TECHNICAL REPORT 26-1 APRIL 2026

SAMPLING AND MEASUREMENT PROTOCOLS FOR THE ADAPTIVE SILVICULTURE FOR CLIMATE CHANGE STUDY

at The Jones Center at Ichauway

JOSHUA J. PUHLICK

Author: Joshua J. Puhlick is an Associate Scientist with The Jones Center at Ichauway in Newton, GA.

Cover Photo: Field crew from the Ecological Silviculture lab measuring snags in the control stand of Block B of the Adaptive Silviculture for Climate Change study at The Jones Center at Ichauway. Photo credit Hunter Nichols.

Recommended Citation: Puhlick, Joshua J. 2026. Sampling and measurement protocols for the Adaptive Silviculture for Climate Change study at The Jones Center at Ichauway. The Jones Center at Ichauway Outreach Catalog: TR 26-1. 25 p. doi.org/10.58497/43516

Contents

PREFACE

This document is intended to help others develop protocols for study sites that are part of the Adaptive Silviculture for Climate Change network. The protocols outlined in this report can also be used and refined for other research that involves the establishment of permanent plots for monitoring stand conditions over time. The protocols were influenced by my involvement with forest inventories and database management at the Penobscot Experimental Forest in central Maine. The protocols that I have outlined in this document are a natural extension of that work with an emphasis on sampling methods and procedures for quantifying forest carbon stocks.

INTRODUCTION

The Adaptive Silviculture for Climate Change (ASCC) project provides a framework for evaluating responses to climate change using four adaptation approaches: control, resistance, resilience, and transition (Nagel et al. 2017; Nagel et al. 2025). Staff at The Jones Center at Ichauway maintain and monitor stand conditions at one of the fourteen ASCC core study sites that occur across the USA and Canada. This study site at Ichauway is one of the five original ASCC sites. Designing and planning the ASCC study at Ichauway began in 2016 (Nagel et al. 2017), and silvicultural treatments that involved timber harvesting were initiated in 2018. Standard forestry measurements conducted by the Ecological Silviculture Lab are the focus of this report. However, research has been conducted on insect, fungal, and slime mold diversity, tree water use, wildlife diversity, and survival of planted turkey oaks in the ASCC stands at Ichauway. The ASCC study at Ichauway is unique because all the stands are maintained with frequent prescribed fire (approximately every two years), which influences the timing of inventories and measurements of carbon pools.

Study Site and Experimental Design

The ASCC study site at Ichauway is located within the southeastern Coastal Plain (31°22′N, 84°48′W). The property is located in Baker County, GA, where average elevation is 50 m (164 ft), and mean annual precipitation and temperature from 1991–2020 were 1333 mm (52 in) and 19.1°C (66°F) (PRISM Climate Group 2021). Soils are predominately well-drained loamy sands over sandy loams. In 2016, four blocks were delineated for the ASCC study at Ichauway to account for the potential influence of soils on treatment outcomes (**Figure 1**). The four adaptation approaches were randomly assigned to stands within each block (**Figure 2**). Details about the blocking scheme and the assignment of treatments to stands are described in Puhlick et al. (2026).

