Ecological Reserves in Maine: Initial Results of Long-Term Monitoring

General Technical Report

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Cover photo

Deboullie Ecological Reserve as seen from the Black Mountain fire tower. Courtesy of J. Schlawin, Maine Natural Areas Program.

Summary

To date, 50 locations with a total area of approximately 175,000 acres make up Maine's Ecological Reserve System. An Ecological Reserve is generally defined as an area where timber harvesting is prohibited and natural disturbance events are allowed to proceed without significant human influence. Ecological Reserves encompass some of the most remote and ecologically important places in Maine. Beginning in 2002 and 2004, respectively, a system of long term monitoring plots was established on state-owned Ecological Reserves and preserves owned by The Nature Conservancy. As of 2017, plots in 20 Reserves were remeasured 10 years after initial inventory, which allowed for the first analysis of changes over time. Furthermore, this initial assessment of Ecological Reserve Monitoring data quantified differences in forest structure between Reserves and Maine's managed forests for a statewide comparison.

Stand metrics calculated and analyzed at the plot level included live tree basal area, very large (diameter at breast height, dbh ≥ 20.1 in) live trees per acre, standing dead trees and large (dbh ≥ 15.8 in) standing dead trees per acre, total and large (diameter at transect intersect ≥ 15.8 in) downed woody debris volume, as well as various growth and yield metrics. US Forest Service Forest Analysis and Inventory (FIA) data from managed forests across Maine were used to calculate the same metrics. Mixed effects modeling was used to evaluate the influence of program (i.e., Ecological Reserve Monitoring or FIA) and time (inventory round 1 or 2 for Ecological Reserve Monitoring plots) on the studied metrics.

Our findings indicate the forest composition of Ecological Reserve plots reflects the distribution of forest types across Maine's forest landscape. For the Ecological Reserves, sampling accuracy was acceptable for some metrics such as basal area and total downed woody debris volume. However, this sampling accuracy applies only to metrics measured on plots within dominant forest types in inventory round 1. Multiple metrics of forest structure suggested greater stand complexity on Ecological Reserves than managed forestland in Maine. This result was most evident in two attributes: very large live trees per acre and large standing dead trees per acre. Longer term sampling data will be needed to verify trends over time. However, this assessment of ten-year changes indicated that Ecological Reserves are still accumulating volume, partially reflecting the past harvesting history of many Reserves prior to their formal establishment as Ecological Reserves.

Background

Upon the enactment of LD 477 by the 119th Maine Legislature in August 2000, a system of Ecological Reserves was established on state lands managed by the Maine Department of Agriculture, Conservation, and Forestry (DACF). Shortly thereafter, Ecological Reserves were designated on lands owned by the Maine Department of Inland Fisheries and Wildlife (DIFW). Beginning in 2004, preserves owned and managed by The Nature Conservancy (TNC) consistent with Ecological Reserve purposes were added to the monitoring system. An Ecological Reserve is generally defined as an area where timber harvesting is restricted and natural disturbance events are allowed to proceed without significant human influence (Maine Ecological Reserves Scientific Advisory Committee 2009). The purposes of the Ecological Reserves System on Maine Public Lands as established by legal statute are to:

(1) Maintain one or more natural community types or native ecosystem types in a natural condition and range of variation,
(2) Contribute to the protection of Maine's biological diversity,
(3) Create a benchmark against which biological and environmental change may be measured, as a site for ongoing scientific research, long-term environmental monitoring, and education, and
(4) Protect sufficient habitat for those species whose habitat needs are unlikely to be met on lands managed for other purposes (Chapter 592, MSRA Section 13076).

While the purposes apply to state-owned lands, The Nature Conservancy and several other conservation organizations manage a suite of their lands consistent with the purposes in statute.

The number of Ecological Reserves and the area included within the Ecological Reserve Monitoring program has been growing steadily since the early 2000s. To date, 50 Reserves (state: 27, TNC: 23) with a total area of approximately 175,000 acres make up Maine’s Ecological Reserve Monitoring System (Figure 1). Ecological Reserves encompass some of the most remote and ecologically important places in Maine, including the Bigelow Range, Debsconeag Lakes Wilderness Area, Great Heath, and many others, and they support vulnerable habitats in the state such as old forests, alpine meadows, vast open peatlands, and coastal headlands. The latest preserve added to the Ecological Reserve Monitoring system is TNC’s Bradley-Sunkhaze Preserve. Although some open wetlands are included within the Ecological Reserves monitoring program (using a separate protocol), only forested systems are included in this analysis.

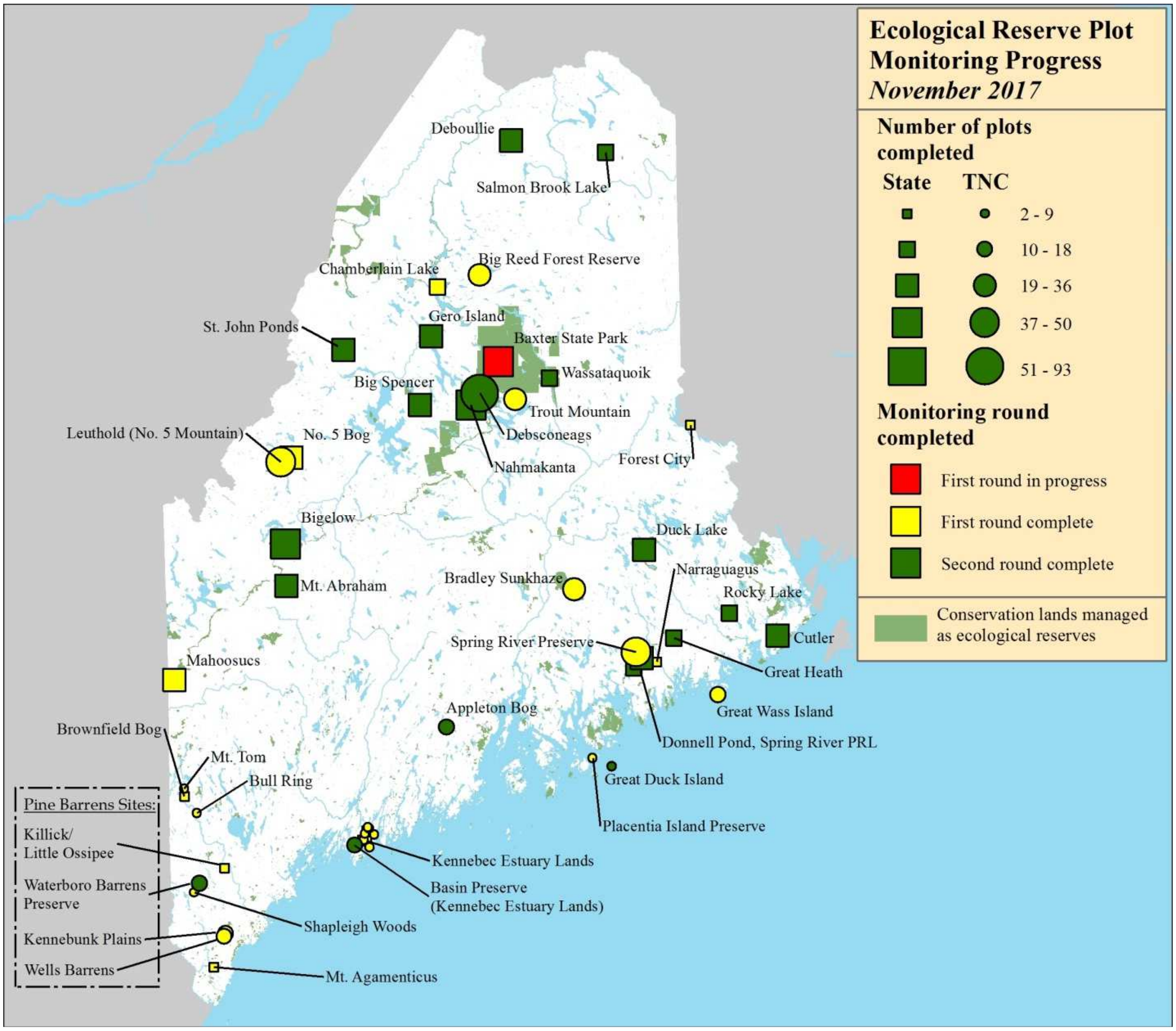

Figure 1. Location, owner, number of plots, and monitoring status of Maine's Ecological Reserves. Map by J. Schlawin, Maine Natural Areas Program.

The Ecological Reserves Scientific Advisory Committee was formed in 2001 to provide oversight of Ecological Reserves and develop a long-term monitoring protocol (Maine Department of Conservation 2003). Beginning in 2002, fine-scale monitoring plots were established in state-owned Ecological Reserves using a measurement protocol closely following US Forest Service Forest Inventory and Analysis (FIA) methodology. TNC began monitoring their reserves in 2004. The goal is to resample each plot in Ecological Reserves every 10 years. As of 2017, plots in 20 Reserves have been fully or partly remeasured (Figure 1), which allows for the first analysis of changes over time and a detailed comparison of Ecological Reserves to forestland managed for timber products.

This report addresses two key questions identified in the original Ecological Reserve Monitoring Plan (Maine Department of Conservation 2003):

(1) Do forest structure and composition of Maine's Ecological Reserves differ from that of Maine's managed forests (using FIA data for comparison)?
(2) Is forest structure and composition on Ecological Reserves changing over time?

It specifically addresses five research questions related to questions (1) and (2) above:

(1) What is the forest-type composition of Reserves, and is it different from that of Maine's managed forests?
(2) What is the density of live and standing dead trees and amount of downed coarse woody debris on Reserves, and is it different from Maine's managed forest?
(3) What is the large live and large standing dead tree density on Reserves and is it different from Maine's managed forest?
(4) What is the forest growth rate on Reserves and is it different from Maine's managed forests?
(5) Were there significant changes in stand-level compositional and structural attributes over the 10-year monitoring period?

In addition, the report also aims to assess accuracy of the Ecological Reserve Monitoring sampling effort, i.e. how statistically reliable are findings for various forest attributes derived from the inventory data collected on Ecological Reserves.

Data collection

Forest Inventory and Analysis

FIA data were collected from a network of permanent plots, with a sampling intensity of approximately one plot per 6,000 acres (Woodall and Monlean 2008). Each plot consisted of four, 24-ft fixed-radius subplots spaced 120 ft apart in a triangular arrangement with one subplot in the center (USDA 2015). All trees (live and standing dead) with a diameter at breast height (dbh) of at least 5.0 in were inventoried on forested subplots. Minimum length of standing dead trees was 4.5 ft. Downed woody debris was sampled along three 24 ft horizontal distance transects emanating from the center of each FIA subplot (azimuths of 30, 150, and 270 degrees) and included downed dead tree and shrub boles, large limbs, and other woody pieces ≥ 3 in diameter at intersection with transect lines (Woodall and Monlean 2008). A standing dead tree was considered downed dead wood when the lean angle of its central bole was greater than 45° from vertical. We used site tree age to quantify and report age of FIA subplots. A site tree was selected off the subplot where possible and is defined as an individual with a dominant or co-dominant crown position throughout its entire life span, of at least 5.0 in dbh, and at least 20 years old. Tree age was determined based on an increment sample taken at breast height with no additional years added for total age (USDA 2014). While data related to measurements of trees < 5.0 in dbh were not used in statistical analysis, they were used to compute descriptive statistics for managed forests (Appendix D, Tables 3 and 4). Specifically, live trees ≥ 1.0 in dbh were inventoried on one, 6.8-ft fixed-radius microplot within each subplot (USDA 2015).

We used data from the three most recent FIA inventories (spanning the years of 2000-2015) because they most closely correspond to the time period of the Maine Ecological Reserve inventories (2002-2017). Forest attributes on FIA subplots were measured approximately every five years. For each subplot, inventory data were used to compute periodic annual growth and yield metrics over an approximately ten-year time period (see the Data Analysis section for details on how growth and yield metrics were derived). For statistical analyses, other static metrics (e.g., snags per acre) were computed for each subplot using the most recent inventory data.

A total of 10,503 FIA subplots were selected for the analysis. We restricted our analysis to FIA subplots without reserve status on private and public land, and that did not have a gain or reduction in forest area over the approximately ten-year time span of forest measurements. Briefly, reserve status is a classification assigned to public lands where management for the production of forest products is permanently restricted through statute or mandate (USDA 2015). The analysis was further restricted to forested portions of FIA subplots to avoid inclusion of non-forest land uses such as cropland or development in our per acre values of forest attributes and growth and yield. Another condition was that the area occupied by all microplots of a plot was in forest land use.

We used standard quality control protocol to account for inconsistencies in the data. For example, trees that were initially inventoried but were later found to be incorrectly tallied were not included in the analysis. Trees that appeared in initial inventories (i.e., in time 1 and/or time 2) but did not occur in subsequent inventories (i.e., in time 2 or time 3) either as live, mortality, or cut trees were also excluded from the analysis. When the recorded species of an individual tree changed over time, the most recent species identification was used for all inventories for that tree. If the diameter and total height of individual trees in subsequent FIA inventories were less than at a previous census, then the most recent measurements were used for the previous inventories. Similarly, if the condition of a tree changed from dead to live in subsequent inventories, previous records were adjusted accordingly. These two protocols were also used for Ecological Reserve plot data.

Ecological Reserve Monitoring

Following the Ecological Reserve Monitoring Plan (Maine Department of Conservation 2003), forest attributes on Ecological Reserves were measured on five to six permanent sample plots per randomly established transect. Plots were spaced 792 ft (12 chains) apart along transects.

Baseline sampling (inventory round 1 hereafter) occurred between 2002 and 2008. Re-sampling of plots (round 2 hereafter) occurred from 2011 to 2017.Only Ecological Reserve plots sampled twice were considered in the analysis reported here (n = 547; Table 1).

Table 1. Number of remeasured plots in each Ecological Reserve.

Reserve	No. of plots
Appleton Bog	10
Big Spencer	30
Bigelow	48
Cutler	29
Deboullie	31
Debsconeags	91
Donnell Pond	18
Duck Lake	26
Gero Island	23
Great Duck Island	5
Great Heath	13
Kennebec Estuary Sites[1]	18
Mt. Abraham	32
Nahmakanta	50
Pine Barrens Sites[2]	19
Rocky Lake	10
Salmon Brook Lake	13
Spring River Lake	29
St. John Ponds	35
Wassataquoik	17
Total	547

1) Basin Preserve only
2) Waterboro Barrens Preserve only

Measurements of live and standing dead trees, downed woody debris, and tree age closely align with FIA protocol (Maine Department of Conservation 2003, USDA 2014). The nested plot design consisted of several subplots of varying sizes where species, dbh, height (on a subsample of trees) and condition (live or dead) of trees, saplings, and seedlings of different sizes were recorded as follows (Figure 2):

(1) 58.9 ft radius plot: all standing trees (live and dead) ≥ 20.1 in dbh with minimum length of 4.5 ft for standing dead trees
(2) 24 ft radius plot: all standing trees (live and dead) ≥ 5 in dbh with minimum length of 4.5 ft for standing dead trees
(3) 6.8 ft radius subplot: all live saplings (between 1 in and 5 in dbh) and all live seedlings less than 1 in dbh; the present analysis did not include trees < 5 in dbh.

