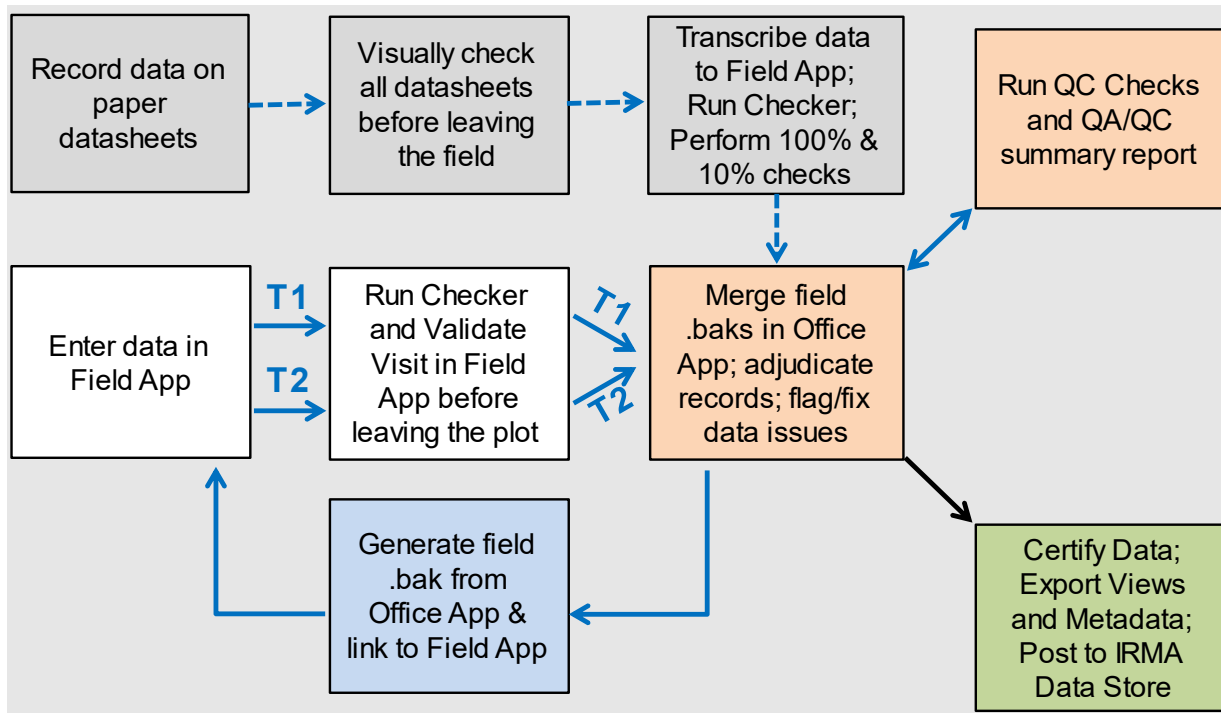


Figure 4. Data workflow for the NETN/MIDN forest monitoring protocol. Tasks in white are the preferred method for data entry. Tasks in grey are performed only if the Field App is not available for digital data entry. Tasks with blue arrows occur on a weekly basis during the field season, with solid lines indicating the preferred workflow and T1 and T2 representing the local database instances and field .bak files that come from each team and that are merged into the Production Database at the end of each week. Quality assurance occurs in white and grey boxes. After tasks in white boxes are complete, data are considered provisional. Quality control procedures are performed on provisional data in orange boxes. At the end of the season and after all tasks in orange boxes are complete, data are certified. The green box reflects the final data package that is certified and posted to the NPS Data Store on IRMA.

After data for a weekly sampling period are entered into the local database instance using the Field App, the crew lead exports the data in a .bak file to be merged into the production database. The Office App is used to merge the new data into the Production Database and to adjudicate any changes to the historic records that are editable. Merging and adjudication typically occur at the end of each field week. After the merge and adjudication are complete, a series of QC checks are performed (See Quality Control section below).

When the Field App is not available and data entry is performed on datasheets, crews must thoroughly review each datasheet for accuracy and completion. Once the Field App is available for data entry, crews must then follow a multi-step data transcription process. First data are entered by two crew members, with one crew member reading off the values in the datasheet and one crew member entering them into the Field App. After data entry is complete, crew members switch roles and then conduct a 100% check of the datasheets against the Field App. After the 100% check for a visit is complete, crews run the checker in the Field App, and any issues encountered should either be fixed (if possible) or flagged in the Field App and noted on the datasheets. If a value cannot be fixed

and/or is missing from the datasheet, it should be entered as "PM" in the database to indicate that the value is permanently missing. Where possible, the 100% check should be completed before data are merged into the Production Database. Once the data are merged into the Production Database, the data are considered provisional.

At the end of the season, a random 10% check is conducted on the data recorded on datasheets. In the 10% check, 10% of datasheets are randomly selected and the data in the Field App are checked against the selected datasheets. If any data entry errors are detected during the 10% check, another 100% check must be conducted, followed by another random 10% check. This process is repeated until no data entry errors are detected during the 10% check. After the data in the Field App are verified to accurately reflect the original field data, the paper forms are archived, and the database is used for all subsequent data activities. For more information on the data transcription process, refer to the Data Management & Quality Assurance/Quality Control SOP in the NETN/MIDN forest monitoring protocol.

QA/QC Sampling

Each year, 5% of plots in NETN and MIDN receive a QA/QC visit, which is a second sample visit by trained staff (i.e., Plant Ecologist and/or Forest Crew Leader). QA/QC visits are used to determine observer error and the repeatability of methods, and are the primary means of determining whether the measurement quality objectives (Table 4) are met for a given year. QA/QC visits are spread out through the season to ensure issues are caught early and to prevent protocol drift later in the season. In NETN, two plots receive a QA/QC visit one to three weeks after forest crew training. Parks sampled for QA/QC are rotated across years, and plots within a park are randomly selected for QA/QC. A second round of two QA/QC visits occurs while the crew is in ACAD to prevent protocol drift and quantify observer error. In MIDN, the first two QA/QC visits are conducted within the first two weeks of the crew implementing the MIDN protocol, and then again conducted later in the season to prevent protocol drift.

Ideally, QA/QC is conducted within two weeks following the original sampling to minimize seasonal variability. Ideally, the crew members conducting the QA/QC visit are not the same individuals who originally measured the plot. However, if staff are limited, crew members can trade roles so that the measurer and recorder are different than when the plot was originally sampled. For more details on QA/QC methods, refer to the Data Management & Quality Assurance/Quality Control SOP in the NETN/MIDN Long-Term Forest Monitoring Protocol. Upon completion of each round of QA/QC, QA/QC summary reports are generated (code and example reports available at: <https://github.com/KateMMiller/forestQAQC>), and NETN/MIDN staff and crew members meet to review the results and discuss any inconsistencies that do not meet the performance standards (Table 4). Where needed, additional training is provided until performance standards are met.

Operational Review

At the completion of the field season, NETN/MIDN staff conduct two levels of operational review (OR) for the protocol (Mitchell et al. 2018). The first OR, which is the Field Season Review, includes the Plant Ecologist and/or Forest Crew Leader meeting Forest Crew Members soon after the field season is completed to identify lessons learned in terms of operational efficiencies, logistical or

technical challenges, unexpected field conditions, etc. Discussing unusual data collection circumstances encountered by the crew and that are not adequately addressed in the SOPs are a key component of this first OR. The second level of OR occurs during the off season with permanent NETN/MIDN staff. During the second OR, results from QA/QC visits and data measurement objectives are reviewed to identify measurements that need fine-tuning or require additional training to ensure repeatability. Staff also discuss any proposed protocol changes or issues encountered during the season that need to be resolved. Changes to the SOPs are not made until after they are discussed and agreed upon during the second OR.