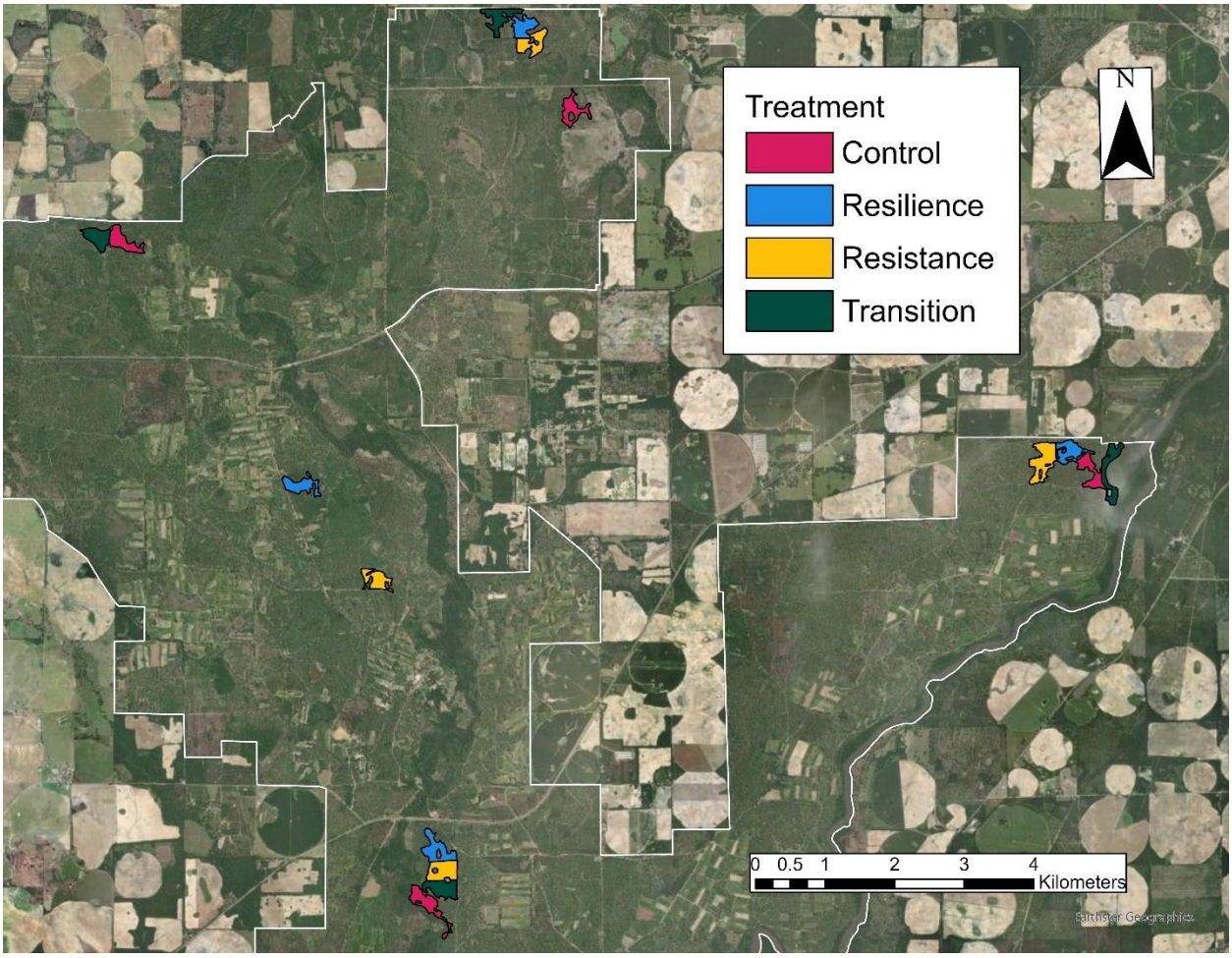

Figure 1. Map of The Jones Center at Ichauway with the ownership boundary shown by white lines, as well as stands of the Adaptive Silviculture for Climate Change study. Figure produced by Gabriel Tigreros and Jason Suggs (The Jones Center at Ichauway).