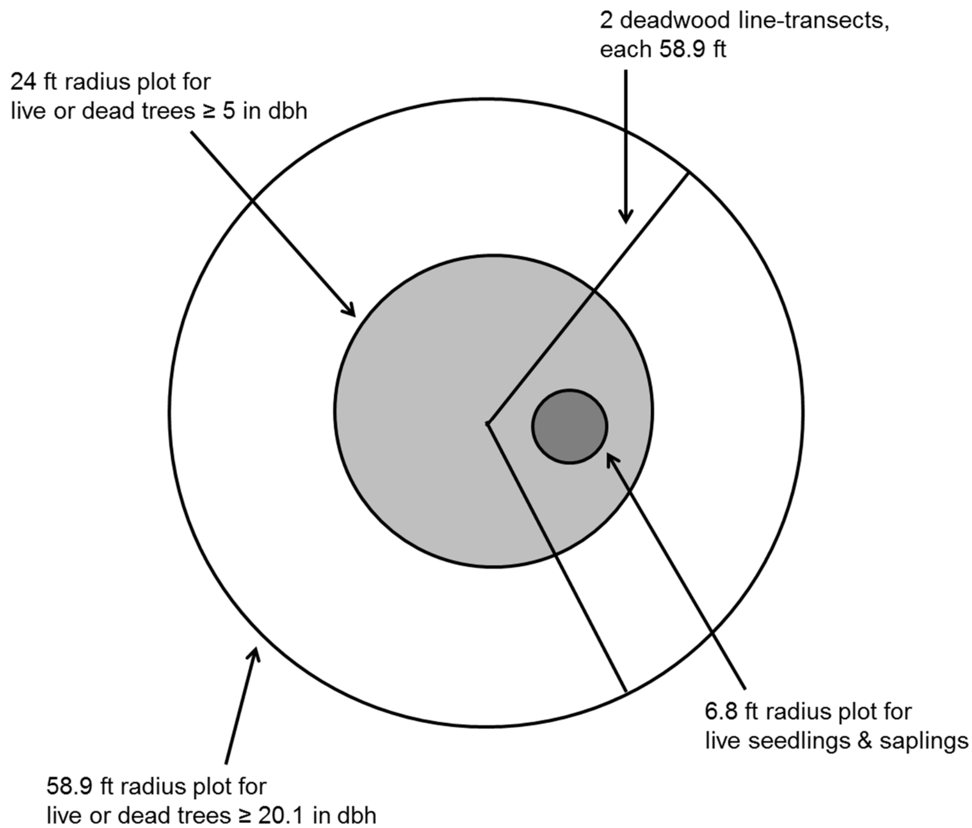

Figure 2. Ecological Reserve nested plot design.

Two transects for downed woody debris were sampled on every plot. Transects extended for 58.9 ft at 30° and 150° from plot center (Figure 2). The diameter of each downed woody debris piece ≥ 3 in in diameter at the transect intersect was measured. A standing dead tree was considered downed dead wood when the lean angle of its central bole was greater than 45° from vertical. For decay class 5 (i.e., the most decayed), pieces needed to be ≥ 5 in diameter where they crossed the transect to be included in the inventory.

To estimate canopy tree age, one tree located outside of each plot but representative of trees inside that plot was cored at breast height for state plots and at 1-ft height for TNC plots. The number of tree rings of each core was counted and species and dbh recorded. Years for growth to height of the core were not added. Only a small subsample of plots was remeasured for canopy tree age during round 2.

Each plot was assigned a primary Natural Community ('NCT' Type) (Gawler and Cutko 2010). Harvest history of each plot was determined by identifying signs of old stumps and skid trails suggesting past harvest activities. Information recorded included estimated time since last harvest in years as well as the potential type of harvest (partial cut, clearcut, etc.).

Data analysis

Metrics calculated at the plot level included:

(1) Mean canopy or site tree age, respectively (years)
(2) Live tree basal area (ft^2 ac^{-1})
(3) Large live trees (dbh ≥ 15.8 in) per acre (TPA, number ac^{-1})
(4) Very large (dbh ≥ 20.1 in) live TPA (number ac^{-1})
(5) Standing dead TPA (number ac^{-1})
(6) Large (dbh ≥ 15.8 in) standing dead TPA (number ac^{-1})
(7) Total downed woody debris volume (ft^3 ac^{-1})
(8) Large (diameter at transect intersect ≥ 15.8 in) downed woody debris volume (ft^3 ac^{-1})
(9) Annual gross growth rate including ingrowth (ft^3 ac^{-1} yr^{-1})
(10) Annual mortality rate (ft^3 ac^{-1} yr^{-1})
(11) Annual net growth rate including ingrowth (ft^3 ac^{-1} yr^{-1})
(12) Annual net change rate (ft^3 ac^{-1} yr^{-1}).

Calculation of live tree basal area and growth and yield metrics of Ecological Reserves were restricted to the 24 ft radius plots. Total and large downed woody debris volumes were quantified using Equation 2 from Woodall and Monlean (2008). All growth and yield metrics were annualized for purposes of comparison. Average annual mortality rate (M) included non-harvest tree mortality only. Average annual gross growth rate including ingrowth was calculated as annualized change in plot volume between time 1 (V1) and time 2 (V2) plus annual mortality plus annual harvest removals (C) (V2 + M + C - V1). Our metric only includes growth on trees that survived the inventory period, which is often called survivor growth; as opposed to accretion, which includes growth on trees that later died or were cut (Husch et al. 2002). Annual net growth rate including ingrowth was quantified as annualized change in plot volume between time 1 and time 2 plus annual harvest removal (V2 + C - V1). We also calculated average annual net change rate (also referred to annual net increase), which is the annualized change in plot volume between time 1 and time 2 (V2 - V1). Since no harvesting took place in Ecological Reserves, annual net growth rate and annual net change rate are the same for Ecological Reserve Monitoring plots.

Metrics were calculated by

(1) Program (Ecological Reserve Monitoring vs. FIA),
(2) Ecological Reserve,
(3) Round (1 vs. 2),
(4) Forest-type group (see below), and
(5) Ecological Reserve Monitoring plots of round 2 without any evidence of harvest activities (non-harvested ERM2 plots hereafter, see Appendix A).

The Natural Community Type recorded for each Ecological Reserve plot was used to define a FIA forest-type group (USDA 2015) for each Reserve plot. Specifically, Natural Community Types were assigned to the following FIA forest-type groups (groups 1-10 below):

(1) Spruce-Fir including
    - Black Spruce Woodland
    - Bluejoint Meadow
    - Spruce Flat
    - Maritime Spruce - Fir Forest
    - Red Spruce - Mixed Conifer Woodland
    - Spruce - Fir - Broom-moss Forest
    - Spruce - Fir - Wood-sorrel - Feather-moss Forest
    - Spruce Heath Barren
    - Spruce - Northern Hardwoods Forest
    - Spruce - Mixed Conifer Woodland
    - Spruce - Fir - Birch Krummholz
    - Spruce - Larch Wooded Bog
    - Spruce Talus Woodland
    - Fir - Heart-leaved Birch Subalpine Forest
    - Atlantic White Cedar Swamp
    - Cedar - Spruce Seepage Forest
    - Northern White Cedar Swamp

(2) Miscellaneous Softwoods including
    - Sheep Laurel Dwarf Shrub Bog

(3) Oak-Pine including
    - Oak - Pine Forest
    - Oak - Pine Woodland

(4) Oak-Hickory including
    - White Oak - Red Oak Forest
    - Red Oak - Northern Hardwoods - White Pine Forest

(5) Elm-Ash-Cottonwood including
- Hardwood River Terrace Forest
- Hardwood Seepage Forest
- Silver Maple Floodplain Forest
- Red Maple - Sensitive Fern Swamp
- Red Maple Wooded Fen

(6) Maple-Beech-Birch including
- Beech - Birch - Maple Forest
- Enriched Northern Hardwood Forest

(7) Aspen-Birch including
- Aspen - Birch Woodland/Forest Complex

(8) Minor Hardwoods including
- Alder Shrub Thicket
- Mixed Graminoid Shrub Marsh

(9) White Pine/Red Pine/Jack Pine including
- Acidic Cliff/Gorge
- Jack Pine Forest
- Jack Pine Woodland
- Red Pine - White Pine Forest
- Red Pine Woodland
- White Pine - Mixed Conifer Forest
- Hemlock Forest
- Hemlock - Hardwood Pocket Swamp.

(10) Loblolly/Shortleaf Pine including
- Pitch Pine Heath Barren
- Pitch Pine - Scrub Oak Barren
- Pitch Pine Rocky Woodland

For FIA subplots, the dominant forest-type group (based on plot area) for the most recent inventory was used to group subplots by forest type. FIA field crews recorded forest types based on the area around subplots and trees sampled on subplots (USDA 2015).

For mortality and trees that were cut between the FIA inventory periods, the last live tree diameter was used to compute tree volume. For the Ecological Reserve plots, height-diameter equations of the Northeast (NE) Variant of the Forest Vegetation Simulator (Dixon and Keyser 2008) were used to predict and impute missing tree heights. This methodology was also used to predict the heights of trees < 5.0 in dbh on FIA plots (Appendix D, Tables 3 and 4); measured heights for trees ≥ 5.0 in were available for trees on subplots. In addition, Honer's (1967) total volume equation was used to estimate stem volume for both programs.

Mixed effects modeling was used to evaluate the influence of program (i.e., Ecological Reserve Monitoring or FIA), inventory round (1 or 2 for Ecological Reserve Monitoring plots, ERM1 and ERM2 hereafter) and forest-type group on the studied metrics. Plots (on transects within Ecological Reserves) were considered the experimental units for the Ecological Reserve Monitoring program and subplots (within plots within counties of the state of Maine) were considered the experimental units for the FIA program. Consequently, the experimental units of both programs were the same size (circular plots with a radius of 24 ft) with the exception of a larger plot size (radius of 58.9 ft) for measuring trees ≥ 20.1 in dbh on the Ecological Reserves (Figure 2). In addition, transects (or plots for the FIA program) within reserves (or Maine's counties for the FIA program) were used as random effects to account for the nested design and correlation structure of the data in both datasets.

With the exception of canopy tree age (or site tree age for the FIA program), net growth including ingrowth, and net change, the data for most metrics comprised a large number of zeros. Conventional parametric statistical approaches cannot analyze such data distributions properly. Therefore, a two-step or hurdle modeling approach was applied that evaluated the zero portion of the data in a first step and subsequently analyzed the non-zero part in a second step. Using transformed binomial data (0/1 for no/yes), the first modeling step predicted the probability of occurrence of, for example, downed woody debris on a certain plot on an absence/presence level (Zuur et al. 2009). Using presence data only by excluding zeros, the second modeling step predicted the amount of e.g. downed woody debris on a certain plot. Models were derived using generalized linear mixed-effects models with a binomial and Gamma error structure for modeling steps 1 and 2, respectively, to account for the underlying dataset characteristics in each step and the function glmmPQL of the package MASS (Ripley et al. 2017) in R (version 3.3.1; R Core Team 2016). In contrast, log transformed canopy tree age (or site tree age for the FIA program), net growth including ingrowth, and net change were evaluated using a mixed effect ANOVA approach and the function lme of the R package nlme (Pinheiro et al 2017). Separate metric-specific models were developed using round (ERM1 vs. ERM2) and program (ERM2 vs. FIA) with forest-type group as an additional predictor variable in both approaches. If a predictor variable of interest (e.g., program, round, or forest-type group) was statistically significant in either one or both modeling steps of the hurdle model approach, the variable was assumed to be influential on the response variable.

In order to assess sampling accuracy of the Ecological Reserve Monitoring data, we evaluated the sampling error of each studied metric (Iles 2003). This analysis was based on the 1103 inventory round 1 plots to account for the entirety of Maine's Ecological Reserve system. Sampling errors were calculated for all plots and by Ecological Reserve and forest-type group.

Results

Forest-type groups

Differences between the relative percentage of forest-type groups for the unmanaged Ecological Reserves and Maine's managed forests (based on Forest Inventory and Analysis data, FIA) were minor (Table 2). For both programs (Ecological Reserve Monitoring and FIA), spruce-fir and maple-beech-birch were the most frequent forest-type groups comprising about 75% of all experimental units. Besides oak-pine and white-red-jack pine forest-type groups, other forest-type groups were less common, on average, across managed forests than Ecological Reserves.

Table 2. Relative percentage of major forest-type groups by program (Ecological Reserve Monitoring and Forest Inventory and Analysis) based on the number of experimental units (plots or subplots depending on the program) used in this study.

Major Forest-Type group (MFTYP)	Ecological Reserves %	(# of plots)	Forest Inventory and Analysis %	(# of subplots)
Aspen-White Birch	7	(39)	7	(746)
Elm-Ash-Cottonwood	3	(19)	2	(223)
Maple-Beech-Birch	19	(103)	31	(3,287)
Minor Hardwoods	1	(8)	0	(0)
Miscellaneous Softwoods	0	(1)	0	(17)[1)]
Oak-Hickory	3	(16)	1	(119)
Oak-Pine	2	(9)	4	(370)
Pitch Pine[2)]	3	(16)	0	(0)
Spruce-Fir	58	(315)	46	(4,812)
White-Red-Jack Pine	4	(21)	9	(929)
Total	100	(547)	100	(10,503)

[1)] includes Eastern redcedar and exotic softwood forest types
[2)] refers to FIA's Loblolly-Shortleaf Pine forest-type group

Stand-level metrics

Results are presented across all forest-type groups and for the two most common forest-type groups, namely maple-beech-birch and spruce-fir (Table 2). Descriptive statistics for all forest-type groups by program and Ecological Reserve can be found in the appendices. While not specifically addressed further hereafter, forest-type group was an influential predictor variable in all evaluated models suggesting significant differences between dominant forest types for all studied forest attributes.

Mean site tree age for FIA subplots (52 years) was significantly lower than mean canopy tree age for ERM2 plots (89 years, $P < 0.0001$). Non-harvested ERM2 plots had a slightly higher mean canopy tree age (93 years). Similar patterns were found for the dominant forest-type groups (Figure 3). Site trees of FIA spruce-fir plots were on average 10 years younger than site trees on FIA maple-beech-birch plots while canopy trees of EMR2 spruce-fir plots were 7 years older than their maple-beech-birch counterparts (Appendix C Table 2, Appendix D Table 2).

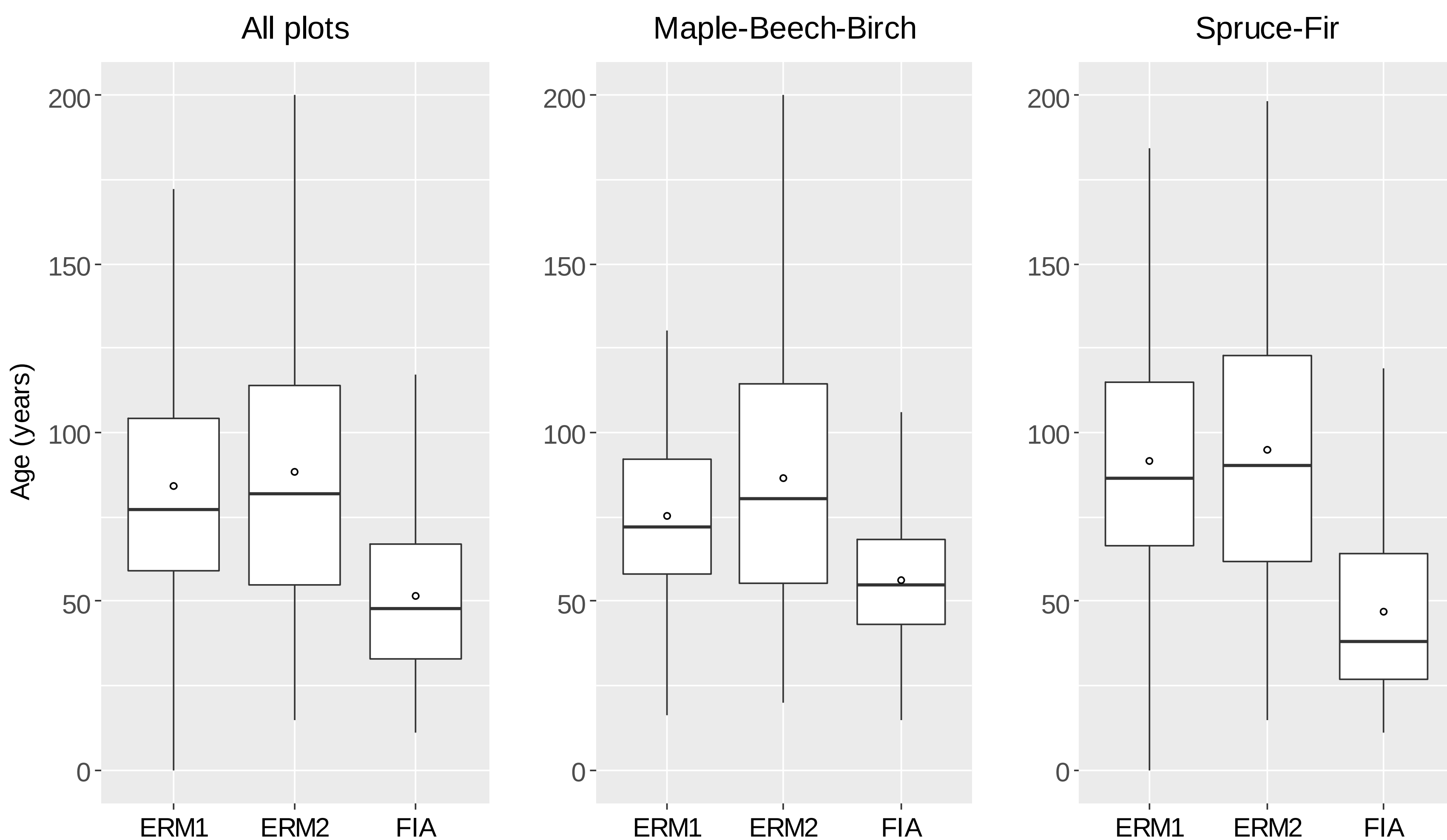

Figure 3. Canopy tree age (years) of inventory round 1 (ERM1) and round 2 Ecological Reserve Monitoring plots (ERM2) and site tree age (years) of Forest Inventory and Analysis (FIA) subplots on managed forestland in Maine. Horizontal lines and empty circles represent the median and the mean, respectively. The boxes define the interquartile range (25-75% quartile) and the vertical lines represent the whiskers of maximal 1.5 times the interquartile range. Observations outside the whisker range which may be considered to be outliers are not depicted.