Quality Control Procedures

Quality control (QC) procedures evaluate data to ensure they meet documented standards and acceptable ranges. While QA procedures occur on raw data as the data are being collected, QC procedures occur on provisional data for this protocol. Data that violate QC standards and/or are outside of acceptable ranges are either rectified through correction or are flagged for a follow-up field check at the next possible field visit.

Data Validation

After data are merged into the Production Database and considered provisional, additional QC checks are conducted on a weekly basis in the form of a weekly QC report (Table 6). Code and example weekly QC reports are available at: <https://github.com/KateMMiller/forestQAQC>. Because much of the data collected for this protocol are entered in the Field App and undergo thorough QA, QC checks are less comprehensive and focus on identifying potential errors in the data that are harder to catch through QA. Many of the QC checks compare the current visit's data with historic data collected on the plot or at the park level. This includes identifying extreme metric values that are plausible, but that are > 99% of the range recorded for a given park. In some cases, these may be typos in the data, or may indicate a major forest response (e.g. flush of seedlings after a large canopy disturbance). Checks for species that are new to a plot or new to a park help flag potentially misidentified species that require extra review by the Plant Ecologist and/or Forest Crew Leader. Commonly mis-entered species, such as *Acer saccharinum* (silver maple), which comes first alphabetically, but is less common than *Acer saccharum* (sugar maple), are also checked for and reviewed by the Plant Ecologist and/or Forest Crew leader. Part of the QC process also looks for potential misuse of sample qualifiers, such as recording SS instead of NP when no species are recorded. Data recorded as "PM" (permanently missing) are also flagged to determine whether it was incorrectly used and why the data are missing. Weekly QC reports are generated by the Plant Ecologist and results are provided to the Forest Crew Leader at the end of each week. The Forest Crew Leader then discusses results of the QC checks at the beginning of each week with the crew to rectify issues where possible, and to prevent issues from being chronic. Errors identified during QC that cannot be corrected are denoted in the Notes field at the record, visit, or location-level, as appropriate. These errors are field checked during the next possible plot visit and are updated in the database where appropriate. Based on assessments of data collected from 2006 – 2021, errors identified during data validation that cannot be corrected occur on <0.001% of the data collected per year. At the end of data collection for each network, the QC checks are again performed on the entire year of data. Any remaining issues identified by the QC checks are either fixed or flagged. Once all QC checks pass, the data are certified for the year (see Data Certification section).

Once merging, adjudication, and QC checks for a given week are complete, the Office App generates a new field .bak. The new field .bak is used to update the local database instance on each field laptop and which is then linked to the Field App at the beginning of the week and data entry resumes.

Table 6. Quality control procedures implemented for the NETN/MIDN forest monitoring protocol. Note that some QC checks are redundant checks that already occur during QA in the Field App. The redundancy is designed to catch instances where crews are not clearing the checker in the Field App before completing a visit. In addition to the corrective actions listed below, all issues returned in the weekly QC reports are discussed with crew members at the beginning of each field week to determine if any issues can be fixed. Further training is also provided where needed.

Activity Type	Activity	Network	Measures	QC Procedures	Corrective Action	When Implemented	Check Type
Plot Establishment	1 Plot Establishment	NETN/MIDN	Plot Location	Compare plot location coordinates in database with coordinates in GIS files from GPS unit.	Correct coordinates in database to match GIS file coordinates.	Establishment of new plot	ArcGIS
	1 Plot Establishment	NETN/MIDN	Plot Location	Check that all plots fall within the park's authorized boundary.	Confirm current park boundary with park staff. Return to field site to capture plot location with GPS.	Establishment of new plot	ArcGIS
	1 Plot Establishment	NETN/MIDN	Plot Information	Check for missing plot-level data	Flag as missing and to be completed at next field visit.	Establishment of new plot	weekly QC
Field Observations	2 Stand Data Collection	NETN/MIDN	Stand Data	Check for "PM" recorded in stand data	Flag for field check during next possible visit	All plot visits	weekly QC
	2 Stand Data Collection	NETN/MIDN	Stand Structure	Check for fluctuating stand structures	Flag for field check during next possible visit	All plot visits	weekly QC
	2 Stand Data Collection	NETN/MIDN	Microtopography	Check for fluctuating microtopography	Flag for field check during next possible visit	All plot visits	weekly QC
	2 Stand Data Collection	NETN/MIDN	Deer Browse Impact (DBI)	Check for DBI = 1 recorded outside of a deer enclosure	Change to PM and flag for field check during next visit.	All plot visits	weekly QC
	2 Stand Data Collection	NETN/MIDN	Deer Browse Impact (DBI)	DBI change > 1 point from previous cycle	Flag for field check during next possible visit	All plot visits	weekly QC
	2 Stand Data Collection	NETN/MIDN	Stand Height	Check for stand heights > 99% range for a given park	Flag for field check during next possible visit	All plot visits	weekly QC
	2 Stand Data Collection	NETN/MIDN	Stand Height	Stand heights 50% higher or lower than previous visit	Flag for field check during next possible visit	All plot visits	weekly QC

Table 6 (continued). Quality control procedures implemented for the NETN/MIDN forest monitoring protocol. Note that some QC checks are redundant checks that already occur during QA in the Field App. The redundancy is designed to catch instances where crews are not clearing the checker in the Field App before completing a visit. In addition to the corrective actions listed below, all issues returned in the weekly QC reports are discussed with crew members at the beginning of each field week to determine if any issues can be fixed. Further training is also provided where needed.

Activity Type	Activity	Network	Measures	QC Procedures	Corrective Action	When Implemented	Check Type
Field Observations (continued)	3 Tree Data Collection	NETN/MIDN	All Tree Data	Check for "PM" recorded in tree data	Flag for field check during next possible visit	All plot visits	weekly QC
	3 Tree Data Collection	NETN/MIDN	Tree Status	Check for trees with impossible status changes (e.g., dead then alive)	Flag for field check during next possible visit	All plot visits	weekly QC
	3 Tree Data Collection	NETN/MIDN	Crown Class	Check for trees with major crown class changes (e.g. subcanopy to codominant)	Flag for field check during next possible visit	All plot visits	weekly QC
	3 Tree Data Collection	NETN/MIDN	DBH outside of tolerance	Check that all trees outside of growth tolerance from previous visit have the DBH Verified box checked.	Flag for field check during next possible visit	All plot visits	weekly QC
	3 Tree Data Collection	NETN/MIDN	Tree Condition	Check for tree conditions applied to the wrong species (e.g. BBD not applied to beech)	Delete incorrect tree condition	All plot visits	weekly QC
	4–6 Sapling, Seedling, Shrub Data Collection	NETN/MIDN	Sample Qualifiers	Check for blank sample qualifiers	Flag for field check during next possible visit	All plot visits	Field App & weekly QC
	4–6 Sapling, Seedling, Shrub Data Collection	NETN/MIDN	Sample Qualifiers	Check for "NS" sample qualifiers	If notes justify reason for NS, no corrective action taken.	All plot visits	weekly QC

Table 6 (continued). Quality control procedures implemented for the NETN/MIDN forest monitoring protocol. Note that some QC checks are redundant checks that already occur during QA in the Field App. The redundancy is designed to catch instances where crews are not clearing the checker in the Field App before completing a visit. In addition to the corrective actions listed below, all issues returned in the weekly QC reports are discussed with crew members at the beginning of each field week to determine if any issues can be fixed. Further training is also provided where needed.