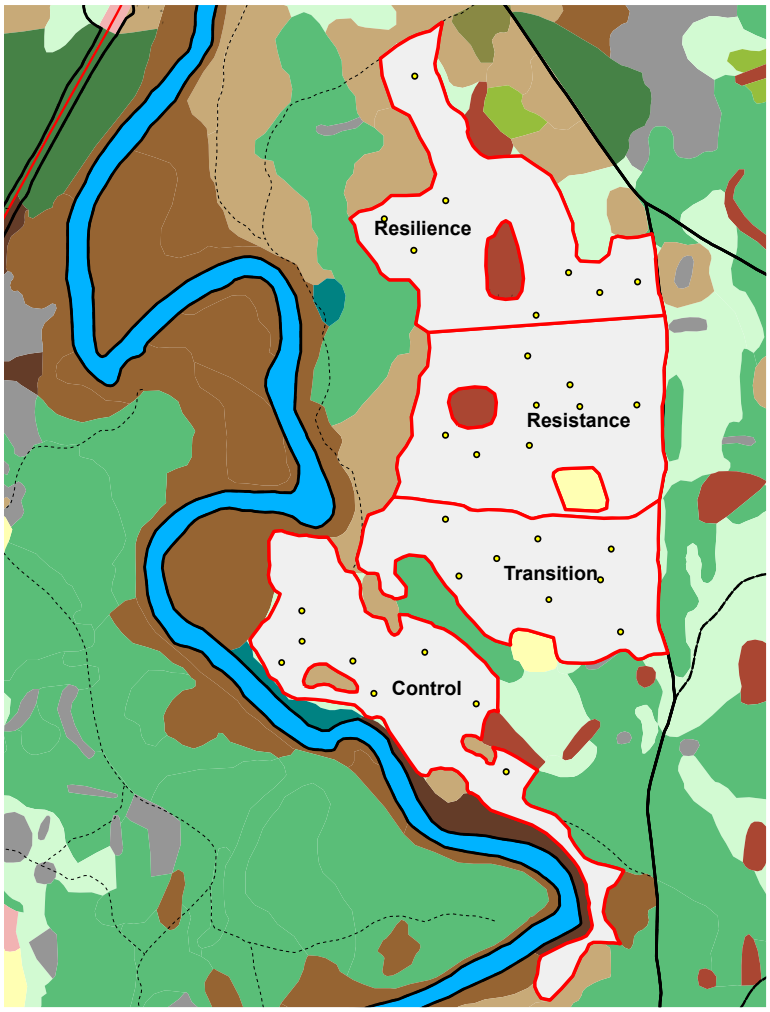

Figure 2. Map of Block C of the ASCC study at Ichauway with stand boundaries shown by red lines. Circles within stands represent permanent plots.

Plot Establishment and Initial Procedures

In 2017, eight 0.08-ha (1/5-ac) circular plots were established in each stand for measuring live trees and snags (i.e., standing dead trees). At the center of each permanent plot, a metal cap was mounted on rebar, and the rebar was pushed into the ground while ensuring that the cap was visible above the groundline. The study name (i.e., ASCC) and a unique plot number were engraved on each metal cap. All live trees with diameter at breast height (DBH; stem diameter at

1.37 m (4.5 ft)) ≥ 12.7 cm (5.0 in) were measured for DBH, height from the groundline to the base of the live crown, and total height, and species were recorded. A bark scribe was used to establish a line where diameter was measured, and the line was oriented towards plot center. Heights were measured with a laser rangefinder. Distance and azimuth from the plot center to trees were determined using a Haglof Postex base station. Each tree was assigned a unique tree number, which was engraved on an aluminum tag and nailed to the base of the tree. All snags with DBH > 10.0 cm (3.9 in) and total height > 1.37 m (4.5 ft) were measured for DBH and total height, and decay class (**Table 1**) and species were recorded. Distance and azimuth from the plot center to snags was also recorded, and each snag was assigned a unique tree number, which was placed on a curly stake at the base of the snag facing plot center.

Table 1. Standing dead tree (snag) decay class descriptions used during the pre-treatment inventory in 2017 and the post-treatment inventory in 2018.

Decay class	Description
1	Recently dead tree with intact tops and the majority of fine branching present.
2	Snags with loose bark, intact tops, and most of the fine branches.
3	Snags with < 50% of coarse branches and < 50% bark.
4	Snags with broken tops and few or no coarse branches; > 6 m in height.
5	Snags with broken tops and no coarse branches; ≤ 6 m in height.