Average live tree basal area was significantly lower for FIA subplots (76 ft^2 ac^{-1}) compared to ERM2 plots (124 ft^2 ac^{-1}, modeling step 1 & 2: $P < 0.0001$). Non-harvested ERM2 plots had a slightly lower mean (122 ft^2 ac^{-1}). The difference in mean basal area between EMR1 (112 ft^2 ac^{-1}) and EMR2 plots was statistically significant (modeling step 1: $P < 0.0001$ & modeling step 2: 0.0025, Appendix B Table 1, Appendix C Table 1). Similar patterns with only minor deviations from the overall means were found for the dominant forest-type groups (Figure 4). Irrespective of program and Round, spruce-fir plots always exhibited higher mean basal area values than their respective maple-beech-birch counterparts (Appendix C Table 2, Appendix D Table 2).

Mean number of large (dbh ≥ 15.8 in) live trees per acre (TPA) was significantly lower for FIA subplots (5.7 ac^{-1}) compared to ERM2 plots (14.7 ac^{-1}, modeling step 1: $P < 0.0001$ & modeling step 2: $P = 0.0073$). Non-harvested ERM2 plots exhibited a lower mean (13.7 ac^{-1}). The increase in average live large tree density in Ecological Reserve plots from round 1 (11.3 ac^{-1}) to round 2 was statistically significant (modeling step 1: $P = 0.0040$ & modeling step 2: P = 0.0472, Appendix B Table 1, Appendix C Table 1). Similar patterns were found for the dominant forest-type groups (Figure 5). However, the difference between EMR1 and EMR2 maple-beech-birch plots was not statistically significant. Maple-beech-birch plots exhibited a substantially higher number of large live TPA compared to spruce-fir plots (Appendix C Table 2, Appendix D Table 2).

Mean number of very large (dbh ≥ 20.1 in) live (TPA) was significantly lower for FIA subplots (1.43 ac^{-1}) compared to ERM2 plots (2.69 ac^{-1}, modeling step 1 & 2: $P < 0.0001$). Non-harvested ERM2 plots had a slightly higher mean (2.72 ac^{-1}). The increase in average very large live TPA on Ecological Reserve Monitoring plots from round 1 (2.08 ac^{-1}) to round 2 was statistically significant (modeling step 1: $P = 0.0251$ & modeling step 2: $P = 0.0308$, Appendix B Table 1, Appendix C Table 1). Similar patterns were found for the dominant forest-type groups with the exception of non-harvested ERM2 spruce-fir plots where the number of very large live TPA was lower compared to all ERM2 spruce-fir plots. Irrespective of program and round, maple-beech-birch plots contained twice as many very large trees compared to spruce-fir plots on average (Appendix B Table 2, Appendix C Table 2, Appendix D Table 2).

Average number of standing dead TPA was significantly lower on FIA subplots (22 ac^{-1}) compared to ERM2 plots (40 ac^{-1}, modeling step 1: $P < 0.0001$ & modeling step 2: $P = 0.0363$). Non-harvested ERM2 plots had a slightly higher mean (42 ac^{-1}). The decrease in average snag density of Ecological Reserve plots from round 1 (42 ac^{-1}) to round 2 was not statistically significant (modeling step 1: $P = 0.3286$ & modeling step 2: $P = 0.5458$, Appendix B Table 1, Appendix C Table 1). Similar patterns were found for the dominant forest-type groups with the exception of non-harvested EMR2 spruce-fir plots having a lower number of standing dead TPA than all ERM2 spruce-fir plots (Figure 6). Irrespective of program and round, spruce-fir plots exhibited a higher number of snags compared to maple-beech-birch plots on average (Appendix B Table 2, Appendix C Table 2, Appendix D Table 2).

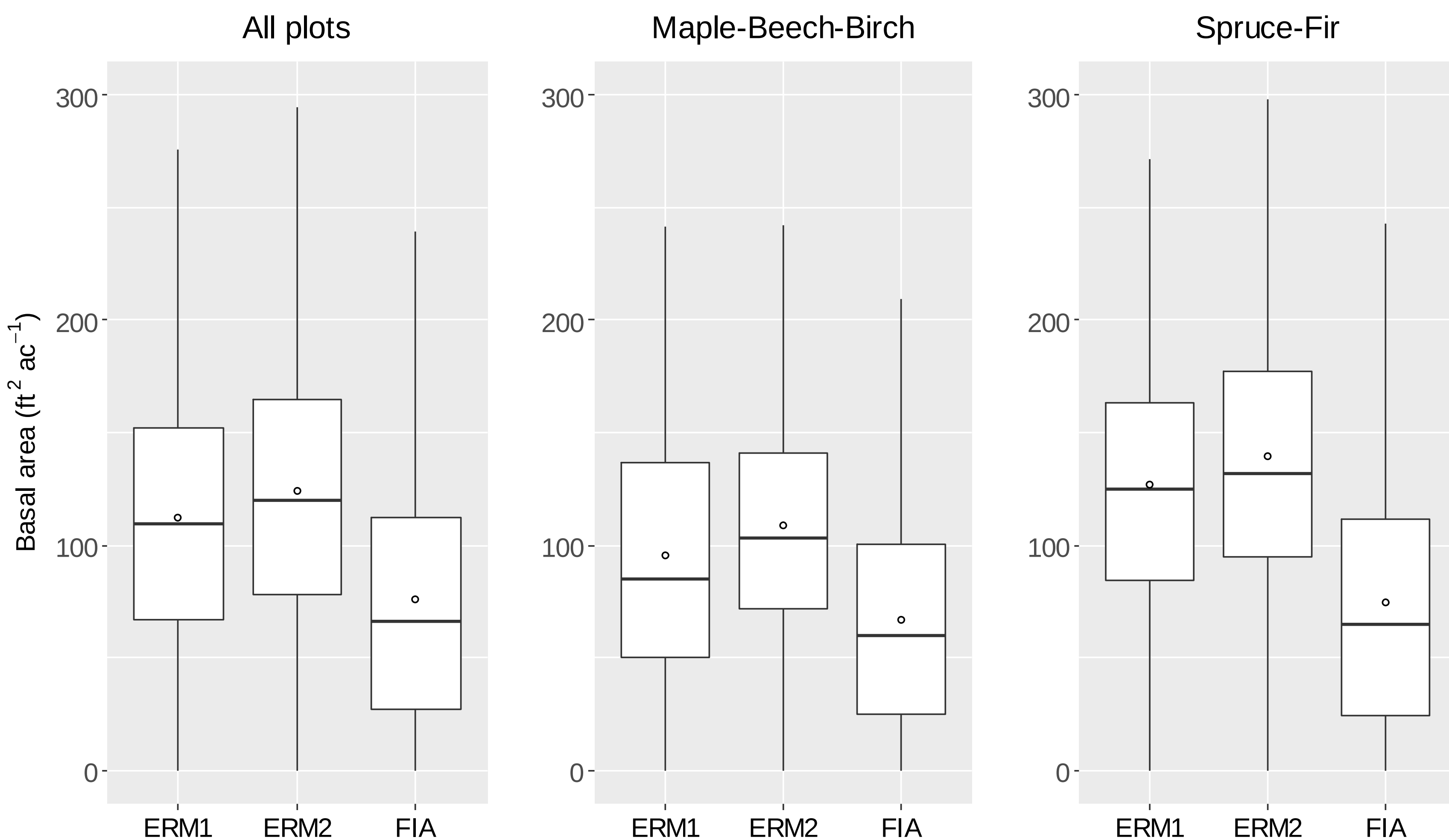

Figure 4. Live tree basal area (ft^2 ac^{-1}) of inventory round 1 (ERM1) and round 2 Ecological Reserve Monitoring plots (ERM2), and Forest Inventory and Analysis (FIA) subplots on managed forestland in Maine. Horizontal lines and empty circles represent the median and the mean, respectively. The boxes define the interquartile range (25-75% quartile) and the vertical lines represent the whiskers of maximal 1.5 times the interquartile range. Observations outside the whisker range which may be considered to be outliers are not depicted.

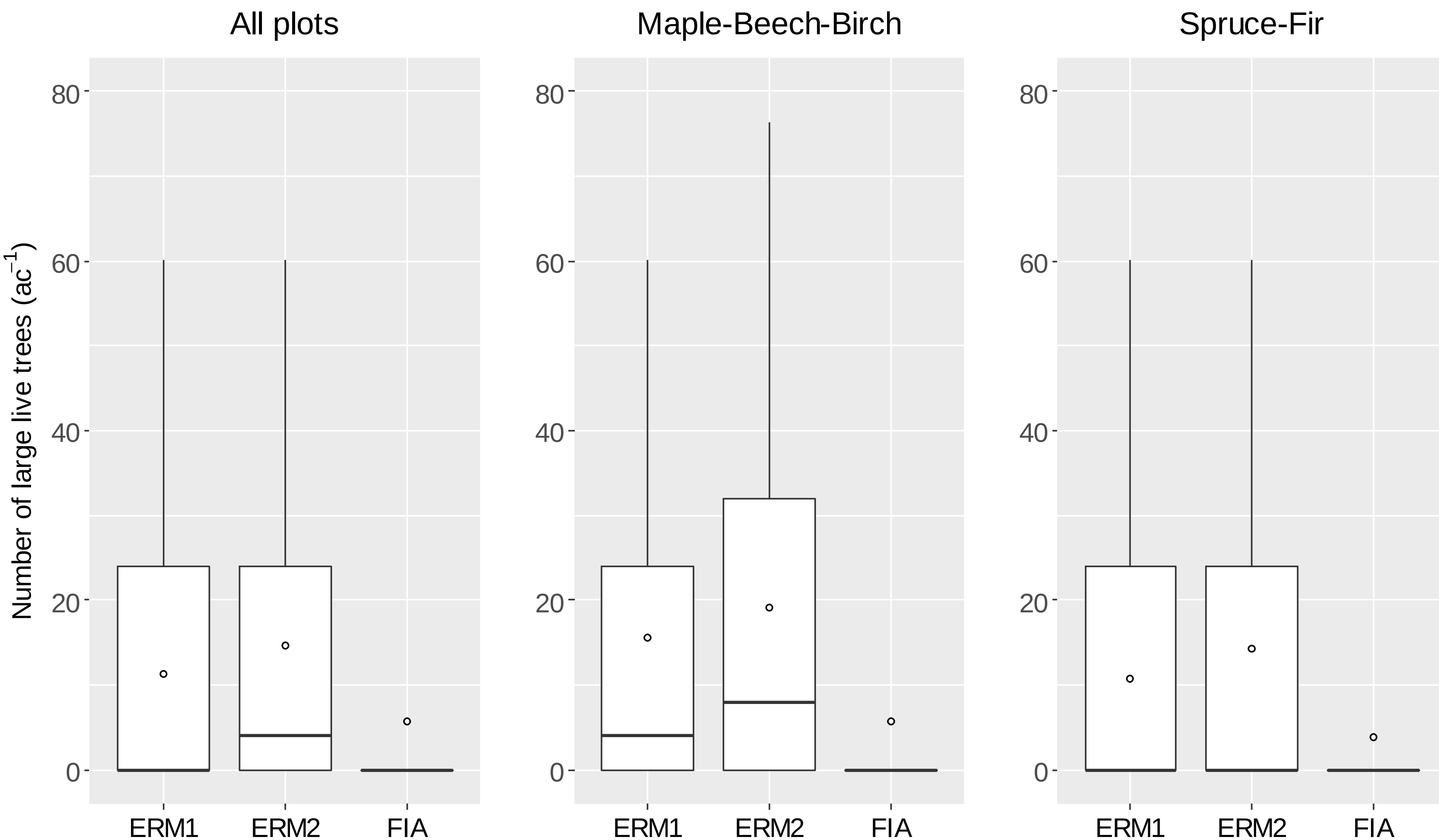

Figure 5. Number of large (dbh ≥ 15.8 in) live trees per acre of inventory round 1 (ERM1) and round 2 Ecological Reserve Monitoring plots (ERM2), non-harvested Ecological Reserve Monitoring plots of round 2 (ERM2 no harvest) and Forest Inventory and Analysis (FIA) subplots on managed forestland in Maine. Horizontal lines and empty circles represent the median and the mean, respectively. The boxes define the interquartile range (25-75% quartile) and the vertical lines represent the whiskers of maximal 1.5 times the interquartile range. Observations outside the whisker range which may be considered to be outliers are not depicted.

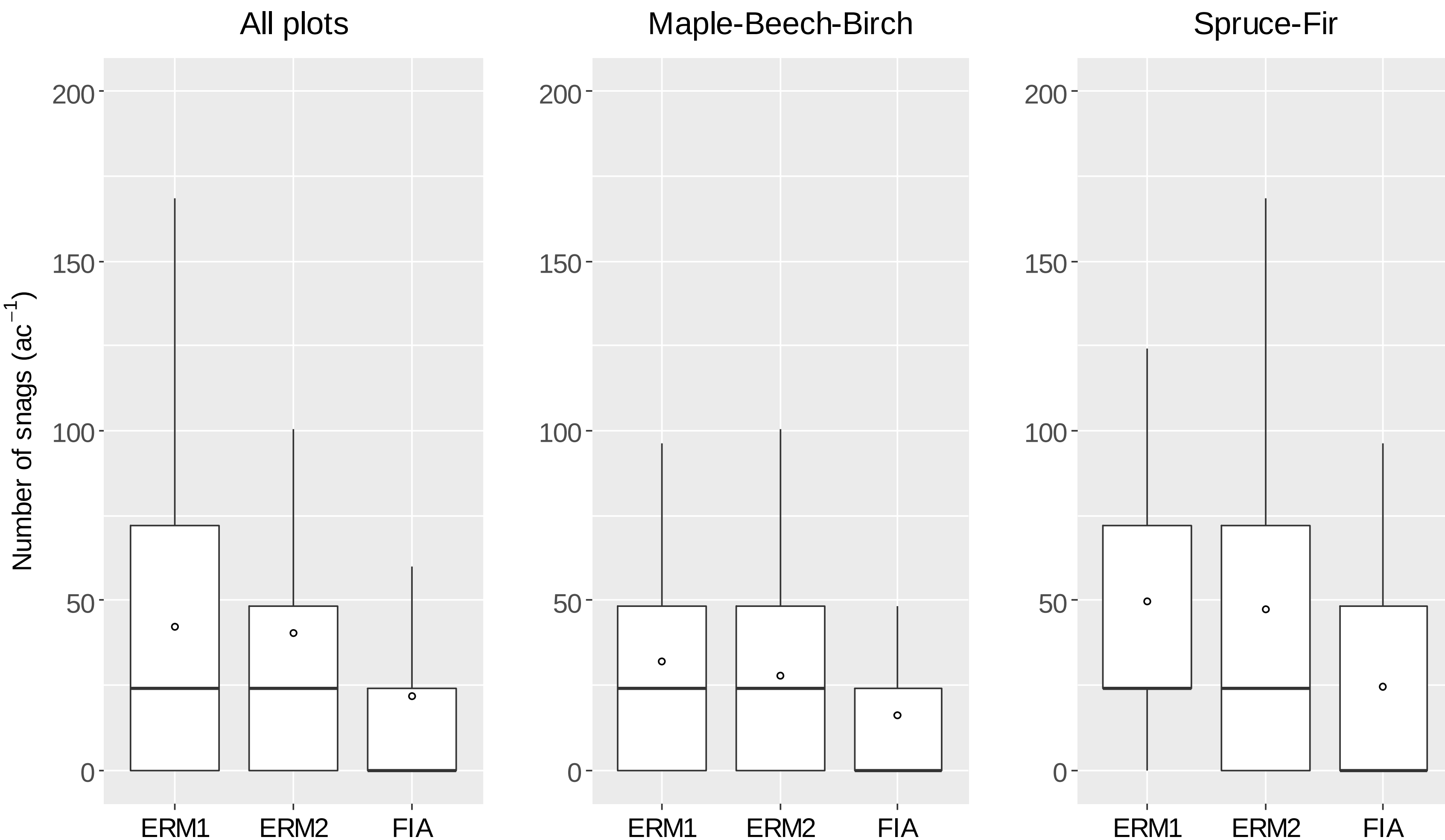

Figure 6. Number of standing dead trees per acre of inventory round 1 (ERM1) and round 2 Ecological Reserve Monitoring plots (ERM2), and Forest Inventory and Analysis (FIA) subplots on managed forestland in Maine. Horizontal lines and empty circles represent the median and the mean, respectively. The boxes define the interquartile range (25-75% quartile) and the vertical lines represent the whiskers of maximal 1.5 times the interquartile range. Observations outside the whisker range which may be considered to be outliers are not depicted.