Activity Type	Activity	Network	Measures	QC Procedures	Corrective Action	When Implemented	Check Type
Field Observations (continued)	4–6 Sapling, Seedling, Shrub Data Collection	NETN/MIDN	All Sapling, Seedling and Shrub Data	Check for "PM" recorded across all metrics	Flag for field check during next possible visit	All plot visits	weekly QC
	4 Sapling Data Collection	NETN/MIDN	Sapling tallies	Identify sapling tallies > 99% range for a given park	Flag for field check during next possible visit	All plot visits	weekly QC
	4 Sapling Data Collection	MIDN	Sapling Status	Check for saplings with impossible status changes (e.g., dead then alive)	Flag for field check during next possible visit	All plot visits	weekly QC
	4 Sapling Data Collection	MIDN	DBH outside of tolerance	Check that all saplings outside of growth tolerance from previous visit have the DBH Verified box checked.	Flag for field check during next possible visit	All plot visits	weekly QC
	4 Sapling Data Collection	MIDN	Sapling Tag Number	Check for duplicate sapling tag numbers in database	Flag for field check during next possible visit	All plot visits	weekly QC
	5 Shrub Data Collection	NETN/MIDN	Sample Qualifiers	Check for "SS" with no shrub data recorded	Flag for field check during next possible visit	All plot visits	weekly QC
	5 Shrub Data Collection	NETN/MIDN	Shrub Cover	Check for species recorded with 0 or missing cover	Flag for field check during next possible visit	All plot visits	weekly QC
	6 Seedling Data Collection	NETN/MIDN	Seedling Tallies	Check for "SS" with no seedling species recorded	Flag for field check during next possible visit	All plot visits	weekly QC
	6 Seedling Data Collection	NETN/MIDN	Seedling Tallies	Check for species recorded with all 0 or missing tallies	Flag for field check during next possible visit	All plot visits	weekly QC
	6 Seedling Data Collection	NETN/MIDN	Seedling Tallies	Identify seedling tallies > 99% range for a given park	Flag for field check during next possible visit	All plot visits	weekly QC

Table 6 (continued). Quality control procedures implemented for the NETN/MIDN forest monitoring protocol. Note that some QC checks are redundant checks that already occur during QA in the Field App. The redundancy is designed to catch instances where crews are not clearing the checker in the Field App before completing a visit. In addition to the corrective actions listed below, all issues returned in the weekly QC reports are discussed with crew members at the beginning of each field week to determine if any issues can be fixed. Further training is also provided where needed.

Activity Type	Activity	Network	Measures	QC Procedures	Corrective Action	When Implemented	Check Type
Field Observations (continued)	7 Quadrat Data Collection	NETN/MIDN	Sample Qualifiers	Check for "NS"	If notes justify reason for NS, no corrective action taken.	All plot visits	weekly QC
	7 Quadrat Data Collection	NETN/MIDN	Sample Qualifiers	Check for "SS" with no species data recorded	Flag for field check during next possible visit	All plot visits	weekly QC
	7 Quadrat Data Collection	NETN/MIDN	All Quadrat Characteristics Data	Check for "PM" recorded across all metrics	Flag for field check during next possible visit	All plot visits	weekly QC
	7 Quadrat Data Collection	NETN/MIDN	All Quadrat Species Data	Check for "PM" recorded across all metrics	Flag for field check during next possible visit	All plot visits	weekly QC
	7 Quadrat Data Collection	NETN/MIDN	Trampled	Check for quadrats with fluctuating trampled statuses between previous visit	Flag for field check during next possible visit	All plot visits	weekly QC
	7 Quadrat Data Collection	NETN/MIDN	Quadrat Cover	Check for species with all 0 cover or missing a cover value	Flag for field check during next possible visit	All plot visits	weekly QC
	8 Additional Species Data Collection	NETN/MIDN	Sample Qualifiers	Check for "NS"	If notes justify reason for NS, no corrective action taken.	All plot visits	weekly QC
	8 Additional Species Data Collection	NETN/MIDN	Sample Qualifiers	Check for missing sample qualifier	Flag for field check during next possible visit	All plot visits	weekly QC
	9 CWD Data Collection	NETN/MIDN	Sample Qualifiers	Check for "NS"	If notes justify reason for NS, no corrective action taken.	All plot visits	weekly QC
	9 CWD Data Collection	NETN/MIDN	All CWD Data	Check for missing sample qualifier	Flag for field check during next possible visit	All plot visits	weekly QC
	9 CWD Data Collection	NETN/MIDN	All CWD Data	Check for "PM" recorded across all metrics	If notes justify reason for NS, no corrective action taken.	All plot visits	weekly QC

Table 6 (continued). Quality control procedures implemented for the NETN/MIDN forest monitoring protocol. Note that some QC checks are redundant checks that already occur during QA in the Field App. The redundancy is designed to catch instances where crews are not clearing the checker in the Field App before completing a visit. In addition to the corrective actions listed below, all issues returned in the weekly QC reports are discussed with crew members at the beginning of each field week to determine if any issues can be fixed. Further training is also provided where needed.

Activity Type	Activity	Network	Measures	QC Procedures	Corrective Action	When Implemented	Check Type
Field Observations (continued)	9 CWD Data Collection	NETN/MIDN	CWD Volume	Identify CWD Volume > 99% percentile for a given park	Flag for field check during next possible visit	All plot visits	weekly QC
	9 CWD Data Collection	NETN/MIDN	CWD Length and Diameter	Identify CWD length or diameter > 99% range for a given park	Flag for field check during next possible visit	All plot visits	weekly QC
	10 Soil Sampling	NETN/MIDN	Sample Qualifiers	Check for "NS"	If notes justify reason for NS, no corrective action taken.	All plot visits	weekly QC
	10 Soil Sampling	NETN/MIDN	Sample Qualifiers	Check for missing sample qualifier	Flag for field check during next possible visit	All plot visits	weekly QC
	10 Soil Sampling	NETN/MIDN	All Soil Sample Data	Check for "PM" recorded across all metrics	Flag for field check during next possible visit	All plot visits	weekly QC
	10 Soil Sampling	NETN/MIDN	Soil Horizon Depth	Identify soil depths > 99% percentile for at least one horizon in a given park	Flag for field check during next possible visit	All plot visits	weekly QC
	3–9 Species Identification	NETN/MIDN	Species identification	Flag species that are new to a plot	Species reviewed and verified by Plant Ecologist	All plot visits	weekly QC
	3–9 Species Identification	NETN/MIDN	Species Identification	Flag species that are new to a park	Species reviewed and verified by Plant Ecologist	All plot visits	weekly QC
	3–9 Species Identification	NETN/MIDN	Species Identification	Flag commonly mis-entered species (e.g., <i>Acer saccharinum</i> vs. <i>Acer saccharum</i>)	Species reviewed and verified by Plant Ecologist	All plot visits	weekly QC

Documentation

Data Certification

Data that have undergone all QA and QC procedures described above are considered “certified” by the NPS. Data certification is the process confirming that:

- Data have been through all QA/QC procedures as outlined above.
- Data either meet specified quality standards, or data that do not meet those standards are appropriately identified and communicated at the record level.
- Data are suitable for general use.

The levels of data processing are:

Raw: Data in their state of original collection, either in the form of paper or electronic field forms, electronic sensor files, or digital media (photo, video, or audio). These data generally have been collected following some QA procedures but have not undergone any QC procedures.

Provisional: Data that have undergone incomplete QA/QC procedures as defined in the QAP and are not suitable for general use. Provisional data may be used in some cases, however, depending on the amount of QA/QC completed, and the intended use.

Accepted: Data that have undergone all QA and QC procedures as defined in a published protocol and associated SOPs. Used in cases where a Quality Assurance Plan has not been developed and approved (i.e., all data collected prior to 2022).

Certified Data. Data that a) have been through all QA/QC procedures as outlined in the Quality Assurance Plan, b) meet expected quality standards, or are appropriately identified and annotated at the record level in cases where they do not meet those standards, c) have documented procedures for data collection, processing, and transformation in appropriate metadata formats, and d) are suitable for use.

The data processing level is documented at the record level in the Production Database and in each Analysis Dataset. In both cases, data processing level is indicated in a Data Processing Level field where raw data are recorded as "R", provisional data are recorded as "P", accepted data are recorded as "A", and certified data are recorded as "C". For this protocol, data are considered provisional once the field .baks are merged into the Production Database. The certified level is the final data processing level, which occurs after the data pass all the QC checks outlined in this QAP and is completed by the Plant Ecologist. Certification is typically done once per year for each network, although may be performed on a park-by-park basis if capacity allows. All subsequent changes to certified data are documented in history tables in the Production Database.