Prior to 2022, trees with a DBH ≥ 8.9 cm (3.5 in) and < 12.7 cm (5.0 in) were tallied on a 0.04-ha (1/10-ac) circular plot sharing the same plot center as the 0.08-ha (1/5-ac) plots. Trees were tallied by the first 14 species listed in **Table 2** or tallied as "Other". Trees with DBH < 8.9 cm (3.5 in) were measured on three, 0.004-ha (1/100-ac) circular plots located at the 0.08-ha (1/5-ac) plot center and 8.02 m (26.3 ft) north and south of the 0.08-ha (1/5-ac) plot center. The centers of north and south subplots were marked with a 30 cm (11.8 in) piece of steel conduit. Trees on the 0.004-ha (1/100-ac) plots were tallied by the classes listed in **Table 3**. For the two

subplots plots located north and south of the 0.08-ha (1/5-ac) plot center, shrubs were tallied by species if they were within 1.26 m (4.13 ft) of these plot centers.

Table 2. Species codes assigned to trees in the ASCC stands at Ichauway.

Letter code	**Scientific name**	**Common name**
PIPA	Pinus palustris	longleaf pine
PITA	P. taeda	loblolly pine
PIEC	P. echinata	shortleaf pine
PIEL	P. elliottii	slash pine
QUFA	Quercus falcata	southern red oak
QUVI	Q. virginiana	live oak
QUST	Q. stellata	post oak
QUIN	Q. incana	bluejack oak
QULV	Q. laevis	turkey oak
QULA	Q. laurifolia	laurel oak
QUNI	Q. nigra	water oak
QUMA	Q. margaretta	sand post oak
SAAL	Sassafras albidum	sassafras
PRSE	Prunus serotina	black cherry
QU01	Quercus species	Oak
PI01	Pinus species	Pine
NYSY	Nyssa sylvatica	black gum
CAAA	Carya alba	mockernut hickory
COFL	Cornus florida	flowering dogwood

Table 3. Small tree and shrub classes prior to 2022 for the ASCC study at Ichauway.

Class	Description
0	Grass-stage longleaf pine < 30 cm in height
1	≥ 30 and ≤ 137 cm in height
2	> 137 cm in height and DBH ≤ 1.4 cm
3	DBH > 1.4 and ≤ 3.9 cm
4	DBH > 3.9 and ≤ 6.5 cm
5	DBH > 6.5 and < 8.9 cm

In 2017 and 2018, understory plant cover was measured using 1 m^2 (3.28 ft^2) sampling frames. The sampling frames were located 4 m (13.1 ft) from plot center at azimuths of 90°, 210°, and 330°. At each of these locations, a piece of steel conduit was inserted into the ground with 3 to 5 cm (1 to 2 in) of conduit exposed above the groundline. For the sampling frame located at 90° from plot center, the conduit marks the northeast corner of the sampling frame. For the sampling frame located at 210 from plot center, the conduit marks the east corner of the sampling frame. For the sampling frame located at 330° from plot center, the conduit marks the south corner of the sampling frame. For each sampling frame, a curly stake was used to mark the corner of the sampling frame that was diagonal to the corner marked with conduit. For plants that were rooted in a sampling frame, field crews moved all portions of those plants into the sampling frame. Portions of plants that were not rooted within the sampling frame were moved outside of the sampling frame. Grasses that form clumps were included in the frame if any portion of the grass was rooted within the sampling frame. Ariel cover was estimated by species, and all woody species < 1 m tall were included in the cover estimates.

Inventory Schedule

Inventories of trees and shrubs were conducted in 2017, after timber harvesting in 2018 but before Hurricane Michael, and every year thereafter until 2022. In 2019, new decay classes

were developed for snags (**Table 4**). In 2022, additional changes (including use of other decay class systems for dead wood) were made to the protocols, which are described in the **Field Procedures from 2022 to 2026** section. In 2022, it was also decided to switch from an annual to a four-year inventory cycle for live trees, and the most recent inventory of live trees was conducted in 2026. Starting in 2022, trees with DBH < 8.9 cm (3.5 in) were only measured on two, 0.004-ha (1/100-ac) circular plots located 8.02 m (26.3 ft) true north and south of the 0.08-ha (1/5-ac) plot centers. Also, all trees with DBH < 12.7 cm (5.0 in) were measured for DBH and species was recorded. In 2022, new protocols for measuring snags, coarse downed woody debris (DWD), stumps, and fine woody debris (FWD) were developed. In 2024, snags were measured for a second time. Because of the relatively short residence time of snags in this ecosystem, it was decided that snags should be measured every two years. All dead wood pools will be measured every four years. As of the time of this report, all dead wood was measured in 2022 and 2026. For each DWD piece that was measured in 2022 and relocated in 2026, the piece was assigned a unique piece number, and it was recorded on field sheets during the DWD inventory. In 2022, the aboveground portions of understory plants, as well as organic horizon and mineral soil samples were collected to estimate their mass and carbon concentration. The frequency of repeated sampling of these carbon pools has yet to be determined. Hemispherical photos and photos to visualize plot conditions have been taken from 2017 to 2022 and are planned for the summer of 2026.