Mean large (dbh ≥ 15.8) standing dead TPA was significantly lower on FIA subplots (0.70 ac^{-1}) compared to ERM2 plots (1.33 ac^{-1}, modeling step 1: $P = 0.0001$ & modeling step 2: $P < 0.0001$). Non-harvested ERM2 plots exhibited a lower mean (0.99 ac^{-1}). The increase in average large snag density of Ecological Reserve plots from round 1 (1.24 ac^{-1}) to round 2 was not statistically significant (modeling step 1: $P = 0.6269$ & modeling step 2: $P = 0.3992$, Appendix B Table 1, Appendix C Table 1). Similar patterns were found for the dominant forest-type groups with the exception of EMR2 spruce-fir plots exhibiting no difference in large dead TPA compared to EMR1 spruce-fir plots. Irrespective of program and round, maple-beech-birch plots always exhibited a higher number of large snags compared to spruce-fir plots on average (Appendix B Table 2, Appendix C Table 2, Appendix D Table 2).

Total downed woody debris volume on FIA subplots (557 ft^3 ac^{-1}) was significantly lower compared to ERM2 plots (644 ft^3 ac^{-1}, modeling step 1: $P < 0.000$ & modeling step 2: $P = 0.2194$). Non-harvested ERM2 plots had a higher mean (708 ft^3 ac^{-1}). The observed decrease in downed woody debris volume of Ecological Reserve Monitoring plots from round 1 (684 ft^3 ac^{-1}) to round 2 was not statistically significant (modeling step 1: $P = 0.8056$ & modeling step 2: $P < 0.3871$, Figure 7, Appendix B Table 1, Appendix C Table 1). Similar patterns were found for the dominant forest-type groups (Appendix B Table 2, Appendix C Table 2, Appendix D Table 2).

Large (diameter ≥ 15.75 in) downed woody debris volume on FIA subplots (26 ft^3 ac^{-1}) was significantly lower compared to ERM2 plots (70 ft^3 ac^{-1}, modeling step 1: $P = 0.0039$ & modeling step 2: $P = 0.2947$). Non-harvested ERM2 plots exhibited a higher mean (75 ft^3 ac^{-1}). The observed increase in large downed woody debris volume of Ecological Reserve Monitoring plots from round 1 (65 ft^3 ac^{-1}) to round 2 was not statistically significant (modeling step 1: $P = 0.2529$ & modeling step 2: $P = 0.1642$, Appendix B Table 1, Appendix C Table 1). Similar patterns were found for the dominant forest-type groups with the exception of large downed woody debris volume of FIA maple-beech-birch subplots not being statistically significant to EMR2 maple-beech-birch plots (Appendix B Table 2, Appendix C Table 2, Appendix D Table 2). Irrespective of program and round, maple-beech-birch plots always exhibited higher large woody debris volumes compared to spruce-fir plots on average.

Average annual gross growth including ingrowth of FIA subplots (69 ft^3 ac^{-1} yr^{-1}) was significantly lower compared to Ecological Reserve Monitoring plots (75 ft^3 ac^{-1} yr^{-1}, modeling step 1: $P = 0.4128$ & modeling step 2: $P < 0.0000$). Non-harvested Ecological Reserve Monitoring plots exhibited a comparable mean (73 ft^3 ac^{-1} yr^{-1}). Similar patterns were observed for the dominant forest-type groups but gross growth rates of FIA maple-beech-birch subplots did not significantly differ from gross growth rates of Ecological Reserve maple-beech-birch plots (Figure 8). Irrespective of program, average gross growth rate of maple-beech-birch plots was lower compared to spruce-fir plots (Appendix B Table 2, Appendix C Table 2, Appendix D Table 2).

Average annual mortality of FIA subplots (18 ft^3 ac^{-1} yr^{-1}) was significantly lower compared to Ecological Reserve Monitoring plots (32 ft^3 ac^{-1} yr^{-1}, modeling step 1: $P < 0.000$ & modeling step 2: $P = 0.7935$). Non-harvested Ecological Reserve Monitoring plots had a slightly higher mean (34 ft^3 ac^{-1} yr^{-1}). Similar patterns were observed for the dominant forest-type groups but mortality rates of FIA maple-beech-birch subplots did not significantly differ from mortality rates of Ecological Reserve maple-beech-birch plots (Figure 9). Compared to spruce-fir plots, mortality rates of maple-beech-birch plots were lower in Ecological Reserves but slightly higher for the FIA program (Appendix B Table 2, Appendix C Table 2, Appendix D Table 2).

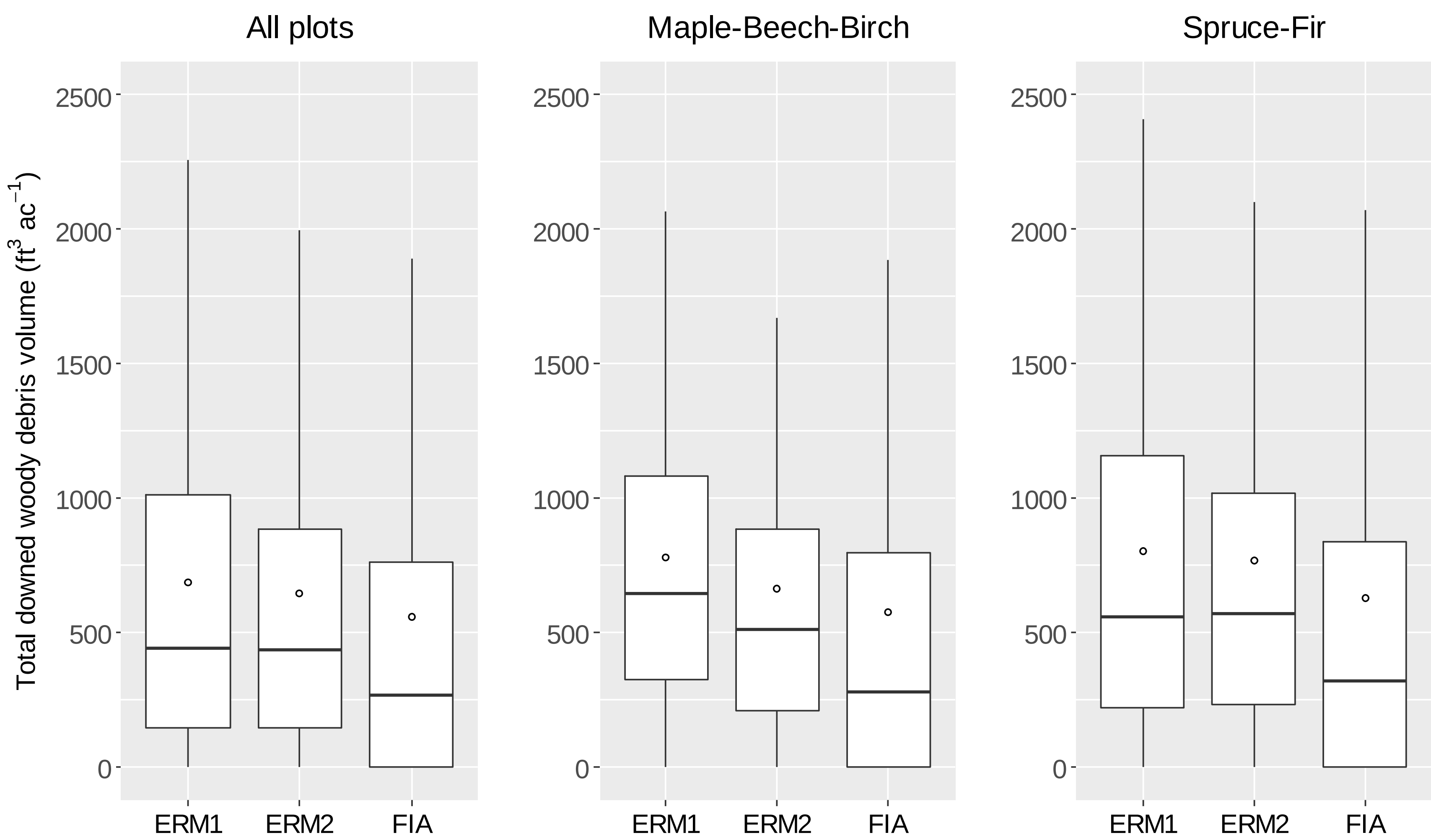

Figure 7. Total downed woody debris volume (ft^3 ac^{-1}) of inventory round 1 (ERM1) and round 2 Ecological Reserve Monitoring plots (ERM2), and Forest Inventory and Analysis (FIA) subplots on managed forestland in Maine. Horizontal lines and empty circles represent the median and the mean, respectively. The boxes define the interquartile range (25-75% quartile) and the vertical lines represent the whiskers of maximal 1.5 times the interquartile range. Observations outside the whisker range which may be considered to be outliers are not depicted.

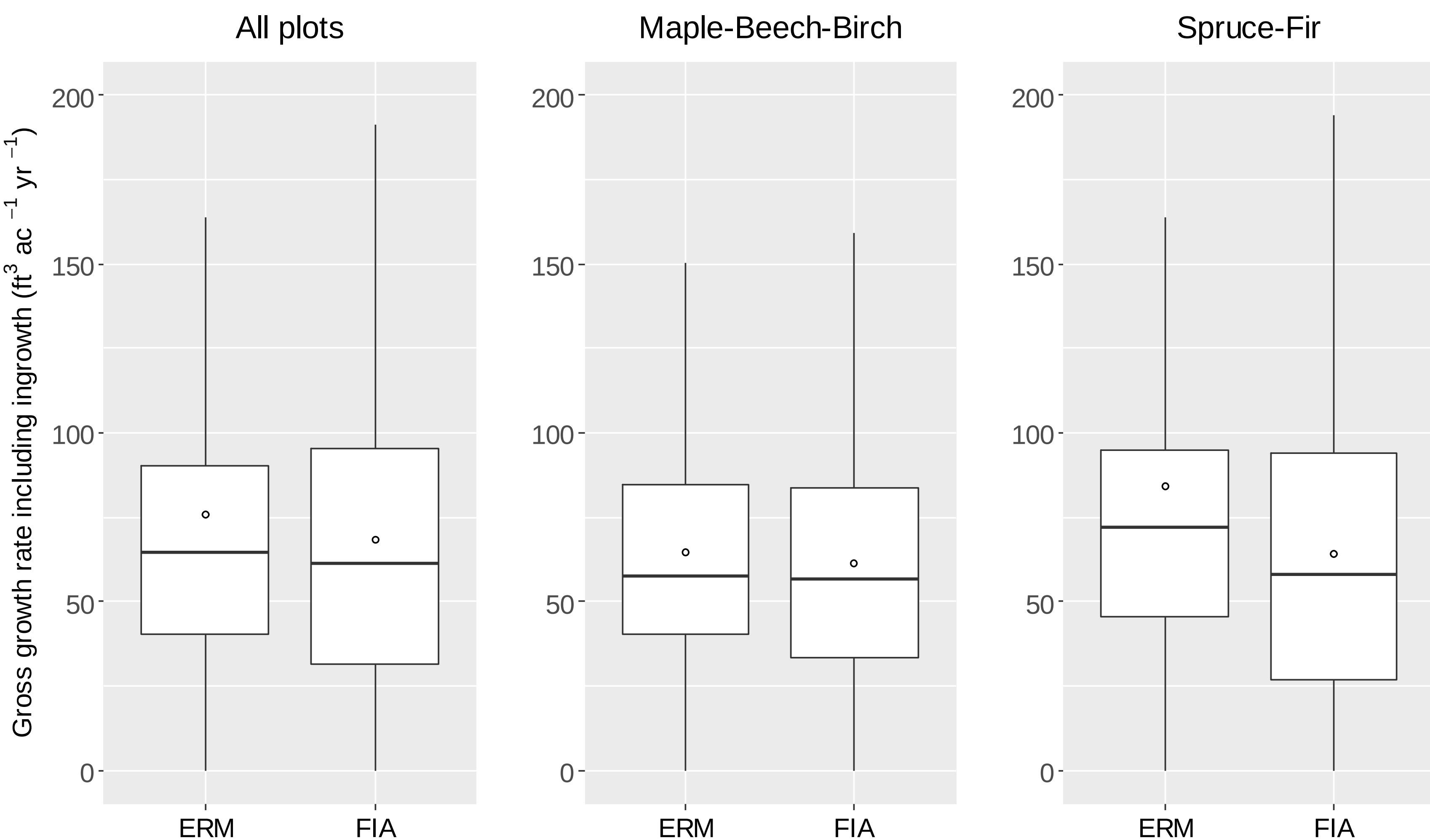

Figure 8. Annual gross growth rates including ingrowth (ft^3 ac^{-1} yr^{-1}) of Ecological Reserve Monitoring plots (ERM) and Forest Inventory and Analysis (FIA) subplots on managed forestland in Maine. Horizontal lines and empty circles represent the median and the mean, respectively. The boxes define the interquartile range (25-75% quartile) and the vertical lines represent the whiskers of maximal 1.5 times the interquartile range. Observations outside the whisker range which may be considered to be outliers are not depicted.