Archive of Records

Once data from a field season have been certified, the following files are archived on each network's server:

- Data Package: a Zip file containing CSVs of the Analysis Datasets and associated metadata containing all previously accepted and certified data.
- Latest version of all the protocol documents, including the network's Narrative, Field SOPs, Summary of Major Protocol Changes and Deviations, Safety Plan and Quality Assurance Plan, Field Note cards, and blank field data sheets used for data collection.
- The latest frontends for the Field and Office App, and a .bak that represents a copy of the certified Production Database.
- Electronic copies of all completed field data sheets, scanned after data verification.
- The most recent shapefile of all sites monitored for this protocol, if updated since last sample.
- Labelled photopoints for every plot visit, separated by year.

In addition, a zip file of the Analysis Datasets and associated metadata for all previously certified and accepted data is posted yearly to the NPS Data Store on IRMA, with references linking the database to the protocol documents.

For all reports generated from the NETN/MIDN forest monitoring protocol, the following files are archived on a given network's server:

- Final manuscript with manuscript submittal form (if NPS NRR/NRTR series), both of which are also posted to the respective NPS Data Store reference.
- Draft of report submitted for peer review, along with peer review comments and author responses to those comments.
- Data Package: a Zip file containing the version of the Analysis Datasets used.
- Analytical code (e.g., R script) and flat data files (e.g., CSV files) used for data analysis presented in the report.

Metadata

Metadata for all Analysis Datasets will be created using the Ecological Metadata Language standard (EML). The R package, EMLassemblyline, will be used to automate the creation of metadata for inclusion in all published Data Packages. EMLassemblyline processes a series of CSV files that outline all the relevant metadata for each data package and generates an XML metadata file.

Wherever possible, the metadata included in the source CSV files will be extracted directly from the Master database.

Information Dissemination

All data reports, analyses, and dissemination of data for general (public) use will be based on accepted or certified data. In general, data will be certified prior to internal use for supporting park-, regional-, or national-level resource management decisions. However, in some cases the use of provisional data (data that have not undergone complete QA/QC as defined in this QAP) may be warranted to base decisions on best-available science.

Communicating Data Quality

Data certification and the processes entailed by that designation (as documented in this QAP) are the primary means by which data quality is communicated to end users. A descriptive paragraph or document for each report or data set will include a link to the NETN/MIDN Forest Monitoring Project in the NPS Data Store (<https://irma.nps.gov/Datastore/Reference/Profile/2189101>) to ensure that data can be traced to the latest version of the protocol, all associated standard operating procedures and documents, and this QAP.

Protocol Quality Assessment

This section outlines a series of periodic reviews and evaluations to be conducted as part of the implementation of this protocol (Table 7). These quality checks promote a cyclic process of continuous feedback and improvement of data quality and protocol methods. The protocol lead is responsible for organizing and conducting the reviews and assessments and for ensuring that summary information, deviations from SOPs, data nonconformities, new ideas and methods, etc. are properly documented through revisions to the protocol narrative, SOPs, Protocol Changes and Deviations document, QAP and/or Safety Plan where relevant.

Table 7. Data quality evaluations to be conducted as a part of implementing the NETN/MIDN forest monitoring protocol.

Evaluation	Purpose & Description	Frequency
Operational Review I	Protocol lead meets with field crew members to identify lessons learned in terms of operational efficiencies, logistical or technical challenges, unexpected field conditions, safety issues, etc. Based on these discussions, the SOPs are clarified or updated as needed to provide better guidance to future field crews. See Operational Review section for more detail.	Annually at completion of field season.
Data Quality Evaluation: Data Completeness	Evaluate the number of sites sampled as compared to the number of sites previously sampled in the panel.	Annual as data are certified.
Data Quality Evaluation: Data Timeliness	Measure of time required to certify data.	Annual as data are certified.
Data Quality Evaluation: Data Quality Assessment	Measure the number of data points that do not meet performance standards based on observer error sampling.	Annual as data are certified.
Operational Review II	Protocol lead obtains feedback from NETN/MIDN staff and on protocol implementation to ensure that the protocol remains in sync with annual monitoring activities. Seeks approval for and documents changes in procedures and equipment. Captures lessons learned from the field season to improve protocol implementation going forward. Provides NETN/MIDN staff with an opportunity to discuss the state of the science of the protocol. Based on these discussions, protocol documents are clarified or updated as needed.	Annually at completion of field season.
Scientific Review	Evaluates whether the protocol meets its stated objectives and produces the best available science. A targeted scientific review addresses one or two specific facets of the protocol (e.g., sampling frequency, field procedures). A full scientific review takes a holistic, in-depth look at the protocol, due to multiple potential areas of concern about the protocol's ability to meet its objectives (Mitchell et al. 2018).	Periodically.

A separate protocol review (which includes a full scientific review and overall assessment of whether the collected data are sufficient to meet protocol objectives) occurs periodically as needed. These should occur when substantial changes are made to protocol objectives or processes, concurrent with a significant data analysis/trend detection report, or as requested by a supervisor. Based on these criteria, protocol reviews occur on an as needed basis.

Roles, Responsibilities, and Qualifications

This section identifies the relationships between all personnel involved in the project, including the lead organization and all contractors and subcontractors. Summaries of staff roles are provided in Table 8. Current names and contact information for NPS staff are available at:

<https://www.nps.gov/im/netn/who-we-are.htm> (NETN) and <https://www.nps.gov/im/midn/about-us.htm> (MIDN).

Table 8. Roles, responsibilities and contact information for persons affiliated with implementation of the NETN/MIDN forest monitoring protocol (Tierney et al. 2022).

Position	Role
Regional Program Manager	Approving QAP and protocol; ensuring that data meet quality objectives.
Network Program Manager	Program coordination; oversight of development and implementation of monitoring protocols; ensure protocol implementation meets NPS scientific integrity standards and all data meet DQOs; conduct appropriate peer review of all published products.
Plant Ecologist/ Protocol Lead	Protocol implementation; lead seasonal staff hiring and training; serve as botany lead; oversee data collection, entry, and verification; lead QA/QC reporting and data certification; ensure all data meet DQOs; organize and conduct protocol quality assessment reviews; lead data analysis and reporting.
Protocol Data Managers	Manage Field and Office App front ends, Development and Production Database instances, and associated Azure Dev Ops project; develop and maintain dataset metadata; post annual data packages to NPS Data Store.
Forest Crew Leader	Lead field data collection and coordinate daily logistics (e.g., plot visit schedule); assist with forest crew training; ensure all forest crew members follow proper data collection procedures; serve as botany lead where Plant Ecologist or Contract Botanist not available; ensure that all field-based QAP procedures are followed; conduct data verification.
Forest Crew Member	Complete mandatory training; collect field data accurately as described in the Standard Operating Procedures; identify plants accurately and/or process unknown plants for later identification; ensure that all field-based QAP procedures are followed; enter data accurately into the project database and follow data entry QAP procedures.
Contract Botanist	Sample quadrat species in parks with high understory diversity and/or where the Plant Ecologist is not available.

Plant Ecologist

The Plant Ecologist is the protocol lead and is responsible for hiring and training field staff, overseeing data collection, implementing the QAP and data certification, and analysis/reporting. The Plant Ecologist is the botany lead for the protocol, and either leads plant identification in the field or validates plant identifications made by crew members. The Plant Ecologist is responsible for developing and revising the protocol, the protocol documents, and the R packages and automated reports for QA/QC and data analysis. The Plant Ecologist must have a solid background in forest

ecology, thorough knowledge of Northeastern and Mid-Atlantic flora, and experience analyzing complex ecological data with repeated measurements.