Table 4. Standing dead tree (snag) decay class descriptions used during the 2019, 2020, and 2021 inventories.

Decay class	Description
1	Fresh Kill – All limbs and branches present; top pointed; 100% bark remaining; intact sapwood and heartwood.
2	Some Branches – A few limbs; no fine branches; top may be broken; variable amount of bark left; sapwood still firm.
3	No Branches – Limb stubs only; top broken; variable amount of bark; soft sapwood.
4	Sloughing Sapwood/Flame line – Few or no stubs from limbs or branches; broken top; variable amount of bark; sloughing sapwood; possible sapwood removed beneath the flame line.
5	Heartwood – No limbs or branches; no bark; heartwood only; charcoal, fat lighter if pine.
6	Fallen – Snag has fallen; bole is resting on the ground; remaining vertical stem > 1.37 m in height.

FIELD PROCEDURES FROM 2022 TO 2026

Overstory Trees

For each plot location, live trees with DBH ≥ 12.7 cm (5.0 in) are measured on a 0.08-ha (1/5-ac) circular plot (radius = 16.06 m (52.7 ft)) (**Figure 3**). Trees are measured starting from true north of plot center and working in a clockwise direction. For trees near the plot boundaries, field crews determine if a tree should be recorded by measuring the distance from the plot center pin (at ground level) to the center of the tree (at ground level). For each tree, the tree number (if previously assigned one) is recorded, or it is assigned a new tree number (one that has not been previously used for trees on the plot). If the tree tag is missing, the tree number is determined from the previous plot inventory records; field crews are provided with a copy of these records for reference in the field. The condition class 1 code (CC1, **Table 5**), as well as a four-letter species code (**Table 2**) is recorded. When species identification is not possible, the tree is assigned to a genus, species group (hardwood or conifer), or listed as unknown. For the condition

classes, the terms merchantable, rough cull, and rotten cull are based on USDA Forest Service Forest Inventory and Analysis definitions (USDA 2023).

Field crews also record the tree's DBH (cm, to one decimal place), height to the lowest live branch (m, to one decimal place), height to the crown point (m, to one decimal place), and total height (m, to one decimal place). Standard points for measuring DBH are chosen according to figure 5-3 in Husch et al. (2003). On page 99 of Husch et al. (2003), the crown point is defined as the position of the first crown-forming branch. Similar to the definition by Husch et al. (2003), but perhaps with a slight modification, the crown point is considered to be the height from the groundline to the location where most of the functional live crown begins. For mature longleaf pines, there can be a substantial distance between the lowest live branch and the next live branch. Office-generated values for the "functional live crown ratio" and live crown ratio can be derived using the height measurements. Azimuth (degrees; true) and distance (m, to two decimal places) is measured from plot center to the tree. If the tree has lean > 5° from vertical, the horizontal distance from the tree's base to a projected point from the top of the tree to a line that is perpendicular to the base of the tree is measured. The height from the projected point to the top of the tree is also measured. For trees with broken tops that have breaks that are not perpendicular to the length of the tree, the top of the tree should be considered the location where 50% of the volume occurs from the bottom of the break and the top of the break**.**