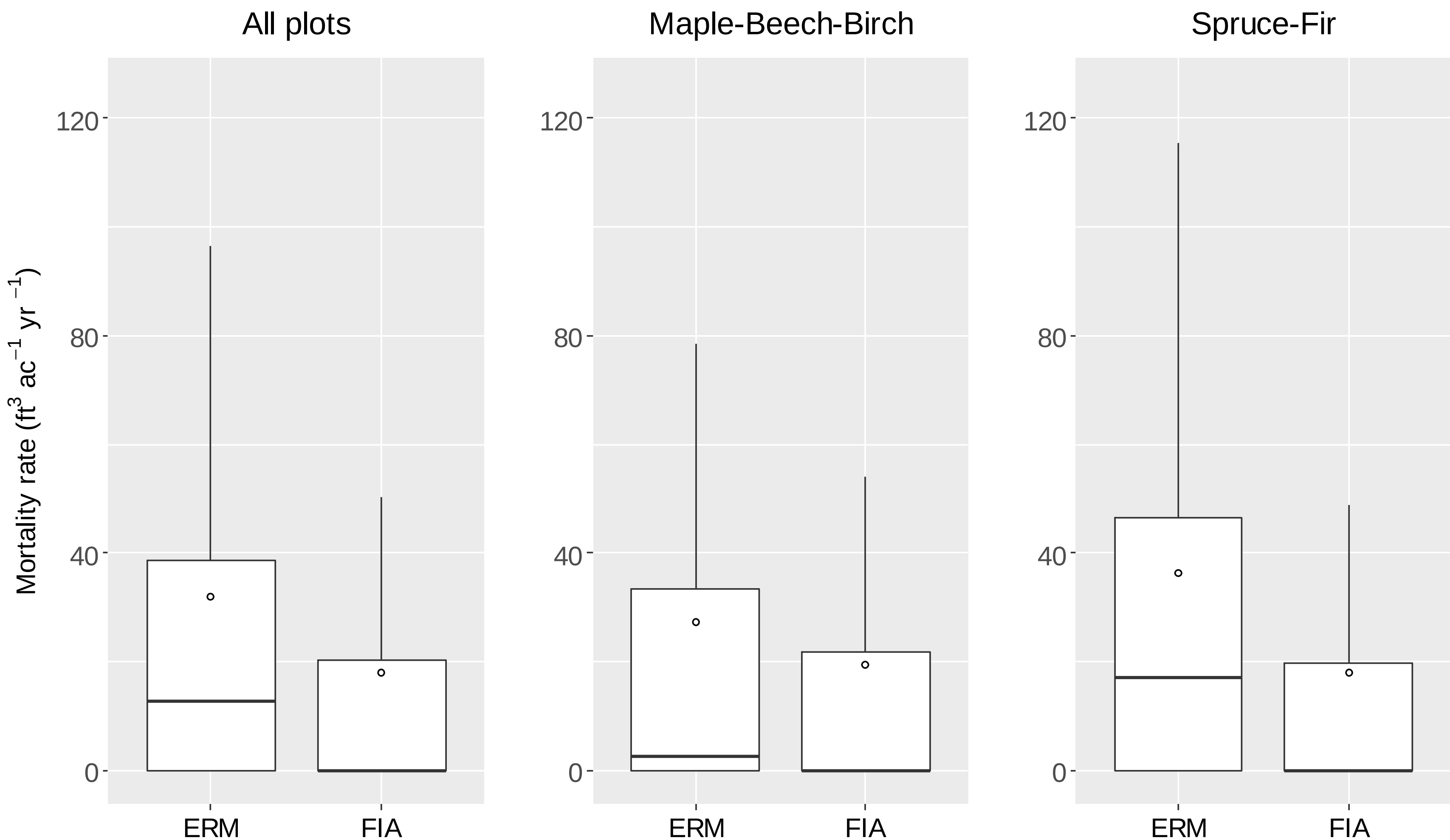

Figure 9. Annual non-harvest mortality rates ($ft^3\ ac^{-1}\ yr^{-1}$) of Ecological Reserve Monitoring plots (ERM) and Inventory and Analysis (FIA) subplots on managed forestland in Maine. Horizontal lines and empty circles represent the median and the mean, respectively. The boxes define the interquartile range (25-75% quartile) and the vertical lines represent the whiskers of maximal 1.5 times the interquartile range. Observations outside the whisker range which may be considered to be outliers are not depicted.

Average annual net growth rate was higher for FIA subplots (50 ft^3 ac^{-1} yr^{-1}) compared to Ecological Reserve Monitoring plots (44 ft^3 ac^{-1} yr^{-1}). However, the difference was not statistically significant (P = 0.2070). Non-harvested Ecological Reserve Monitoring plots exhibited a comparable mean (39 ft^3 ac^{-1} yr^{-1}). While FIA maple-beech-birch subplots also exhibited a higher net growth rate compared to Ecological Reserve plots of the same forest-type group, a contrary pattern was found for the spruce-fir forest-type group (Figure 10). The observed differences between the two programs also were not significant for the dominant forest-type groups.

Average annual net change of FIA subplots (18 ft^3 ac^{-1} yr^{-1}) was significantly lower compared to Ecological Reserve plots (44 ft^3 ac^{-1} yr^{-1}, P = 0.0399). Non-harvested Ecological Reserve Monitoring plots exhibited a comparable mean (39 ft^3 ac^{-1} yr^{-1}). Similar patterns were found for the dominant forest-type groups but net change rates of FIA maple-beech-birch subplots did not significantly differ from net change rates of Ecological Reserve maple-beech-birch plots (Figure 11). Irrespective of program, average net change rate of maple-beech-birch plots was lower compared to spruce-fir plots (Appendix B Table 2, Appendix C Table 2, Appendix D Table 2).

A summary of all results is presented in Table 3.

Table 3. Overview of statistical comparisons of metrics between Ecological Reserve Monitoring plots of inventory round 1 (ERM1) and round 2 (ERM2) as well as between Forest and Analysis Program (FIA) subplots on managed forestland in Maine and ERM2 plots. Triangles pointing up represent lower means for ERM1 plots compared to ERM2 plots and for FIA subplots compared to EMR2 plots, respectively. Triangles pointing down represent higher means for ERM1 plots compared to ERM2 plots. A dash represents no difference between ERM1 plots and ERM2 plots. Grey background coloring depicts statistical significance.

	ERM2 vs ERM1			ERM2 vs FIA		
	All plots	Maple-Beech-Birch	Spruce-Fir	All plots	Maple-Beech-Birch	Spruce-Fir
Tree age				▲	▲	▲
Live basal area	▲	▲	▲	▲	▲	▲
Large TPA	▲	▲	▲	▲	▲	▲
Very large TPA	▲	▲	▲	▲	▲	▲
Snag density	▼	▼	▼	▲	▲	▲
Large snag density	▲	▲	—	▲	▲	▲
Total CWD Vol	▼	▼	▲	▲	▲	▲
Large CWD Vol	▲	▼	▲	▲	▲	▲
Gross growth rate				▲	▲	▲
Mortality rate				▲	▲	▲
Net growth rate				▼	▼	▲
Net change rate				▲	▲	▲

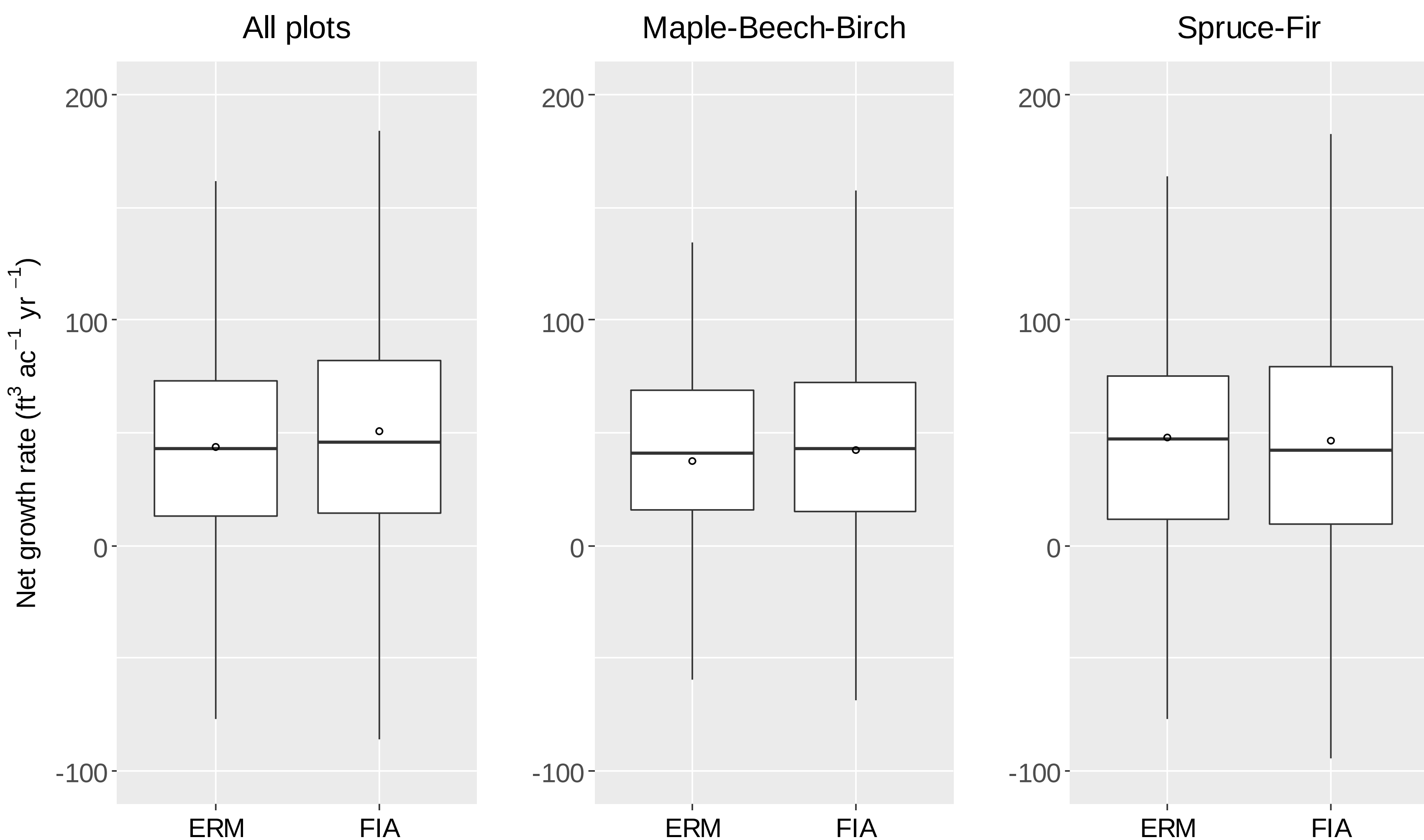

Figure 10. Annual net growth rates (ft^3 ac^{-1} yr^{-1}) of Ecological Reserve Monitoring plots (ERM) and Forest Inventory and Analysis (FIA) subplots on managed forestland in Maine. Horizontal lines and empty circles represent the median and the mean, respectively. The boxes define the interquartile range (25-75% quartile) and the vertical lines represent the whiskers of maximal 1.5 times the interquartile range. Observations outside the whisker range which may be considered to be outliers are not depicted.

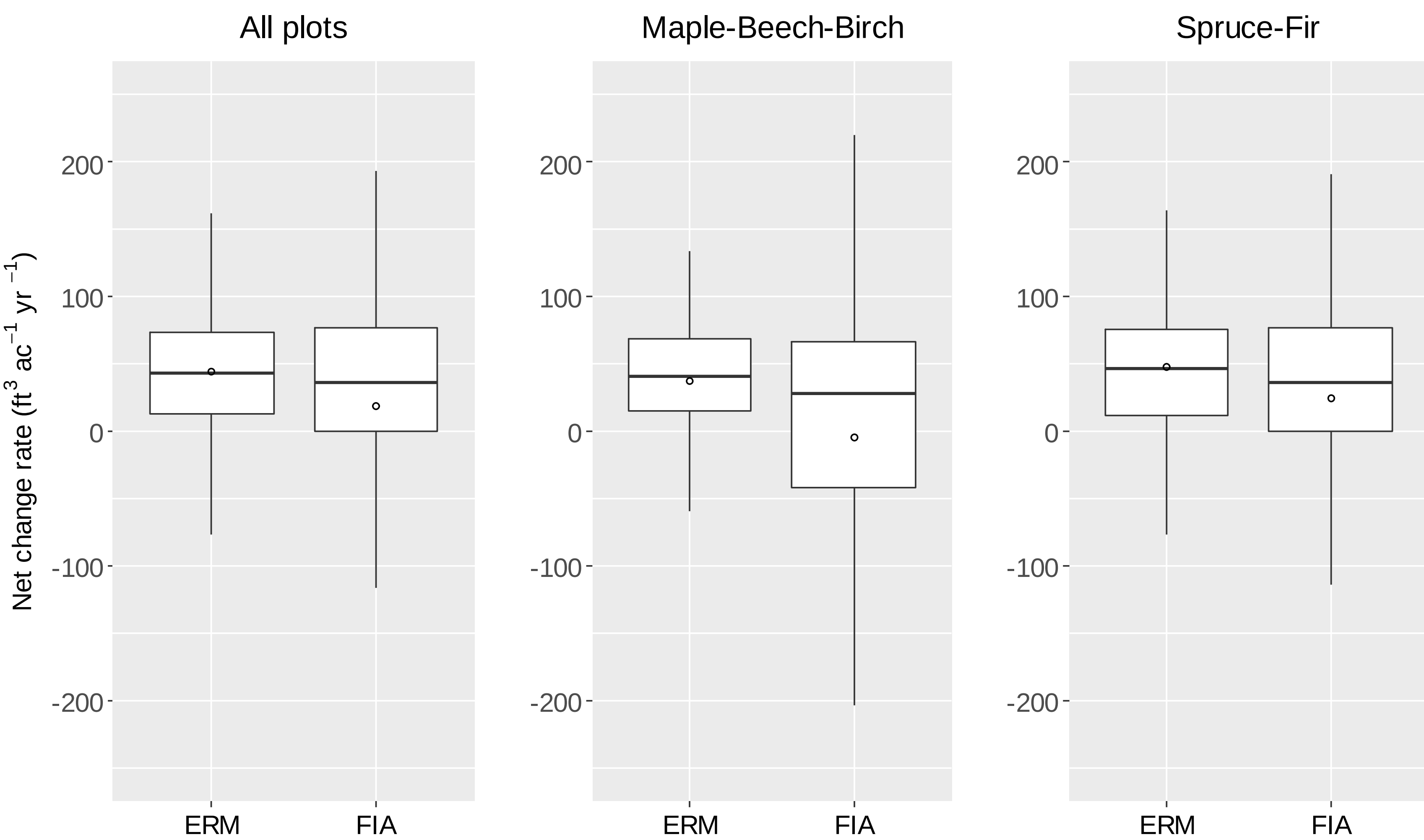

Figure 11. Annual net change rates ($ft^3\ ac^{-1}\ yr^{-1}$) of Ecological Reserve Monitoring plots (ERM) and Forest Inventory and Analysis (FIA) subplots on managed forestland in Maine. Horizontal lines and empty circles represent the median and the mean, respectively. The boxes define the interquartile range (25-75% quartile) and the vertical lines represent the whiskers of maximal 1.5 times the interquartile range. Observations outside the whisker range which may be considered to be outliers are not depicted.

Sampling accuracy

For the Ecological Reserve Monitoring program, sampling accuracy was quantified using percent sampling error which varied by metric and type of plots evaluated (Table 4). Percent sampling error was equal or lower than 15% for basal area and total woody debris volume, irrespective of forest-type group. Metrics associated with higher intrinsic natural variation such as number of large snags and large woody debris volume exhibited much greater percent sampling errors. Percent sampling errors higher than 15% were found for most individual Ecological Reserves irrespective of the evaluated metric.

Table 4. Percent sampling error as a measure of sampling accuracy of total downed woody debris (total CWD) volume, very large (dbh ≥ 20.1 in) live trees per acre (TPA), and large (dbh ≥ 15.8 in) standing dead TPA based on the 1103 Ecological Reserve Monitoring (ERM) plots of inventory round 1. Numbers provided for individual Ecological Reserves represent mean percent sampling error (and range across all Ecological Reserves).

	Basal area	Total CWD volume	Very large TPA	Large dead TPA
All ERM plots	4	7	13	28
Individual reserves	30 (9-99)	58 (14-201)	69 (0-236)	118 (0-278)
Maple-Beech-Birch	10	15	23	52
Spruce-Fir	5	9	19	39

Discussion and conclusions

These analyses represent the first systematic assessment of forest attributes on the Maine Ecological Reserves using inventory data collected since their establishment. Several key conclusions are evident:

1. Although the Ecological Reserves included in this study occupy only about 2% of Maine's landscape, the forest composition of Ecological Reserve plots reflects the distribution of forest types across Maine's forest landscape. This result supports the validity of overall comparisons between Reserves and Maine's managed forests.

2. Multiple metrics of forest structure suggest greater stand complexity on Ecological Reserves than managed forestland in Maine. This result was most pronounced in two attributes: very large live TPA and large standing dead TPA. The means of these two metrics were nearly twice as high on Ecological Reserve plots (2.69 ac^{-1} and 1.33 ac^{-1}, respectively) compared to FIA plots on managed forestland (1.43 ac^{-1} and 0.70 ac^{-1}, respectively). Ecological Reserves plots also had significantly greater mean live basal area (124 vs 76 ft^2 ac^{-1}) and downed woody debris (644 vs 557 ft^3 ac^{-1}). These results confirm findings of other studies that have shown the abundance of ecologically valuable structural forest attributes is commonly greater in unmanaged than in managed forests (Dieler et al. 2017, Jonsson et al. 2005, Lassauce et al. 2011, Lonsdale et al. 2008, Silver et al. 2013, Winter and Möller 2008, Young et al. 2017). The Nature Conservancy's Big Reed Forest in northern Maine is one of the Northeast's largest tracts of old growth forest. Using results from 25 Ecological Reserve plots of Big Reed Reserve as benchmarks, much greater structural complexity can be expected in old forests with no history of harvest. In particular, very large live trees per acre (4.48 ac^{-1}), large snag density (4.97 ac^{-1}), and total downed woody debris volume (1166 ft^3 ac^{-1}) were all considerably higher on Big Reed Forest (Figure 11) (Note that the Big Reed plots were not considered in the multiple analyses above because the plots have not yet been remeasured).