Forest Crew Leader

The Forest Crew Leader assists the Plant Ecologist with most project-related tasks (e.g., hiring and training forest crew members, helping with analysis and reporting), oversees data collection in the field, coordinates daily logistics and communication during the field season, leads pre-season preparation for training and field work (e.g., purchases equipment, updates safety equipment and contacts, compiles training binders, etc.), and inventories and organizes forest equipment and supplies in the post-season. The Forest Crew Leader must be able to identify or key out all woody species likely to be encountered across the NETN/MIDN parks and be the botany lead for all but the parks and plots with a high diversity of graminoids (e.g., Saratoga National Historical Park), which are sampled either by the Plant Ecologist or Contract Botanist.

Forest Crew Members

Given the current field season schedule consisting of 2 months sampling NETN parks and 2 months sampling MIDN/NCBN parks, at least three Forest Crew Members are required to implement the data collection for this protocol. Teams typically work as two teams of two people, with one team including the Forest Crew Leader. Typically, the team without the Forest Crew Leader has an assigned Assistant Crew Leader, and this person is often a returning forest crew member with more advanced plant identification skills and knowledge of the parks. Forest Crew Members are responsible for data collection in the field and data entry (where needed) into the Field App. Forest Crew Members are often recent college-graduates who have strong interest or experience in forest ecology and/or botany. They must be able to learn and identify woody plants in the Northeast and Mid-Atlantic Regions. All other identifications are either conducted or verified by the Forest Crew Leader and/or Plant Ecologist. Specific tasks that the Forest Crew Members are responsible for include:

- complete mandatory training
- collect field data accurately as described in the Standard Operating Procedures
- identify woody plants accurately and/or process unknown plants for later identification
- ensure that all field-based QA procedures are followed
- enter data accurately into the database or on datasheets and follow QA procedures

Contract Botanist

The Contract Botanist samples quadrat species in parks with high understory diversity when the Plant Ecologist is not available and is the lead on plant identification during those visits. Parks that typically require a contract botanist are Minute Man National Historical Park, Roosevelt-Vanderbilt National Historic Sites, and Saratoga National Historical Park. The contract botanist must have a thorough knowledge of the flora in the park they are sampling.

Data Manager

The Data Managers are responsible for maintaining the Field and Office Apps, the Development and Production databases, the associated Azure Dev Ops project, and the database metadata. They are responsible for posting the data package to the NPS Data Store for a given year of certified data. Currently, these responsibilities are shared between the NETN and MIDN Data Managers.

Network Program Manager

The Program Manager is responsible for ensuring that the protocol is aligned with and contributing towards network goals. The Program Manager also provides support in budget, personnel, and logistical matters. They are responsible for reviewing and ensuring publications derived from protocol implementation meet NPS scientific integrity standards, that data and reports are released in a timely fashion, and that the QAP is implemented as written and approved. Currently these roles are split between the NETN Program Manager, who provides scientific and program oversight to the protocol, and the MIDN Ecologist, who handles the cooperative agreements associated with the protocol.

Regional Program Manager

The Regional Program Manager is responsible for approving this QAP, and accountable for ensuring that data being collected under approved protocols meet stated quality objectives.

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Appendix A. Quality Assurance checks implemented in the Field Application

Table A1. Database Quality Assurance checks implemented in the application user interface organized by protocol module and Field Name in the database.

Module	Field Name	Quality Check	Network
Plots/Plots Add	Park Unit Code	1. Picklist 2. Locked for existing plots 3. Required field for new plots	NETN/MIDN
Plots/Plots Add	Plot Number	1. Locked for existing plots 2. Required field for new plots	NETN/MIDN
Plots/Plots Add	Location Type	1. Picklist 2. Locked for existing plots 3. Required field for new plots	NETN/MIDN
Plots/Plots Add	GRTS_Order	1. Locked for existing plots 2. Required field for new plots	NETN/MIDN
Plots/Plots Add	Panel	1. Picklist 2. Locked for existing plots 3. Required field for new plots	NETN/MIDN
Plots/Plots Add	Protected Status	1. Picklist 2. Locked for existing plots 3. Required field for new plots	NETN/MIDN
Plots/Plots Add	UTM E	1. X Coordinate must be between 258100 And 713979	NETN/MIDN
Plots/Plots Add	UTM N	1. Y Coordinate must be between 4100975 And 4921021	NETN/MIDN
Plots/Plots Add	Stand Origin Year	1. Stand origin year must not occur in the future or before 2000	NETN/MIDN
Plots/Plots Add	Coord System	1. Picklist 2. Locked for existing plots 3. Required field for new plots	NETN/MIDN
Plots/Plots Add	UTM Zone	1. Picklist 2. Locked for existing plots 3. Required field for new plots	NETN/MIDN
Plots/Plots Add	Physiographic Class	1. Picklist 2. Locked for existing plots 3. Required field for new plots	NETN/MIDN
Plots/Plots Add	GPS Accuracy (m)	1. Locked for existing plots 2. Required field for new plots	NETN/MIDN

Table A1 (continued). Database Quality Assurance checks implemented in the application user interface organized by protocol module and Field Name in the database.

Module	Field Name	Quality Check	Network
Plots/Plots Add	Aspect	1. Plot aspect is a whole number between 0 and 360; 0 when the slope is < 3 degrees; 360 when it is north 2. Locked for existing plots	NETN/MIDN
Plots/Plots Add	Orientation	1. Plot orientation is a whole number between 1 and 360 2. Unlocked for existing plots 3. Required field for new plots	NETN/MIDN
Plots/Plots Add	Stunted Woodland	1. Locked for existing plots 2. Required field for new plots	NETN/MIDN
Plots/Plots Add	Abandoned	1. Locked for existing plots 2. Required field for new plots	NETN/MIDN
Plots/Plots Add	Orientation Changed	1. Unlocked for existing plots	NETN/MIDN
Plots/Plots Add	Directions	1. Unlocked for existing plots 2. Required field for new plots	NETN/MIDN
Date/Observers	Contact Name	1. Picklist 2. Cannot enter Contact name twice	NETN/MIDN
Date/Observers	Verified Data	Only one user can verify data	NETN/MIDN
Date/Observers	Plant ID Specialist	Only one user can be the Plant ID specialist	NETN/MIDN
Stand/Slope	UC	Slope must be between -45 and 45 degrees	NETN/MIDN
Stand/Slope	UP	Slope must be between -45 and 45 degrees	NETN/MIDN
Stand/Slope	BR	Slope must be between -45 and 45 degrees	NETN/MIDN
Stand/Slope	BC	Slope must be between -45 and 45 degrees	NETN/MIDN
Stand/Slope	BL	Slope must be between -45 and 45 degrees	NETN/MIDN
Stand/Tree Heights/Intermediate	Tree #	1. Picklist is limited to Trees on plot with a Crown Class of "Intermediate" 2. Check for duplicate Tree Number	NETN/MIDN
Stand/Tree Heights/Intermediate	Height	1. Warn user if Height >= 7 And Height < 8 or > 40 And Height <= 60 2. Height cannot be outside the range between 7 and 60 meters	NETN/MIDN

Table A1 (continued). Database Quality Assurance checks implemented in the application user interface organized by protocol module and Field Name in the database.