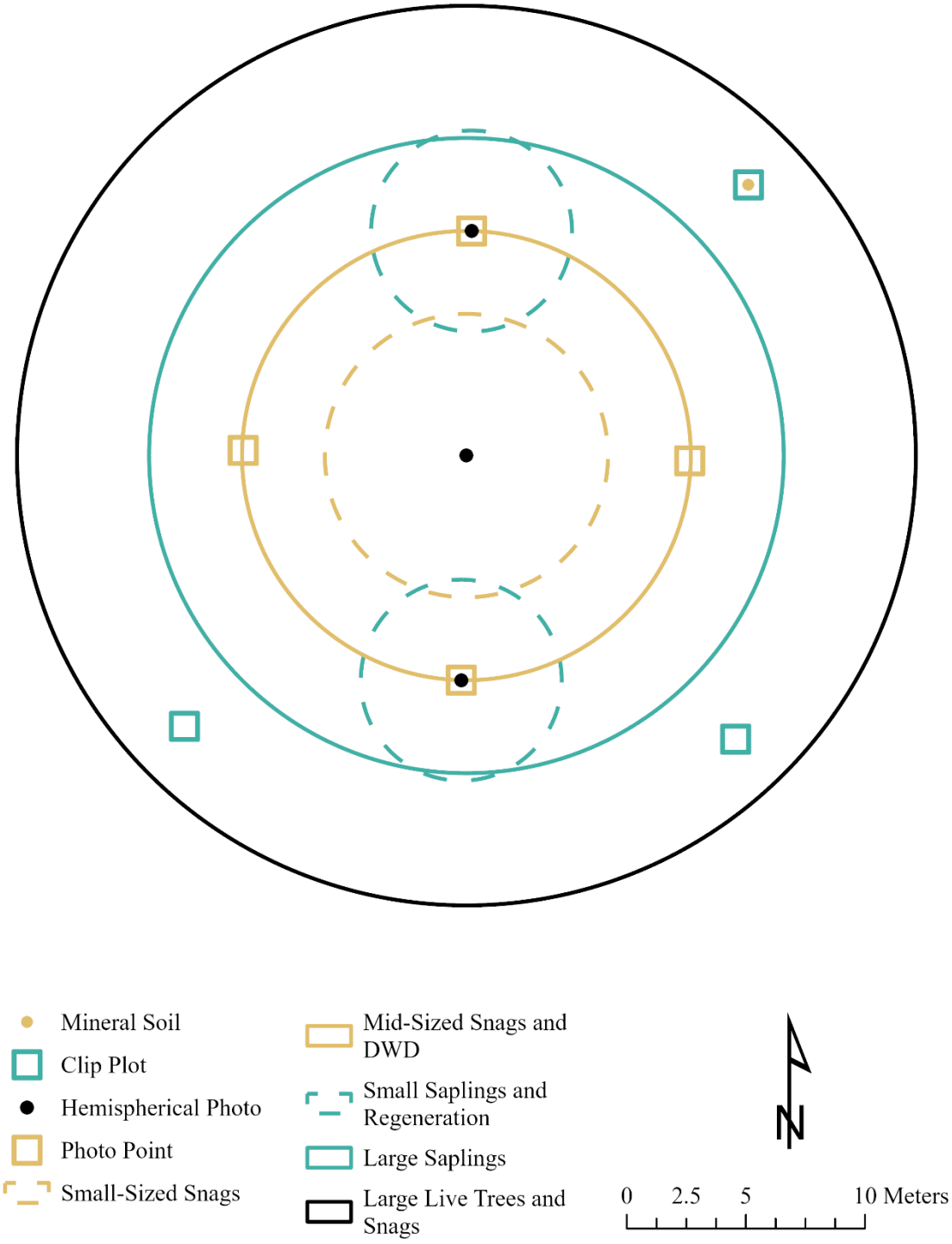

Figure 3. Permanent plot design used for inventories conducted from 2022 to 2026.

Table 5. Tree condition codes assigned to trees with diameter at breast height ≥ 12.7 cm (5.0 in). The codes are refinements of those produced by Waskiewicz et al. (2015).