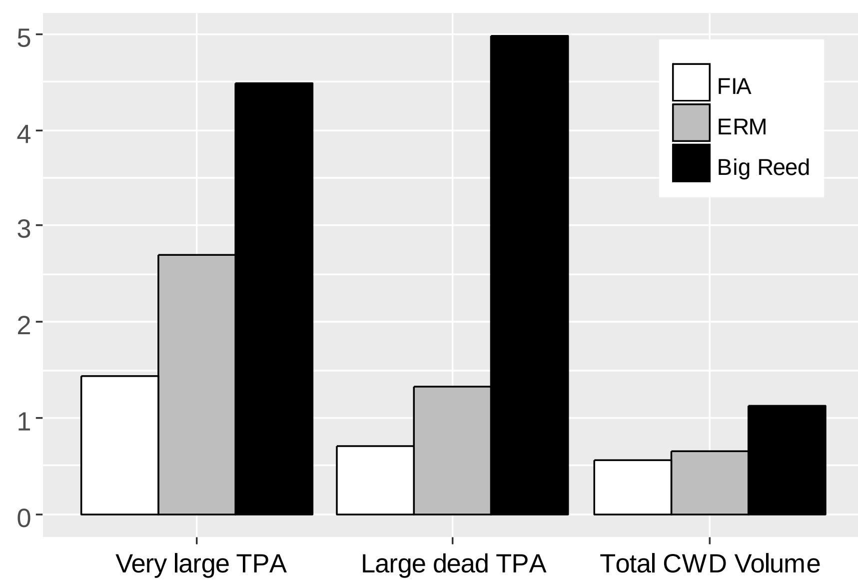

Figure 11. Structural attributes including very large (dbh ≥ 20.1 in) trees per acre (TPA), large (dbh ≥ 15.8 in) standing dead TPA, and downed woody debris volume (total CWD Volume, 1,000 ft^3 ac^{-1}) of managed forest (FIA – Forest Inventory and Analysis subplots), Ecological Reserves (ERM), and the Big Reed Forest Reserve.

3. Ten-year changes in sampled metrics on Ecological Reserve Monitoring plots were statistically significant for basal area, large trees per acre, and very large trees per acre, with overall increases in mean values for these metrics. Although not statistically significant, there were unexpected ten-year trends observed for some of metrics, such as a decrease in total downed woody debris volume. This result may reflect the cycles of woody debris accumulation and decomposition resulting from the 1980s spruce budworm outbreak (Puhlick et al. 2016), but it may also reflect the inclusion of comparatively young as well as recently managed forestland in the Ecological Reserve Monitoring program. In addition, it is possible that reliable long-term trends of downed woody debris are undetectable within the 10-year time frame sampled here.

4. One of the more surprising findings was that net growth rates for Ecological Reserves (44 ft^3 ac^{-1} yr^{-1}) were comparable to those on managed forests (50 ft^3 ac^{-1} yr^{-1}), despite the fact that the average annual natural mortality rate on Ecological Reserve plots (32 ft^3 ac^{-1} yr^{-1}) was significantly higher than on managed lands (18 ft^3 ac^{-1} yr^{-1}). This finding suggests that relatively older forests (e.g., Reserves with an average canopy tree age of 89 years) can have comparable growth rates to younger managed forests (managed forest FIA plots with an average site tree age of 52 years). The Ecological Reserve plots had, on average, a greater number of large TPA, and large trees have been shown to accumulate a high portion of the overall stand volume (Stephenson et al. 2014). On the Reserves, the relatively high natural mortality rate could allow surviving trees to take advantage of growing space, which could lead to an increase in stand gross growth. It is important to consider that this study involved analyses using trees ≥ 5.0 in dbh, and that including trees < 5.0 in dbh could result in different conclusions. For managed forests, we present metrics that include trees ≥ 1.0 in dbh in Appendix D, Tables 3 and 4.

5. Non-harvested Ecological Reserve plots, i.e., plots without visual evidence of harvest activities, generally did not show greater structural complexity in comparison to all Reserve plots. This result may reflect the fact many non-harvested plots occur at high elevation and/or in very wet areas that limit development of forest structure.

6. For the Ecological Reserves, the sampling accuracy (estimated using the 1103 Ecological Reserve plots sampled in round 1) appears to be acceptable for metrics of interest such as basal area and total downed woody debris volume. This sampling accuracy applies to all plots and to the dominant forest-type groups. The smaller number of plots sampled within each Reserve (typically between 5 and 40) result in higher variances, with percent sampling errors mostly exceeding 15%. To achieve sampling errors below the 15% threshold would likely require increasing the number of plots in each Reserve; as a rule of thumb, the number of plots should be increased four-fold to reduce the sampling error by 50%.

This initial assessment of Ecological Reserve Monitoring data quantifies differences in forest structure between Reserves and Maine's managed forests, and it validates the utility of the sampling design for statewide comparisons. An understanding of forest structure in unmanaged lands (i.e., Ecological Reserves) is useful at highlighting which attributes may be lacking in a managed landscape, providing forest managers with targets for goals for retention of features at the tree, stand, and landscape level.

Longer term sampling data will be needed to verify trends over time. However, this assessment of ten-year changes indicates that Ecological Reserves are still accumulating volume, reflecting the past harvesting history of many Reserves prior to their dedication. Based on comparisons with

Big Reed Forest, it will likely be decades before many Reserves exhibit true old growth characteristics.

This assessment focused on basic attributes of forest structure. However, additional Ecological Reserve data are available for other research questions involving regeneration (saplings and seedlings) and herbaceous data. Furthermore, because Ecological Reserve and FIA plots cover both latitudinal and elevational gradients, these plot data may prove useful in assessing the long-term impacts of climate change on Maine's forests.

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Appendices

Appendix A

Table 1. Total number of remeasured Ecological Reserve Monitoring plots and number of remeasured Ecological Reserve Monitoring plots without any visual evidence of harvest activities (including percentage of total) analyzed in this report by Ecological Reserve.

Ecological Reserve	Total # of plots	# non-harvested plots	(%)
Appleton Bog	10	4	(40)
Big Spencer	30	9	(30)
Bigelow	48	16	(33)
Cutler	29	15	(52)
Deboullie	31	6	(19)
Debsconeags	91	75	(82)
Donnell Pond	18	16	(89)
Duck Lake	26	11	(42)
Gero Island	23	15	(65)
Great Duck Island	5	0	(0)
Great Heath	13	10	(77)
Kennebec Estuary Sites	18	11	(61)
Mt. Abraham	32	16	(50)
Nahmakanta	50	19	(38)
Pine Barrens Sites	19	9	(47)
Rocky Lake	10	5	(50)
Salmon Brook Lake	13	3	(23)
Spring River Lake	29	15	(52)
St. John Ponds	35	0	(0)
Wassataquoik	17	5	(29)
Total	547	260	(48)

Appendix B

Ecological Reserve Monitoring Round 1 Descriptive Statistics

Table 1. Canopy tree age at breast height as well as stand-level metrics including basal area (ft^2 ac^{-1}) and trees per acre (TPA) for trees ≥ 5.0 inches diameter at breast height on plots across Maine Ecological Reserves of round 1 and later remeasured in round 2 (N = 547). Downed coarse woody debris (CWD) volume (ft^3 ac^{-1}) includes pieces ≥ 3.0 inches diameter at transect line intersect.

Attribute	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
Canopy Tree Age	0	59	77	84	104	300
Live Basal Area	0	67	109	112	151	477
Live Large TPA	0	0	0	11.3	24.1	100.3
Live Very Large TPA	0	0	0	2.1	4	40
Standing Dead TPA	0	0	24	42	72	265
Large Standing Dead TPA	0	0	0	1.2	0	48.1
Downed CWD	0	142	440	684	1012	4460
Downed Large CWD	0	0	0	65	0	3383

Table 2. Canopy tree age at breast height as well as stand-level metrics including basal area (ft^2 ac^{-1}) and trees per acre (TPA) for trees ≥ 5.0 inches diameter at breast height on plots across Maine Ecological Reserves of round 1 and later remeasured in round 2 by forest-type group. Downed coarse woody debris (CWD) volume (ft^3 ac^{-1}) includes pieces ≥ 3.0 inches diameter at transect line intersect.

Forest-type group & attribute	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
Aspen-White Birch						
Canopy Tree Age	15	45	59	61	73	155
Live Basal Area	0	43	66	69	94	164
Live Large TPA	0	0	0	3.7	2	28.1
Live Very Large TPA	0	0	0	0.6	0	4
Standing Dead TPA	0	0	24	36	48	120
Large Standing Dead TPA	0	0	0	0	0	0
Downed CWD	0	65	182	310	414	1537
Downed Large CWD	0	0	0	0	0	0
Elm-Ash-Cottonwood						
Canopy Tree Age	42	47	60	75	88	145
Live Basal Area	0	60	85	89	115	232
Live Large TPA	0	0	0	9.3	6	48.1
Live Very Large TPA	0	0	0	2.9	4	20
Standing Dead TPA	0	0	24	28	48	72
Large Standing Dead TPA	0	0	0	2.5	0	24.1
Downed CWD	0	49	400	565	609	2716
Downed Large CWD	0	0	0	41	0	786
Loblolly-Shortleaf Pine						
Canopy Tree Age	32	46	62	72	105	119
Live Basal Area	15	55	88	88	120	157
Live Large TPA	0	0	0	4.5	0	48.1
Live Very Large TPA	0	0	0	0	0	0
Standing Dead TPA	0	0	12	23	30	120
Large Standing Dead TPA	0	0	0	0	0	0
Downed CWD	0	0	32	71	133	294
Downed Large CWD	0	0	0	0	0	0

Table 2. Extended.

Forest-type group & attribute	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
Maple-Beech-Birch						
Canopy Tree Age	0	58	72	75	92	226
Live Basal Area	0	50	85	95	137	241
Live Large TPA	0	0	4	15.5	24.1	100.3
Live Very Large TPA	0	0	0	3	4	24
Standing Dead TPA	0	0	24	32	48	217
Large Standing Dead TPA	0	0	0	1.7	0	28.1
Downed CWD	0	325	647	778	1084	3672
Downed Large CWD	0	0	0	109	0	2873
Minor Hardwoods						
Canopy Tree Age	33	49	65	65	81	97
Live Basal Area	0	0	2	8	14	26
Live Large TPA	0	0	0	0	0	0
Live Very Large TPA	0	0	0	0	0	0
Standing Dead TPA	0	0	0	0	0	0
Large Standing Dead TPA	0	0	0	0	0	0
Downed CWD	0	0	0	605	1155	2255
Downed Large CWD	0	0	0	98	0	786
Miscellaneous Softwoods						
Canopy Tree Age	82	82	82	82	82	82
Live Basal Area	0	0	0	0	0	0
Live Large TPA	0	0	0	0	0	0
Live Very Large TPA	0	0	0	0	0	0
Standing Dead TPA	0	0	0	0	0	0
Large Standing Dead TPA	0	0	0	0	0	0
Downed CWD	0	0	0	0	0	0
Downed Large CWD	0	0	0	0	0	0

Table 2. Extended.

Forest-type group & attribute	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
Oak-Hickory						
Canopy Tree Age	35	49	57	60	68	102
Live Basal Area	0	32	74	73	100	141
Live Large TPA	0	0	0	9.3	24.1	32.1
Live Very Large TPA	0	0	0	1.7	4	8
Standing Dead TPA	0	24	48	64	78	193
Large Standing Dead TPA	0	0	0	2	0	24.1
Downed CWD	0	0	141	155	205	789
Downed Large CWD	0	0	0	0	0	0
Oak-Pine						
Canopy Tree Age	45	59	66	73	85	110
Live Basal Area	24	68	84	106	127	275
Live Large TPA	0	0	12	20.5	32.1	64
Live Very Large TPA	0	0	0	7.1	8	40
Standing Dead TPA	0	0	0	8	24	24
Large Standing Dead TPA	0	0	0	0	0	0
Downed CWD	0	49	116	132	155	370
Downed Large CWD	0	0	0	0	0	0
Spruce-Fir						
Canopy Tree Age	0	66	86	92	115	300
Live Basal Area	0	84	125	127	163	477
Live Large TPA	0	0	0	10.8	24.1	100.3
Live Very Large TPA	0	0	0	1.7	4	24
Standing Dead TPA	0	24	24	50	72	265
Large Standing Dead TPA	0	0	0	1.3	0	48.1
Downed CWD	0	218	556	801	1156	4460
Downed Large CWD	0	0	0	66	0	3383

Table 2. Extended.

Forest-type group & attribute	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
White-Red-Jack Pine						
Canopy Tree Age	30	60	69	97	128	250
Live Basal Area	79	128	162	162	199	313
Live Large TPA	0	0	24.1	23.1	44.1	56
Live Very Large TPA	0	0	4	5.9	4	32
Standing Dead TPA	0	4	24	35	48	120
Large Standing Dead TPA	0	0	0	0.2	0	4
Downed CWD	0	53	213	445	491	1960
Downed Large CWD	0	0	0	80	0	1676

Appendix C

Ecological Reserve Monitoring Round 2 Descriptive Statistics

Table 1. Canopy tree age at breast height as well as stand-level metrics including basal area (ft^2 ac^{-1}) and trees per acre (TPA) for trees ≥ 5.0 inches diameter at breast height on remeasured round 2 plots across Maine Ecological Reserves (N = 547). Downed coarse woody debris (CWD) volume (ft^3 ac^{-1}) includes pieces ≥ 3.0 inches diameter at transect line intersect. Also, annual gross growth, mortality, and net change rates for total stem volume (ft^3 ac^{-1} yr^{-1}; inside bark, excluding stump and top volume) over an approximately ten-year period.

Attribute	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
Canopy Tree Age	15	55	82	89	114	252
Live Basal Area	0	78	120	124	165	560
Live Large TPA	0	0	4	14.7	24.1	152.4
Live Very Large TPA	0	0	0	2.7	4	40
Standing Dead TPA	0	0	24	40	48	289
Large Standing Dead TPA	0	0	0	1.3	0	48.1
Downed CWD	0	142	434	644	885	5891
Downed Large CWD	0	0	0	70	0	5110
Gross Growth + Ingrowth	0	41	64	75	90	572
Mortality	0	0	12	32	38	397
Net Change	-266	13	43	44	73	544

Table 2. Canopy tree age at breast height as well as stand-level metrics including basal area (ft^2 ac^{-1}) and trees per acre (TPA) for trees ≥ 5.0 inches diameter at breast height on remeasured round 2 plots across Maine Ecological Reserves by forest-type group. Downed coarse woody debris (CWD) volume (ft^3 ac^{-1}) includes pieces ≥ 3.0 inches diameter at transect line intersect. Also, annual gross growth, mortality, and net change rates for total stem volume (ft^3 ac^{-1} yr^{-1}; inside bark, excluding stump and top volume) over an approximately ten-year period.

Forest-type group & attribute	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
Aspen-White Birch						
Canopy Tree Age	17	49	62	68	86	164
Live Basal Area	0	54	75	80	109	175
Live Large TPA	0	0	0	4.6	4	48.1
Live Very Large TPA	0	0	0	0.9	0	8
Standing Dead TPA	0	24	24	43	72	169
Large Standing Dead TPA	0	0	0	0	0	0
Downed CWD	0	120	207	330	399	1997
Downed Large CWD	0	0	0	0	0	0
Gross Growth + Ingrowth	0	29	44	52	61	144
Mortality	0	0	7	18	23	163
Net Change	-135	16	37	33	57	130
Elm-Ash-Cottonwood						
Canopy Tree Age	38	51	66	73	83	176
Live Basal Area	0	62	85	93	122	189
Live Large TPA	0	0	0	13.9	28.1	60.1
Live Very Large TPA	0	0	0	3.8	6	20
Standing Dead TPA	0	0	24	21	24	72
Large Standing Dead TPA	0	0	0	1.9	0	24.1
Downed CWD	0	52	215	561	761	2721
Downed Large CWD	0	0	0	78	0	1486
Gross Growth + Ingrowth	0	34	45	59	63	205
Mortality	0	0	10	45	33	341
Net Change	-190	14	30	14	44	126

Table 2. Extended.