Module	Field Name	Quality Check	Network
Stand/Tree Heights/Codominant	Tree #	1. Picklist is limited to Trees on plot with a Crown Class of "Codominant" 2. Check for duplicate Tree Number	NETN/MIDN
Stand/Tree Heights/Codominant	Height	1. Warn user if Height ≥ 8 And Height < 10 Or Height > 40 And Height ≤ 60 2. Height cannot be outside the range between 7 and 60 meters	NETN/MIDN
Stand/Stand Info	Crown Closure	Picklist	NETN/MIDN
Stand/Stand Info	Stand Structure	Picklist	NETN/MIDN
Stand/Stand Info	Deer Browse Line	Picklist	NETN/MIDN
Stand/Stand Info	Water On Plot	Picklist	NETN/MIDN
Stand/Stand Info	Microtopography	Picklist	NETN/MIDN
Stand/Stand Info	Earthworm	Picklist	NETN
Stand/Forest Floor Cover	Bare Soil	Picklist	NETN/MIDN
Stand/Forest Floor Cover	Rock	Picklist	NETN/MIDN
Stand/Forest Floor Cover	Trampled	Picklist	NETN/MIDN
Stand/Forest Floor Cover	Surface Water	Picklist	NETN/MIDN
Stand/Forest Floor Cover	Non-Vascular	Picklist	NETN/MIDN
Stand/Forest Floor Cover	Lichen	Picklist	NETN/MIDN
Stand/Vascular Plant Cover	% Low ($<0.5\text{m}$)	Picklist	NETN/MIDN
Stand/Vascular Plant Cover	% Mid ($0.5\text{--}2\text{m}$)	Picklist	NETN/MIDN
Stand/Vascular Plant Cover	% High ($2\text{--}5\text{m}$)	Picklist	NETN/MIDN
Stand/Photos	Weather Condition	Picklist	NETN/MIDN
Stand/Photos	Camera	Picklist	NETN/MIDN
Stand/Photos	Plot Photos Taken	See Table A2	NETN/MIDN
Stand/Photos	Microplot Photos Taken	See Table A2	NETN/MIDN
Stand/Photos	ID Photo Taken	See Table A2	NETN/MIDN

Table A1 (continued). Database Quality Assurance checks implemented in the application user interface organized by protocol module and Field Name in the database.

Module	Field Name	Quality Check	Network
Stand/Disturbances	Disturbance	1. Picklist 2. Cannot enter additional disturbances once "None" or "Permanently Missing" is selected 3. Cannot enter "None" or "Permanently Missing" if another disturbance is already entered 4. Warning if user enters the same disturbance code twice 5. If "None" is selected, pre-populate Threshold and Cover Classes with "NA" 6. If "Permanently Missing" is entered, pre-populate Threshold and Cover Class with "PM"	NETN/MIDN
Stand/Disturbances	Threshold	Picklist	NETN/MIDN
Stand/Disturbances	Cover Class	Picklist	NETN/MIDN
Tree Data /Add New Tree	Tag	Check for duplicate tag on current NETN Plot; required field	NETN
Tree Data /Add New Tree	Tag	Check for duplicate tag on any MIDN Plot; required field	MIDN
Tree Data /Add New Tree	Species	1. Picklist 2. Required field	NETN/MIDN
Tree Data /Add New Tree	Fork	Fork can only be one alphanumeric character	NETN/MIDN
Tree Data /Add New Tree	Azimuth	Required field; Azimuth must be between 0 and 360	NETN/MIDN
Tree Data /Add New Tree	Distance	Required field; Distance must be between 0 and 14.2	NETN/MIDN
Tree Data /Add New Tree	Is DBH Unusual	None	NETN/MIDN
Tree Data /Add New Tree	Status	1. Picklist limited based on type of plot (Existing or New) 2. Required field	NETN/MIDN
Tree Data	Tag	1. Warn user prior to change to Tag 2. Check for duplicate tag on current NETN Plot 3. On change, populate old tag into the notes field	NETN

Table A1 (continued). Database Quality Assurance checks implemented in the application user interface organized by protocol module and Field Name in the database.

Module	Field Name	Quality Check	Network
Tree Data	Tag	1. Warn user prior to change to Tag 2. Check for duplicate tag on any MIDN Plot 3. On change, populate old tag into the notes field	MIDN
Tree Data	Species	1. Picklist 2. Warn user prior to change 3. On change, populate old species ID into the notes field of the record	NETN/MIDN
Tree Data	Fork	Fork can only be one alphanumeric character	NETN/MIDN
Tree Data	Azimuth	Azimuth must be between 0 and 360	NETN/MIDN
Tree Data	Distance	Distance must be between 0 and 14.2	NETN/MIDN
Tree Data	Is DBH Unusual	If selected require user to enter an explanatory note	NETN/MIDN
Tree Data	Status	1. Picklist 2. Subforms are loaded based on the entered status to hide fields that are not relevant 3. If status is "XS", warn user to confirm tree is not dead 4. If a change in status will conflict with any existing tree data, the user is warned prior to deleting the conflicting values	NETN
Tree Data	Status	1. Picklist 2. Subforms are loaded based on the entered status to hide fields that are not relevant. 3. If status is "XO", warn to add a note 4. If status is "XS", warn user to confirm it is not dead, then check for previous sapling records and create record as appropriate 5. If status is "TR", check to see if sapling status record is compatible 6. If status is "NL", check status at previous visit and if also "NL", change status to "XO" in the current visit 7. If a change in status will conflict with any existing tree data, the user is warned prior to deleting the conflicting values	MIDN

Table A1 (continued). Database Quality Assurance checks implemented in the application user interface organized by protocol module and Field Name in the database.

Module	Field Name	Quality Check	Network
Tree Data	DBH	1. Valid DBH values fall between 10 and 250 2. DBH cannot be >12 if Status is RS 3. A DBH value that has increased by ≥ 3cm or decreased by 0.1 cm will warn a user to verify their measurement	NETN/MIDN
Tree Data	Verified	None	NETN/MIDN
Tree Data	Crown Class	1. Picklist 2. Warns user if they select "Permanently Missing"	NETN/MIDN
Tree Data	Tree Conditions	1. Condition picklist limited by tree status (Alive or Dead) 2. Each condition can be used once per tree per visit 3. Here can be only one condition when the value is set to "Healthy"	NETN/MIDN
Tree Data	Vine Species	1. Picklist 2. Each vine taxon can only be used once per tree per visit 3. Vine Species is required if Vine Position is entered	NETN/MIDN
Tree Data	Vine Position	1. Picklist 2. Vine Position is a required field if Vine Species is entered	NETN/MIDN
Tree Data	Foliage Condition	1. Picklist 2. Each foliage condition can only be used once per tree per visit 3. There can be only one condition entered when the value is set to "NO" (No conditions)	NETN/MIDN
Tree Data	Percent Leaves	1. Picklist 2. Required field if Foliage Condition is entered 3. If Foliage Condition is "NO", then Percent Leaves will be auto-populated with "NA"	NETN/MIDN

Table A1 (continued). Database Quality Assurance checks implemented in the application user interface organized by protocol module and Field Name in the database.

Module	Field Name	Quality Check	Network
Tree Data	Percent Leaf Area	1. Picklist 2. Required field if Foliage Condition is entered 3. If Foliage Condition is NO, S, W, L, or O then Percent Leaf Area will be auto-populated with "NA"	NETN/MIDN
Tree Data	Total Foliage Condition	1. Picklist 2. If Foliage Condition is "NO", then total Foliage Condition will be auto-populated with "NA"	NETN/MIDN
Tree Data	HWA Status	1. Load the HWA status subform only if species is <i>Tsuga canadensis</i> 2. Picklist	NETN/MIDN
Tree Data	BBD Status	1. Load the BBD status subform only if species is <i>Fagus grandifolia</i> 2. Picklist	NETN/MIDN
Microplot/Saplings	Sapling Sampled?	1. Picklist 2. If qualifier is changed to "Not Sampled", warns user to record a note 3. A change in sample qualifier status will warn user if there are existing records that would be deleted by a change in the sample qualifier	NETN/MIDN
Microplot/NETN Saplings	Species	1. Picklist 2. Check for duplicate Species in the same microplot 3. Prompt user to enter a species count for Taxa that have more than DBH records 4. Prevent user from entering an 11th DBH for a species in the same microplot 5. Check for species that should be entered as a shrub and not a sapling	NETN
Microplot/NETN Saplings	DBH	Sapling DBH must be between 1 and 9.9 centimeters	NETN
Microplot/Saplings Count	Species	1. New Count form opens with the Species already populated with the correct Species 2. Picklist	NETN
Microplot/Saplings Count	Count	Valid count values are between 0 and 50	NETN

Table A1 (continued). Database Quality Assurance checks implemented in the application user interface organized by protocol module and Field Name in the database.