CC1	
2	Tree ≥ 5.0 inches DBH and merchantable
3	Tree ≥ 5.0 inches DBH and rough cull
4	Tree ≥ 5.0 inches DBH and rotten cull
5	Ingrowth to pole class (≥5.0 inches DBH) and merchantable
6	Ingrowth to pole class (≥ 5.0 inches DBH) and rough cull
7	Ingrowth to pole class (≥ 5.0 inches DBH) and rotten cull
A	Mortality: animal damage
B	Mortality: breakage
D	Dead wood: recorded as mortality or dead wood in previous inventory
F	Mortality: consumed by fires
G	Mortality: girdled
H	Mortality: harvest
I	Mortality: insect or disease
L	Mortality: lightning (lightning scar visible on the tree)
S	Mortality: suppression
U	Mortality: uprooted by the wind
X	Mortality: other or undetermined cause of death
Z	Could not be located
CC2	
N	Dead wood: previously recorded stump or downed snag that is indistinguishable from the forest floor
D	Downed tree bole that is still attached to the stump
S	Standing snag (see methods for differences between a snag and stump)
P	Stump (see methods for differences between a snag and stump)
0	None of the above

Large Saplings

For each plot location, large live saplings are measured on a 0.04-ha (1/10-ac) circular plot (radius = 11.34 m (37.2 ft)). This plot shares the same plot center as the 0.08-ha (1/5-ac) circular plot for measuring overstory live trees. Large saplings are defined as trees with DBH ≥ 8.9 cm (3.5 inches) but no larger than 12.7 cm (5.0 inches). Trees are measured starting from true north of plot center and working clockwise. For trees near the plot boundaries, field crews determine if a tree should be recorded by measuring the distance from the plot center pin (at ground level) to the center of the tree (at ground level). For each tree, a four-letter species code (**Table 2**) is recorded. When species identification is not possible, the tree is assigned to a genus, species group (hardwood or conifer), or listed as unknown. The tree's DBH (cm, to one decimal place) is also recorded.

Small Saplings and Regeneration

For each plot location, small saplings and shrubs are measured on two 0.004-ha (1/100-ac) circular subplots (radius = 3.59 m (11.8 ft)). The centers of these subplots are located 8.02 m (26.3 ft) from plot center at azimuths of true north and south. Small saplings and shrubs are defined as woody vegetation that are at least 1.37 m (4.5 ft) tall with DBH < 8.9 cm (3.5 in). Trees and shrubs are measured starting from true north of subplot center and working clockwise. For trees and shrubs near the subplot boundaries, field crews determine if a tree or shrub should be recorded by measuring the distance from the subplot center conduit (at ground level) to the center of the tree or shrub (at ground level). For each tree and shrub, a four-letter species code (**Table 2**) is recorded. When species identification is not possible, the tree or shrub is assigned to

a genus, species group (hardwood or conifer), or listed as unknown. Diameter at breast height (cm, to one decimal place) is also recorded.

For longleaf pine seedlings < 1.37 m (4.5 ft) tall, height (cm, to one decimal place) from the groundline to the base of the apical bud is recorded. Longleaf pines in the grass stage are only measured if individuals have a groundline diameter ≥ 2.54 cm (1 in). If the base of the apical bud is located at the ground line, a height of 0 cm (0 in) is recorded. For other tree species and shrubs ≥ 30 cm (11.8 in) and < 1.37 m (4.5 ft) tall, individuals are tallied by species. For pines, the top of seedling is considered the base of the apical bud.

Understory Vegetation

The aboveground portions of understory plants are collected from 1 m^2 (3.28 ft^2) sampling frames. The centers of the sampling frames are located 14 m (45.9 ft) from plot center at azimuths of true NE, SE, and SW. Each sampling frame is positioned so that one of its corners is in alignment with the center of the sampling frame and plot center (i.e., true NE, SE, or SW of plot center). For each sampling frame, the date, plot number, azimuth from plot center (i.e., NE, SE, or SW), and species guild are labeled on paper bags and data sheets. All non-woody vegetation rooted within the sampling frame is clipped. Longleaf pines with a diameter ≤ 2 cm (0.8 in) at a height of 10 cm from the groundline are clipped. All other woody plants < 1.37 m (4.5 ft) tall are clipped. The specific guilds are: FB = forbs, FN = ferns, mushrooms, moss, and lichens, LG = legumes, OG = other grasses, WG = wiregrass, MO = mesic oaks (QUVI, QULA, and QUNI; **Table 2**), XO = xeric and upland oaks (QUFA, QULV, QUIN, QUST, QUMA; **Table 2**), RU = *Rubus* sp., WD = other woody species including woody vines, PI = poison ivy, poison oak, poison sumac, LP = longleaf pine, OP = other pine, YU = yucca, palmetto, and cacti.