Forest-type group & attribute	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
Loblolly-Shortleaf Pine						
Canopy Tree Age	NA	NA	NA	NA	NA	NA
Live Basal Area	20	58	99	99	130	177
Live Large TPA	0	0	0	5	1	28.1
Live Very Large TPA	0	0	0	0.5	0	4
Standing Dead TPA	0	0	24	27	48	120
Large Standing Dead TPA	0	0	0	0	0	0
Downed CWD	0	0	94	119	126	680
Downed Large CWD	0	0	0	0	0	0
Gross Growth + Ingrowth	10	29	59	56	75	110
Mortality	0	0	13	23	36	87
Net Change	-65	23	42	33	59	91
Maple-Beech-Birch						
Canopy Tree Age	20	55	80	86	114	209
Live Basal Area	0	72	103	109	141	272
Live Large TPA	0	0	8	19.1	32.1	100.3
Live Very Large TPA	0	0	4	4.2	8	28
Standing Dead TPA	0	0	24	28	48	169
Large Standing Dead TPA	0	0	0	2.1	0	28.1
Downed CWD	0	210	512	662	886	5148
Downed Large CWD	0	0	0	101	0	4371
Gross Growth + Ingrowth	0	41	57	64	85	231
Mortality	0	0	1	26	33	304
Net Change	-191	16	42	39	69	231

Table 2. Extended.

Forest-type group & attribute	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
Minor Hardwoods						
Canopy Tree Age	30	35	37	45	39	100
Live Basal Area	0	7	16	17	22	43
Live Large TPA	0	0	0	0.5	0	4
Live Very Large TPA	0	0	0	0.5	0	4
Standing Dead TPA	0	0	0	0	0	0
Large Standing Dead TPA	0	0	0	0	0	0
Downed CWD	0	0	0	251	467	1024
Downed Large CWD	0	0	0	0	0	0
Gross Growth + Ingrowth	0	3	12	14	21	38
Mortality	0	0	0	0	0	0
Net Change	0	3	12	14	21	38
Miscellaneous Softwoods						
Canopy Tree Age	53	53	53	53	53	53
Live Basal Area	3	3	3	3	3	3
Live Large TPA	0	0	0	0	0	0
Live Very Large TPA	0	0	0	0	0	0
Standing Dead TPA	0	0	0	0	0	0
Large Standing Dead TPA	0	0	0	0	0	0
Downed CWD	0	0	0	0	0	0
Downed Large CWD	0	0	0	0	0	0
Gross Growth + Ingrowth	4	4	4	4	4	4
Mortality	0	0	0	0	0	0
Net Change	4	4	4	4	4	4

Table 2. Extended.

Forest-type group & attribute	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
Oak-Hickory						
Canopy Tree Age	47	58	75	80	88	158
Live Basal Area	7	57	95	92	136	169
Live Large TPA	0	0	2	11	25	32.1
Live Very Large TPA	0	0	0	3.5	4	28
Standing Dead TPA	0	18	26	35	48	120
Large Standing Dead TPA	0	0	0	1.8	0	24.1
Downed CWD	0	75	289	304	400	1039
Downed Large CWD	0	0	0	0	0	0
Gross Growth + Ingrowth	8	22	55	60	79	168
Mortality	0	0	5	9	12	33
Net Change	0	21	44	51	74	159
Oak-Pine						
Canopy Tree Age	NA	NA	NA	NA	NA	NA
Live Basal Area	0	66	88	111	149	300
Live Large TPA	0	0	12	20.5	32.1	64
Live Very Large TPA	0	0	0	7.1	8	40
Standing Dead TPA	0	0	0	5	0	24
Large Standing Dead TPA	0	0	0	0	0	0
Downed CWD	0	0	30	41	49	179
Downed Large CWD	0	0	0	0	0	0
Gross Growth + Ingrowth	0	46	50	64	80	142
Mortality	0	0	8	39	28	200
Net Change	-179	0	46	25	66	142

Table 2. Extended.

Forest-type group & attribute	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
Spruce-Fir						
Canopy Tree Age	15	62	90	95	123	252
Live Basal Area	0	95	132	140	178	560
Live Large TPA	0	0	0	14.4	24.1	152.4
Live Very Large TPA	0	0	0	2.1	4	32
Standing Dead TPA	0	0	24	48	72	289
Large Standing Dead TPA	0	0	0	1.3	0	48.1
Downed CWD	0	234	567	765	1015	5891
Downed Large CWD	0	0	0	68	0	3632
Gross Growth + Ingrowth	0	45	72	84	95	572
Mortality	0	0	17	36	46	397
Net Change	-266	11	47	48	75	544
White-Red-Jack Pine						
Canopy Tree Age	19	70	89	96	114	215
Live Basal Area	110	126	173	183	220	380
Live Large TPA	0	8	28	30.4	48.1	96.3
Live Very Large TPA	0	0	0	6.3	8	36
Standing Dead TPA	0	24	28	49	72	144
Large Standing Dead TPA	0	0	0	1.3	0	24.1
Downed CWD	0	52	204	486	417	5140
Downed Large CWD	0	0	0	243	0	5110
Gross Growth + Ingrowth	55	72	124	126	154	250
Mortality	0	0	30	41	53	267
Net Change	-114	55	80	84	112	250

Table 3. Canopy tree age at breast height as well as stand-level metrics including basal area (ft^2 ac^{-1}) and trees per acre (TPA) for trees ≥ 5.0 inches diameter at breast height on remeasured round 2 plots across Maine Ecological Reserves by Ecological Reserve. Downed coarse woody debris (CWD) volume (ft^3 ac^{-1}) includes pieces ≥ 3.0 inches diameter at transect line intersect. Also, annual gross growth, mortality, and net change rates for total stem volume (ft^3 ac^{-1} yr^{-1}; inside bark, excluding stump and top volume) over an approximately ten-year period.

Forest-type group & attribute	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
Appleton Bog						
Canopy Tree Age	49	69	82	93	123	139
Live Basal Area	82	144	172	189	201	389
Live Large TPA	0	1	24.1	14.8	24.1	24.1
Live Very Large TPA	0	0	0	0.4	0	4
Standing Dead TPA	0	0	24	29	48	72
Large Standing Dead TPA	0	0	0	0	0	0
Downed CWD	0	13	196	257	421	824
Downed Large CWD	0	0	0	0	0	0
Gross Growth + Ingrowth	54	95	158	187	195	572
Mortality	0	18	23	67	29	397
Net Change	-227	45	97	120	149	544
Big Spencer						
Canopy Tree Age	38	62	104	105	130	252
Live Basal Area	15	80	106	108	131	214
Live Large TPA	0	0	0	14.7	24	72.2
Live Very Large TPA	0	0	0	3.5	4	24
Standing Dead TPA	0	0	26	44	48	217
Large Standing Dead TPA	0	0	0	2.7	0	28.1
Downed CWD	0	266	452	621	778	3407
Downed Large CWD	0	0	0	64	0	1917
Gross Growth + Ingrowth	1	35	59	69	86	231
Mortality	0	0	17	41	59	248
Net Change	-112	-22	35	29	72	231

Table 3. Extended.

Forest-type group & attribute	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
Bigelow						
Canopy Tree Age	19	71	86	94	117	209
Live Basal Area	0	91	133	132	165	249
Live Large TPA	0	0	6	18.8	28.1	100.3
Live Very Large TPA	0	0	4	4.2	5	28
Standing Dead TPA	0	24	48	47	72	144
Large Standing Dead TPA	0	0	0	3.3	0	28.1
Downed CWD	0	249	666	778	1026	2813
Downed Large CWD	0	0	0	48	0	1540
Gross Growth + Ingrowth	0	37	57	53	72	115
Mortality	0	9	27	48	79	266
Net Change	-266	-24	11	5	51	80
Cutler						
Canopy Tree Age	29	42	53	64	72	136
Live Basal Area	0	36	97	91	137	172
Live Large TPA	0	0	0	2.9	0	24.1
Live Very Large TPA	0	0	0	0.4	0	8
Standing Dead TPA	0	0	24	56	72	265
Large Standing Dead TPA	0	0	0	0	0	0
Downed CWD	0	0	283	331	408	1251
Downed Large CWD	0	0	0	0	0	0
Gross Growth + Ingrowth	0	34	67	62	85	116
Mortality	0	0	3	28	32	145
Net Change	-111	13	37	34	69	115

Table 3. Extended.

Forest-type group & attribute	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
Deboullie						
Canopy Tree Age	40	80	94	104	129	225
Live Basal Area	29	87	142	149	186	560
Live Large TPA	0	2	12	23.2	30.1	152.4
Live Very Large TPA	0	0	0	3	4	16
Standing Dead TPA	0	24	24	42	48	169
Large Standing Dead TPA	0	0	0	1.8	0	24.1
Downed CWD	0	284	632	892	1123	3126
Downed Large CWD	0	0	0	92	0	2034
Gross Growth + Ingrowth	12	54	71	88	109	234
Mortality	0	0	9	17	20	89
Net Change	-15	44	63	71	80	221
Debsconeags						
Canopy Tree Age	56	62	111	95	112	135
Live Basal Area	33	93	131	144	183	380
Live Large TPA	0	0	4	16.3	26.1	76.2
Live Very Large TPA	0	0	0	2.9	4	36
Standing Dead TPA	0	0	24	31	48	169
Large Standing Dead TPA	0	0	0	0.3	0	24.1
Downed CWD	0	336	600	770	991	4012
Downed Large CWD	0	0	0	89	0	3632
Gross Growth + Ingrowth	17	43	72	88	97	559
Mortality	0	0	15	38	42	331
Net Change	-191	16	55	50	80	228

Table 3. Extended.

Forest-type group & attribute	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
Donnell Pond						
Canopy Tree Age	39	56	86	87	114	143
Live Basal Area	42	101	110	117	140	205
Live Large TPA	0	0	0	9.8	19.1	56.1
Live Very Large TPA	0	0	0	1.8	4	8
Standing Dead TPA	0	0	24	39	48	144
Large Standing Dead TPA	0	0	0	0	0	0
Downed CWD	0	164	344	499	706	1531
Downed Large CWD	0	0	0	0	0	0
Gross Growth + Ingrowth	23	41	47	51	62	89
Mortality	0	0	20	26	34	95
Net Change	-43	4	26	25	50	81
Duck Lake						
Canopy Tree Age	34	57	89	104	144	215
Live Basal Area	58	103	125	135	167	251
Live Large TPA	0	0	4	18	24.1	76.2
Live Very Large TPA	0	0	0	3.2	4	28
Standing Dead TPA	0	24	26	40	48	144
Large Standing Dead TPA	0	0	0	0.3	0	4
Downed CWD	0	204	423	527	771	1723
Downed Large CWD	0	0	0	44	0	1155
Gross Growth + Ingrowth	25	46	72	77	92	250
Mortality	0	0	10	16	28	63
Net Change	-25	31	58	61	78	250

Table 3. Extended.

Forest-type group & attribute	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
Gero Island						
Canopy Tree Age	21	69	102	88	106	151
Live Basal Area	7	76	125	130	185	237
Live Large TPA	0	0	4	20.7	42.1	96.3
Live Very Large TPA	0	0	0	3	6	12
Standing Dead TPA	0	22	28	44	60	144
Large Standing Dead TPA	0	0	0	4.5	0	48.1
Downed CWD	124	569	936	1536	1614	5891
Downed Large CWD	0	0	0	252	0	2179
Gross Growth + Ingrowth	2	41	76	75	111	136
Mortality	0	0	17	29	41	163
Net Change	-135	20	58	46	88	132
Great Duck Island						
Canopy Tree Age	36	48	73	87	138	140
Live Basal Area	150	206	210	219	233	294
Live Large TPA	0	0	0	9.6	0	48.1
Live Very Large TPA	0	0	0	0	0	0
Standing Dead TPA	0	0	24	34	48	96
Large Standing Dead TPA	0	0	0	0	0	0
Downed CWD	0	50	174	263	502	591
Downed Large CWD	0	0	0	0	0	0
Gross Growth + Ingrowth	182	198	287	286	354	411
Mortality	0	0	0	6	0	32
Net Change	150	198	287	280	354	411

Table 3. Extended.

Forest-type group & attribute	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
Great Heath						
Canopy Tree Age	24	53	82	74	98	127
Live Basal Area	4	28	117	110	165	235
Live Large TPA	0	0	0	8.3	4	48.1
Live Very Large TPA	0	0	0	0.9	0	4
Standing Dead TPA	0	24	72	67	96	193
Large Standing Dead TPA	0	0	0	0	0	0
Downed CWD	0	28	364	459	657	1913
Downed Large CWD	0	0	0	0	0	0
Gross Growth + Ingrowth	3	42	57	72	93	157
Mortality	0	7	16	26	41	76
Net Change	-52	6	42	46	74	157
Kennebec Estuary Sites						
Canopy Tree Age	NA	NA	NA	NA	NA	NA
Live Basal Area	17	50	109	103	154	206
Live Large TPA	0	0	6	13.8	24.1	48.1
Live Very Large TPA	0	0	0	3.1	4	24
Standing Dead TPA	0	0	12	27	24	120
Large Standing Dead TPA	0	0	0	1.3	0	24.1
Downed CWD	0	0	58	359	108	5140
Downed Large CWD	0	0	0	284	0	5110
Gross Growth + Ingrowth	6	33	55	59	74	154
Mortality	0	0	8	43	48	267
Net Change	-179	-3	39	16	52	142

Table 3. Extended.

Forest-type group & attribute	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
Mt. Abraham						
Canopy Tree Age	24	70	104	103	131	185
Live Basal Area	4	101	133	136	173	293
Live Large TPA	0	0	0	6.9	5	48.1
Live Very Large TPA	0	0	0	0.9	0	8
Standing Dead TPA	0	24	48	74	102	289
Large Standing Dead TPA	0	0	0	0.8	0	24.1
Downed CWD	0	225	769	997	1520	5148
Downed Large CWD	0	0	0	137	0	4371
Gross Growth + Ingrowth	1	56	81	83	105	260
Mortality	0	0	27	37	44	179
Net Change	-174	13	46	46	84	209
Nahmakanta						
Canopy Tree Age	15	64	81	87	99	232
Live Basal Area	0	70	98	120	142	420
Live Large TPA	0	0	4	17.8	27.1	132.4
Live Very Large TPA	0	0	0	4.3	4	32
Standing Dead TPA	0	0	24	39	67	169
Large Standing Dead TPA	0	0	0	0.6	0	28.1
Downed CWD	0	138	374	559	824	2721
Downed Large CWD	0	0	0	32	0	1596
Gross Growth + Ingrowth	0	39	59	83	106	322
Mortality	0	0	8	29	36	296
Net Change	-238	20	41	54	80	252

Table 3. Extended.

Forest-type group & attribute	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
Pine Barrens Sites						
Canopy Tree Age	NA	NA	NA	NA	NA	NA
Live Basal Area	0	76	99	108	137	300
Live Large TPA	0	0	0	7	2	64
Live Very Large TPA	0	0	0	3.2	0	40
Standing Dead TPA	0	0	24	25	48	120
Large Standing Dead TPA	0	0	0	0	0	0
Downed CWD	0	18	93	137	161	680
Downed Large CWD	0	0	0	0	0	0
Gross Growth + Ingrowth	0	46	60	61	81	110
Mortality	0	5	19	25	33	87
Net Change	-65	24	50	37	59	91
Rocky Lake						
Canopy Tree Age	30	68	78	79	92	125
Live Basal Area	0	67	110	115	141	245
Live Large TPA	0	0	0	4.8	0	24.1
Live Very Large TPA	0	0	0	0	0	0
Standing Dead TPA	0	24	36	36	48	96
Large Standing Dead TPA	0	0	0	0	0	0
Downed CWD	0	143	393	398	581	1102
Downed Large CWD	0	0	0	0	0	0
Gross Growth + Ingrowth	0	44	78	78	92	168
Mortality	0	0	2	7	8	32
Net Change	0	38	62	72	92	159

Table 3. Extended.