Module	Field Name	Quality Check	Network
Microplot/MIDN Saplings	Tag	1. Warn user prior to change to Tag 2. Check for duplicate tag on any MIDN Plot 3. On change, populate old tag into the notes field	MIDN
Microplot/MIDN Saplings	Species	1. Picklist 2. Warn user prior to change 3. On change, populate old species ID into the notes field of the record 4. Check for species that should be instead entered as a shrub	MIDN
Microplot/MIDN Saplings	Fork	Fork can only be one alphanumeric character	MIDN
Microplot/MIDN Saplings	Status	1. Picklist 2. Prevent the entering of a DBH value for Status values that do not require DBH 3. If status is "TR", confirm with user, then create a new tree record 4. Check tree and sapling status values are compatible across sapling and tree forms 5. If status is "NL", check status at previous visit and if also "NL", change status to "XO" in the current visit, if not prompt user to record notes	MIDN
Microplot/MIDN Saplings	DBH	1. A user must enter a status record before entering a DBH value 2. Sapling DBH must be between 1 and 9.9 centimeters 3. A change in DBH value ≥ 3 or ≤ -0.1 cm prompts user to recheck their DBH measurement	MIDN
Microplot/MIDN Saplings	Verified	None	MIDN
Microplot/Shrubs	Shrubs Sampled?	1. Picklist 2. If qualifier is changed to "Not Sampled", warns user to record a note 3. A change in sample qualifier status will warn user if there are existing records that would be deleted by a change in the sample qualifier	NETN/MIDN

Table A1 (continued). Database Quality Assurance checks implemented in the application user interface organized by protocol module and Field Name in the database.

Module	Field Name	Quality Check	Network
Microplot/Shrubs	Species	1. Picklist 2. Prevent entering a duplicate Species for the same microplot	NETN/MIDN
Microplot/Shrubs	Cover Class	Picklist	NETN/MIDN
Microplot/Seedlings	Seedling Sampled?	1. Picklist 2. If qualifier is changed to "Not Sampled", warns user to record a note 3. A change in sample qualifier status will warn user if there are existing records that would be deleted by a change in the sample qualifier	NETN
Microplot/Seedlings	Species	1. Picklist 2. Check for Species that should instead be entered a shrub 3. Prevent entering duplicate Species for the same microplot	NETN
Microplot/Seedlings	15–30cm	Count must be between 0 and 255	NETN
Microplot/Seedlings	30–100cm	Count must be between 0 and 255	NETN
Microplot/Seedlings	1–1 1/2m	Count must be between 0 and 255	NETN
Microplot/Seedlings	>1 1/2m	Count must be between 0 and 255	NETN
Quadrat Data	Sampled?	1. Picklist 2. If status change will conflict with existing values, user is warned prior to deletion 3. If User selects "Not Sampled" they are warned to add a note explaining why sampling did not occur	NETN/MIDN
Quadrat Data	Trampled?	None	NETN/MIDN
Quadrat Data	Cover	Picklist	NETN/MIDN
Quadrat Species	Sampled?	1. Picklist 2. If status change will conflict with existing values, user is warned prior to deletion 3. If User selects "Not Sampled" they are warned to add a note explaining why sampling did not occur	NETN/MIDN
Quadrat Species	Species	1. Picklist 2. Check for species added more than once, one must be germinant and the other not germinant. If user agrees, the second entry is marked as germinant	NETN/MIDN

Table A1 (continued). Database Quality Assurance checks implemented in the application user interface organized by protocol module and Field Name in the database.

Module	Field Name	Quality Check	Network
Quadrat Species	Cover	1. Picklist 2. Cover Class is a required field 3. At least one quadrat must have a cover class greater than 0%	NETN/MIDN
Quadrat Seedlings	Sampled?	1. Picklist 2. If status change will conflict with existing values, user is warned prior to deletion 3. If User selects "Not Sampled" they are warned to add a note explaining why sampling did not occur	MIDN
Quadrat Seedlings	Species	1. Picklist 2. Check for Species that should instead be entered a shrub 3. Prevent entering duplicate Species for the same Quadrat	MIDN
Quadrat Seedlings	Count	Seedling count must be a positive number that is less than 255	MIDN
Quadrat Seedlings	Cover	Picklist	MIDN
Quadrat Seedlings	Collected	None	MIDN
Quadrat Seedlings	Browse Count	1. If a user enters 0 for each size class, this does not permit a value to be entered 2. Browsed Count cannot be more than the sum of all counts for each seedling size class	MIDN
Additional Species	Sample Qualifier	1. Picklist 2. Warn user if a change in the sample qualifier will result in deleting of existing records 3. If user enters "Not Sampled", prompt user to record a reason in the notes field	NETN/MIDN
Additional Species	Species	1. Picklist 2. Check for species added more than once	NETN/MIDN
Additional Species	Confidence	Picklist	NETN/MIDN
Additional Species	Collected	None	NETN/MIDN

Table A1 (continued). Database Quality Assurance checks implemented in the application user interface organized by protocol module and Field Name in the database.

Module	Field Name	Quality Check	Network
CWD Transect	Sample Qualifier	1. Picklist 2. Warn user if a change in the sample qualifier will result in deleting of existing records 3. If user enters "Not Sampled", prompt user to record a reason in the notes field	NETN/MIDN
CWD Transect	Distance	1. Distance is a required field 2. Valid distance values are between 0 and 15 meters	NETN/MIDN
CWD Transect	Species	1. Picklist 2. Species is a required field	NETN/MIDN
CWD Transect	Diameter	1. Diameter is a required field 2. Valid Diameter values are greater than or equal to 10cm	NETN/MIDN
CWD Transect	Multiple ID	Picklist	NETN/MIDN
CWD Transect	Decay	1. Picklist 2. Decay Class is a required field 3. Warns user if they select "Permanently Missing"	NETN/MIDN
CWD Transect	Length	1. Length is a required field 2. Valid length values are between 1 and 100 meters	NETN/MIDN
CWD Transect	Is Hollow	None	NETN/MIDN
Soil	Sample Type	1. Picklist 2. Value defaults to "Excavation" for ACAD plots, "Core" for all other plots	NETN
Soil	Sample Position	Picklist	NETN
Soil	Horizon Type	Picklist	NETN
Soil	Sample Qualifier	1. Picklist 2. Subform is locked if Sample Qualifier is Null or "Not Sampled" 3. Warn user if a change in the sample qualifier will result in deleting of existing records 4. If user enters "Not Sampled", prompt user to record a reason in the notes field	NETN

Table A1 (continued). Database Quality Assurance checks implemented in the application user interface organized by protocol module and Field Name in the database.

Module	Field Name	Quality Check	Network
Soil	Soil Layer	1. Picklist 2. Soil Layer is a required field 3. Check for duplicate soil layer types	NETN
Soil	Depth_cm	Valid depth values are between 0 and 30	NETN

Table A2. Database Quality Assurance checks implemented in the application user interface checker tool organized by protocol module and Error Name.