Forest-type group & attribute	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
Salmon Brook Lake						
Canopy Tree Age	36	75	91	101	126	185
Live Basal Area	9	101	147	161	198	345
Live Large TPA	0	0	0	7.4	0	48.1
Live Very Large TPA	0	0	0	0	0	0
Standing Dead TPA	0	48	72	65	72	193
Large Standing Dead TPA	0	0	0	1.9	0	24.1
Downed CWD	0	461	660	820	1215	1997
Downed Large CWD	0	0	0	0	0	0
Gross Growth + Ingrowth	6	44	50	56	80	99
Mortality	0	9	15	26	29	85
Net Change	-78	1	44	30	63	89
Spring River Lake						
Canopy Tree Age	37	72	98	102	121	235
Live Basal Area	7	63	119	102	132	208
Live Large TPA	0	0	0	7.7	24.1	32.1
Live Very Large TPA	0	0	0	1.9	0	28
Standing Dead TPA	0	24	28	46	72	120
Large Standing Dead TPA	0	0	0	1.8	0	24.1
Downed CWD	0	83	287	387	584	1091
Downed Large CWD	0	0	0	0	0	0
Gross Growth + Ingrowth	8	35	50	51	65	126
Mortality	0	0	7	24	26	287
Net Change	-247	21	35	27	50	109

Table 3. Extended.

Forest-type group & attribute	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
St. John Ponds						
Canopy Tree Age	20	30	50	53	77	108
Live Basal Area	0	19	43	69	122	199
Live Large TPA	0	0	4	15.5	24.1	84.2
Live Very Large TPA	0	0	0	2.4	4	20
Standing Dead TPA	0	0	0	10	14	72
Large Standing Dead TPA	0	0	0	1.3	0	24.1
Downed CWD	0	94	434	537	760	2268
Downed Large CWD	0	0	0	104	0	2075
Gross Growth + Ingrowth	0	23	41	49	67	125
Mortality	0	0	0	11	0	218
Net Change	-134	18	33	38	62	118
Wassataquoik						
Canopy Tree Age	39	56	69	67	76	99
Live Basal Area	0	86	128	133	160	298
Live Large TPA	0	4	32.1	32.8	48.1	96.3
Live Very Large TPA	0	0	4	5.9	8	20
Standing Dead TPA	0	0	8	25	24	120
Large Standing Dead TPA	0	0	0	5.2	4	48.1
Downed CWD	0	111	196	436	567	1711
Downed Large CWD	0	0	0	87	0	1486
Gross Growth + Ingrowth	0	42	76	89	145	205
Mortality	0	0	29	63	80	341
Net Change	-190	0	31	26	76	196

Appendix D

FIA Descriptive Statistics

Table 1. Site tree age at breast height and stand-level metrics including basal area ($ft^2\ ac^{-1}$) and trees per acre (TPA) for trees ≥ 5.0 inches diameter at breast height on forested portions of Forest Inventory and Analysis (FIA) subplots on managed lands in Maine (N = 10,503). Downed coarse woody debris (CWD) volume ($ft^3\ ac^{-1}$) includes pieces ≥ 3.0 inches diameter at transect line intersect. Annual growth, mortality, and cut rates for total stem volume ($ft^3\ ac^{-1}\ yr^{-1}$; inside bark, excluding stump and top volume) over an approximately ten-year period.

Attribute	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
Site Tree Age	11	33	48	52	67	142
Live Basal Area	0	27	66	76	112	426
Live TPA	0	96	169	185	265	843
Live Large TPA	0	0	0	5.7	0	168.5
Live Very Large TPA	0	0	0	1.4	0	96.3
Standing Dead Basal Area	0	0	0	9	12	222
Standing Dead TPA	0	0	0	22	24	506
Large Standing Dead TPA	0	0	0	0.70	0	48.14
Standing Dead Very Large TPA	0	0	0	0.18	0	48.14
Downed CWD	0	0	264	557	762	6204
Downed Large CWD	0	0	0	26	0	3763
Gross Growth + Ingrowth	0	32	61	68	95	475
Mortality	0	0	0	18	20	614
Cut	0	0	0	32	0	970
Net Growth + Ingrowth	-462	14	46	50	82	475
Net Change	-970	0	37	18	77	475

Table 2. Site tree age at breast height and stand-level metrics including basal area (ft^2 ac^{-1}) and trees per acre (TPA) for trees ≥ 5.0 inches diameter at breast height on forested portions of Forest Inventory and Analysis (FIA) subplots on managed lands in Maine by forest-type group. Downed coarse woody debris (CWD) volume (ft^3 ac^{-1}) includes pieces ≥ 3.0 inches diameter at transect line intersect. Annual growth, mortality, and cut rates for total stem volume (ft^3 ac^{-1} yr^{-1}; inside bark, excluding stump and top volume) over an approximately ten-year period.

Forest-type group & attribute	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
Aspen-White Birch						
Site Tree Age	17	31	44	45	55	89
Live Basal Area	0	17	48	59	87	302
Live TPA	0	66	144	173	265	794
Live Large TPA	0	0	0	2.5	0	72.2
Live Very Large TPA	0	0	0	0.6	0	48.1
Standing Dead Basal Area	0	0	0	8	8	94
Standing Dead TPA	0	0	0	22	24	361
Large Standing Dead TPA	0	0	0	0.29	0	24.07
Standing Dead Very Large TPA	0	0	0	0.03	0	24.07
Downed CWD	0	0	124	409	426	3911
Downed Large CWD	0	0	0	0	0	0
Gross Growth + Ingrowth	0	24	53	63	86	301
Mortality	0	0	0	16	20	240
Cut	0	0	0	23	0	644
Net Growth + Ingrowth	-223	9	39	47	72	272
Net Change	-666	0	34	24	71	272
Elm-Ash-Cottonwood						
Site Tree Age	31	45	60	58	67	88
Live Basal Area	0	23	60	68	103	312
Live TPA	0	72	144	168	265	626
Live Large TPA	0	0	0	3.8	0	72.2
Live Very Large TPA	0	0	0	1.2	0	48.1
Standing Dead Basal Area	0	0	4	12	17	135
Standing Dead TPA	0	0	24	29	48	337
Large Standing Dead TPA	0	0	0	1.08	0	48.14
Standing Dead Very Large TPA	0	0	0	0.32	0	24.07
Downed CWD	0	0	0	138	194	1065
Downed Large CWD	0	0	0	0	0	0
Gross Growth + Ingrowth	0	20	49	59	87	317
Mortality	0	0	0	17	21	198
Cut	0	0	0	7	0	606
Net Growth + Ingrowth	-107	3	35	42	69	317
Net Change	-509	0	33	35	68	317

Table 2. Extended.

Forest-type group & attribute	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
Maple-Beech-Birch						
Site Tree Age	15	43	55	56	68	115
Live Basal Area	0	25	60	67	100	322
Live TPA	0	72	144	153	217	770
Live Large TPA	0	0	0	5.8	0	96.3
Live Very Large TPA	0	0	0	1.4	0	72.2
Standing Dead Basal Area	0	0	0	8	10	213
Standing Dead TPA	0	0	0	16	24	241
Large Standing Dead TPA	0	0	0	0.85	0	48.14
Standing Dead Very Large TPA	0	0	0	0.3	0	48.14
Downed CWD	0	0	280	573	793	6181
Downed Large CWD	0	0	0	57	0	3763
Gross Growth + Ingrowth	0	33	56	62	84	335
Mortality	0	0	0	19	22	534
Cut	0	0	0	47	57	970
Net Growth + Ingrowth	-416	15	43	42	72	327
Net Change	-907	-42	27	-5	66	327
Miscellaneous Softwoods						
Site Tree Age	27	28	29	29	29	30
Live Basal Area	0	35	58	81	150	199
Live TPA	0	48	217	290	602	698
Live Large TPA	0	0	0	0	0	0
Live Very Large TPA	0	0	0	0	0	0
Standing Dead Basal Area	0	0	0	< 1	0	4
Standing Dead TPA	0	0	0	3	0	24
Large Standing Dead TPA	0	0	0	0	0	0
Standing Dead Very Large TPA	0	0	0	0	0	0
Downed CWD						
Downed Large CWD						
Gross Growth + Ingrowth	0	52	112	141	247	282
Mortality	0	0	0	0	0	0
Cut	0	0	0	36	0	270
Net Growth + Ingrowth	0	52	112	141	247	282
Net Change	-91	0	100	105	247	282

Table 2. Extended.

Forest-type group & attribute	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
Oak-Hickory						
Site Tree Age	35	49	56	53	60	67
Live Basal Area	0	63	89	98	128	319
Live TPA	0	144	193	204	265	457
Live Large TPA	0	0	0	8.3	12	96.3
Live Very Large TPA	0	0	0	1.4	0	24.1
Standing Dead Basal Area	0	0	0	4	5	57
Standing Dead TPA	0	0	0	13	24	169
Large Standing Dead TPA	0	0	0	0.2	0	24.07
Standing Dead Very Large TPA	0	0	0	0	0	0
Downed CWD	0	0	194	237	410	630
Downed Large CWD	0	0	0	0	0	0
Gross Growth + Ingrowth	0	57	77	84	102	314
Mortality	0	0	0	10	9	147
Cut	0	0	0	15	0	457
Net Growth + Ingrowth	-14	49	68	74	94	314
Net Change	-357	37	65	59	89	314
Oak-Pine						
Site Tree Age	36	44	54	54	67	70
Live Basal Area	0	61	95	108	147	393
Live TPA	0	120	193	198	265	602
Live Large TPA	0	0	0	15	24.1	120.4
Live Very Large TPA	0	0	0	4.8	0	72.2
Standing Dead Basal Area	0	0	0	9	10	214
Standing Dead TPA	0	0	0	23	24	193
Large Standing Dead TPA	0	0	0	0.85	0	48.14
Standing Dead Very Large TPA	0	0	0	0.26	0	24.07
Downed CWD	0	0	140	388	480	2068
Downed Large CWD	0	0	0	0	0	0
Gross Growth + Ingrowth	0	58	91	102	129	392
Mortality	0	0	0	15	17	373
Cut	0	0	0	42	10	681
Net Growth + Ingrowth	-346	45	78	87	119	382
Net Change	-573	8	63	44	112	382

Table 2. Extended.

Forest-type group & attribute	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
Spruce-Fir						
Site Tree Age	11	27	38	47	64	142
Live Basal Area	0	24	65	75	112	402
Live TPA	0	96	193	203	289	843
Live Large TPA	0	0	0	3.9	0	168.5
Live Very Large TPA	0	0	0	0.9	0	96.3
Standing Dead Basal Area	0	0	0	10	13	222
Standing Dead TPA	0	0	0	25	48	506
Large Standing Dead TPA	0	0	0	0.63	0	48.14
Standing Dead Very Large TPA	0	0	0	0.1	0	48.14
Downed CWD	0	0	319	630	834	6204
Downed Large CWD	0	0	0	13	0	2519
Gross Growth + Ingrowth	0	27	58	64	94	386
Mortality	0	0	0	18	20	614
Cut	0	0	0	22	0	670
Net Growth + Ingrowth	-462	9	42	46	79	386
Net Change	-610	0	36	24	76	386
White-Red-Jack Pine						
Site Tree Age	20	48	62	62	77	115
Live Basal Area	0	62	108	114	158	426
Live TPA	0	120	193	211	289	770
Live Large TPA	0	0	0	13.5	24.1	120.4
Live Very Large TPA	0	0	0	3.7	0	96.3
Standing Dead Basal Area	0	0	0	10	13	144
Standing Dead TPA	0	0	0	23	24	385
Large Standing Dead TPA	0	0	0	0.83	0	48.14
Standing Dead Very Large TPA	0	0	0	0.23	0	24.07
Downed CWD	0	0	124	399	505	2947
Downed Large CWD	0	0	0	28	0	1990
Gross Growth + Ingrowth	0	61	97	105	139	475
Mortality	0	0	0	18	22	533
Cut	0	0	0	43	0	803
Net Growth + Ingrowth	-429	42	80	87	125	475
Net Change	-722	4	63	44	117	475

Table 3. Basal area (ft^2 ac^{-1}) and trees per acre (TPA) for trees ≥ 1.0 inches diameter at breast height on forested portions of Forest Inventory and Analysis (FIA) subplots on managed lands in Maine (N = 10,503). Also, annual growth, mortality, and cut rate for total stem volume (ft^3 ac^{-1} yr^{-1}; inside bark, excluding stump and top volume) over an approximately ten-year period.

	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
Live Basal Area	0	61	108	113	158	456
Live TPA	0	361	924	1412	1860	13614
Gross Growth + Ingrowth	0	56	88	96	128	560
Mortality	0	0	9	26	35	614
Cut	0	0	0	33	0	970
Net Growth + Ingrowth	-462	28	68	69	109	553
Net Change	-965	0	59	36	104	553

Table 4. Basal area ($ft^2\ ac^{-1}$) and trees per acre (TPA) for trees ≥ 1.0 inches diameter at breast height on forested portions of Forest Inventory and Analysis (FIA) subplots on managed lands in Maine by forest-type group. Also, annual growth, mortality, and cut rate for total stem volume ($ft^3\ ac^{-1}\ yr^{-1}$).

Forest-type group & attribute	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
Aspen-White Birch						
Live Basal Area	0	48	95	101	145	375
Live TPA	0	378	1092	1481	2099	10219
Gross Growth + Ingrowth	0	54	88	96	130	344
Mortality	0	0	13	28	38	243
Cut	0	0	0	24	0	644
Net Growth + Ingrowth	-160	25	65	67	105	304
Net Change	-670	8	60	43	104	304
Elm-Ash-Cottonwood						
Live Basal Area	0	38	83	89	125	326
Live TPA	0	144	492	714	1080	3408
Gross Growth + Ingrowth	0	29	62	72	101	327
Mortality	0	0	8	22	33	198
Cut	0	0	0	7	0	606
Net Growth + Ingrowth	-107	6	41	50	80	325
Net Change	-509	4	39	42	79	325
Maple-Beech-Birch						
Live Basal Area	0	51	92	94	133	364
Live TPA	0	300	744	1095	1499	8996
Gross Growth + Ingrowth	0	52	79	84	111	335
Mortality	0	0	10	28	38	534
Cut	0	0	0	48	59	970
Net Growth + Ingrowth	-416	23	59	56	92	334
Net Change	-965	-39	45	8	85	334
Miscellaneous Softwoods						
Live Basal Area	0	62	75	103	165	256
Live TPA	0	96	602	643	998	1668
Gross Growth + Ingrowth	0	97	136	157	255	297
Mortality	0	0	0	5	1	48
Cut	0	0	0	49	0	330
Net Growth + Ingrowth	0	97	120	152	255	297
Net Change	-179	0	108	103	255	297

Table 4. Extended.

Forest-type group & attribute	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
Oak-Hickory						
Live Basal Area	0	80	116	120	155	319
Live TPA	0	337	613	846	1164	3095
Gross Growth + Ingrowth	12	72	91	98	122	314
Mortality	0	0	6	19	22	147
Cut	0	0	0	15	0	457
Net Growth + Ingrowth	-63	50	74	79	104	314
Net Change	-315	42	71	65	99	314
Oak-Pine						
Live Basal Area	0	76	117	129	171	393
Live TPA	0	241	565	809	1089	6897
Gross Growth + Ingrowth	1	72	106	115	143	399
Mortality	0	0	10	25	31	373
Cut	0	0	0	42	10	681
Net Growth + Ingrowth	-342	46	85	90	122	396
Net Change	-571	17	69	47	117	396
Spruce-Fir						
Live Basal Area	0	67	120	123	174	456
Live TPA	0	506	1201	1821	2436	13614
Gross Growth + Ingrowth	0	56	93	98	134	560
Mortality	0	0	9	26	33	614
Cut	0	0	0	23	0	670
Net Growth + Ingrowth	-462	26	72	72	117	553
Net Change	-643	9	67	49	115	553
White-Red-Jack Pine						
Live Basal Area	0	82	133	135	183	426
Live TPA	0	265	565	851	1116	6945
Gross Growth + Ingrowth	0	74	110	119	153	475
Mortality	0	0	9	25	33	535
Cut	0	0	0	44	0	803
Net Growth + Ingrowth	-420	50	88	94	131	475
Net Change	-717	12	71	50	125	475