Module	Error Name	Definition	Network
Date/Observers	PM(Code_PM)	List of all the lookups where permanently missing was entered	NETN/MIDN
Date/Observers	TooFew_Obsrvrs	Less than the required 2 observers were recorded	NETN/MIDN
Stand	Bare Soil Cover	Checker shows name of data field that requires a value, but was left null	NETN/MIDN
Stand	Clear Codom Hghts	Caused when a height has been recorded for a codominant tree when the Stand Structure is early successional	NETN/MIDN
Stand	Clear Inter Hghts	Caused when a height has been recorded for an intermediate tree when the Stand Structure is early successional	NETN/MIDN
Stand	Cover (stratum)	Checker shows the stratum that requires a value, but was left null	NETN/MIDN
Stand	Derived Plot	Checker shows name of data field that requires a value, but was left null	NETN/MIDN
Stand	Disturbance_NA_(count)	When threshold or coverclass of NA but disturbance is other than None	NETN/MIDN
Stand	Earthworm_Missing	Earthworm not recorded	NETN
Stand	ID Photos	Checker shows name of data field that requires a value, but was left null	NETN/MIDN
Stand	Inter > Codom ?	Indicates intermediate tree with a height taller than a codominant tree	NETN/MIDN
Stand	Lichen Cover	Checker shows name of data field that requires a value, but was left null	NETN/MIDN
Stand	Microplot Photos	Checker shows name of data field that requires a value, but was left null	NETN/MIDN
Stand	Need Disturbance	Stand disturbance left blank. Use 'No Disturbance' if plot is not disturbed	NETN/MIDN
Stand	Non-Vasc Cover	Checker shows name of data field that requires a value, but was left null	NETN/MIDN
Stand	Note Plot Aspect	add a note for the plot that the aspect needs to be fixed in the office database by the plant ecologist	NETN/MIDN
Stand	Plot Photos	Checker shows name of data field that requires a value, but was left null	NETN/MIDN
Stand	Rock Cover	Checker shows name of data field that requires a value, but was left null	NETN/MIDN
Stand	Slope_(trans)	Checker shows name of data field that requires a value, but was left null	NETN/MIDN

Table A2 (continued). Database Quality Assurance checks implemented in the application user interface checker tool organized by protocol module and Error Name.

Module	Error Name	Definition	Network
Stand	Stand Info	Missing values for Stand Structure, Crown Closure, Water Plot, Deer Browse, and Microtopography	NETN/MIDN
Stand	Trampled Cover	Checker shows name of data field that requires a value, but was left null	NETN/MIDN
Stand	Water Cover	Checker shows name of data field that requires a value, but was left null	NETN/MIDN
Tree	BBD_Err_(var)	Missing BBD records	NETN/MIDN
Tree	BBD_ORPHAN(var)	Either a BBD condition with no classifier or a classifier with no condition	NETN/MIDN
Tree	COND_%_ERROR(var)	Occurs when erroneous percentages are entered for a given foliage condition	NETN/MIDN
Tree	Condition_Err_(var)	Missing condition records	NETN/MIDN
Tree	Crown_Err_(var)	Missing crown class records	NETN/MIDN
Tree	DBH_Err_(var)	Triggered by the following: a) Tree is dead and upright, but missing DBH; b) Tree is excluded/Missing/Down and has DBH; c) Live tree missing DBH	NETN/MIDN
Tree	Decay_Err_(var)	Caused by dead tree without a decay class (or live tree with)	NETN/MIDN
Tree	Foliage_%_Zero(var)	Count of foliage condition (other than NO) recorded with 0% of tree affected	NETN/MIDN
Tree	Foliage_Err_(var)	Missing foliage condition records	NETN/MIDN
Tree	Foliage_NA_(count)	When percent leaves, or percent leaf area of NA used with foliage condition other than none	NETN/MIDN
Tree	HWA_Err_(var)	Missing HWA records	NETN/MIDN
Tree	HWA_ORPHAN(var)	Either an HWA condition with no classifier or a classifier with no condition	NETN/MIDN
Tree	No_Status_(var)	Count of tree records missing 'Status' value	NETN/MIDN
Tree	Null_Az_Dist_(Code)	Missing Azimuth or Distance	NETN/MIDN
Tree	Recruit_DBH_(var)	Count of records where dbh > 12. The tree status RS (recruit standing) is only allowed for trees 12cm or less	NETN/MIDN
Tree	Species_Cond_(code)	When there is a condition recorded that does not match the species of the tree	NETN/MIDN
Tree	Status_Conflict_(treenum)	trees whose status is invalid based on their origin	NETN/MIDN
Tree	Tot_Fol_Err_(var)	Missing total foliage record	NETN/MIDN

Table A2 (continued). Database Quality Assurance checks implemented in the application user interface checker tool organized by protocol module and Error Name.

Module	Error Name	Definition	Network
Tree	TotFol_OutOfRange_(#Code)	When sum of lower limits are greater than the total upper limit or whose sum of upper limits are less than total lower limit	NETN/MIDN
Tree	TotFoliage_NA_(count)	When total foliage of NA used with foliage condition other than none	NETN/MIDN
Tree	VINE_ORPHAN(var)	Either a vine condition with no species or vine species with no vine condition	NETN/MIDN
Microplot	Micro_Incomplete(code)	Some but not all observations made for a microplot	NETN/MIDN
Microplot	Micro_Note(code)	When a note is blank and the sample qualifier is anything other than successfully sampled	NETN/MIDN
Microplot	No_Status_Sap(count)	Number of Saplings that do not have a status set	MIDN
Microplot	Null_Cover(code_code)	When a coverclass was left blank for a shrub species	NETN/MIDN
Microplot	Null_Micro_Sap(count)	Count of microplots where sapling is SS but there are not measurements	NETN/MIDN
Microplot	Null_SapCount(count)	Number of count records expected where the DBH measures are ≥ 10 for a species	NETN
Microplot	Null_SeedSize	Indicates there is a seedling species missing counts for one or more size classes	NETN
Microplot	Sap_NullDBH(count)	Count of records where a DBH is missing	NETN/MIDN
Microplot	Sap_Status_Conflict_(var)	Number of saplings whose status is invalid based on their origin	MIDN
Microplot	Seedling_AllZero(count_code)	Microplots where the counts for seedling size classes are all zero	NETN
Microplot	SeedMissing(count)	Count of microplots where seed is successfully sampled but there are no seed records	NETN
Microplot	Shrub_Cover(code)	Microplot where shrub sample qualifier says successfully sampled but no child records	NETN/MIDN
Microplot	Status_DBH(Code)	New saplings with dbh > 2 then status must be AM otherwise can't be AM	MIDN
Microplot	Wrong_SapCount(count)	Number of count records where insufficient number of DBH measures for a species	NETN
Quadrat Data	Quad_Char(Quad_Char)	Quadrat shown as successfully sampled that is missing cover records	NETN/MIDN

Table A2 (continued). Database Quality Assurance checks implemented in the application user interface checker tool organized by protocol module and Error Name.

Module	Error Name	Definition	Network
Quadrat Data	Quad_Incomplete(code)	Some but not all observations made for a quadrat	NETN/MIDN
Quadrat Data	Quad_Note(code)	When a note is blank and the sample qualifier is anything other than successfully sampled	NETN/MIDN
Quadrat Species	Dup_Spp_(count)	Quadrat with more than one of the same species that has the same germinant flag	NETN
Quadrat Species	Spp_Cover(Quad)	Quadrat shown as successfully sampled but missing species cover class record	NETN/MIDN
Quadrat Seedling	Browse_Count	Indicates logical errors in browse count vs seedling count	MIDN
Quadrat Seedling	Null_SeedSize	A size class is missing a count	MIDN
Quadrat Seedling	SeedMissing(code)	Seedling records are either missing altogether of the cover class is not specified	MIDN
Additional Species	ADD_Note	Additional species not sampled with no notes	NETN/MIDN
Additional Species	Missing_No_Spp	No additional species identified	NETN/MIDN
Additional Species	TSN # Quad Dup	Additional species already identified in the quadrats	NETN/MIDN
CWD	CWD_Note(Code)	Transect where not sampled with no notes	NETN/MIDN
CWD	Length_Null_(Code)	Length not recorded for a given transect	NETN/MIDN
CWD	No_CWD_(Code)	Data not collected for a given transect	NETN/MIDN
Soil	(layer) OutOfRange_(sample#)	Erroneous depth for a specific sample and layer	NETN
Soil	Missing L or T(sample#)	Missing depth for a specific sample and layer	NETN
Soil	No_Soil_(Count)	Numer of successfully sampled soils without corresponding depth measurements	NETN
Soil	Soil_Note	Sample sequence not sampled with no notes	NETN
Soil	Soil_Required	Indicates missing horizon or soil position qualifiers	NETN

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525