Soils

Because all the ASCC stands at Ichauway are frequently burned, the soil organic (O) horizon is often limited to an O_i horizon, which is mainly composed of fresh pine needles and herbaceous litter. Hence, O_i, O_e, and O_a horizons are not collected separately for the ASCC stands at Ichauway. Litter is collected using a 0.5 m^2 (1.64 ft^2) sampling frame that is situated within the sampling frame for collecting understory vegetation. The 0.25 m^2 (0.82 ft^2) sampling frame is positioned so that one of its corners coincides with the corner of the clip plot that is closest to plot center. Litter includes cones, catkins, and other materials not accounted for along the transects for measuring fine woody debris (FWD) at the surface of the O horizon. Litter is collected after understory vegetation is clipped from the sampling frame.

Mineral soil is collected from the center of the sampling frame for clipping understory vegetation that is located NE of plot center. Mineral soil samples are collected after vegetation is clipped from the sampling frame and litter is collected. Because the first 10 cm (3.9 in) of mineral soil is often friable, a 10-cm (4 in) long brass ring with an internal diameter of 5.1 cm (2.0 in) is used to extract soil from the surface of the mineral soil to a depth of 10 cm (4 in). A wooden board is placed on top of the ring, and force is applied to the board so that the ring can be inserted into the soil. Then, soil is excavated from around the ring so that it can be removed and the soil within the ring is placed in a sealed plastic bag. Additionally, samples are collected from the 10–20 (4–8 in) and 20–50 cm (8–12 in) depth increments using an impact driven, split soil corer that contains 10-cm (4 in) long brass rings with internal diameters of 5.1 cm (2.0 in). Sample bags are labeled with the date, plot number, and depth increment.

Dead Wood

Measurement of coarse downed woody debris (DWD), stumps, and fine woody debris (FWD) are usually conducted before measurements of live trees and shrubs. Dead trees attached to the stump-root system that are > 45° from vertical are considered DWD. In situations where only a portion of the tree remains at breast height (e.g., a splintered tree), the tree is considered a snag (i.e., a standing dead tree) if there is ≥ 50% bole wood at or above breast height; otherwise, it should be classified as a stump. According to these criteria, snags include standing dead trees that have < 50% bole wood remaining at breast height, but no or little bole wood reduction at heights above 1.37 m (4.5 ft) which are less impacted by fire. The estimate of bole wood at breast height is based on the last recorded live tree DBH measurement. Estimates of bole wood at certain points above breast height are subjective but take into consideration the presence of bark and sapwood. For snags that were never measured as live or dead trees, diameter at ground line and an equation by Palik and Pederson (1996) are used to estimate DBH at time of tree death. Diameter at ground line is measured with calipers at two locations (if possible; otherwise, one location) and the values are averaged. Intact wood and bark at the base of the snag are used to determine the best locations to measure groundline diameter. Woody portions of trees separated from the stump or bole of a tree are considered DWD. For such pieces that are located above the forest floor (e.g., caught within the branches of live or dead trees), ocular estimates of piece diameters and length should be made.

Downed Woody Debris

A 0.02 ha (1/20-ac) circular plot (radius = 8.02 m (26.3 ft)) is used to measure DWD. This plot shares the same plot center as the 0.08-ha (1/5-ac) circular plot for measuring overstory

live trees. Each piece of DWD with a small-end diameter ≥ 7.6 cm (3.0 in) is measured. Pieces are measured starting from true north and working in a clockwise direction. For pieces that cross the plot boundary, only the portion lying within the plot is measured. If the largest ends of such pieces are outside the plot, the piece is measured if it has a diameter ≥ 7.6 cm (3.0 in) at the plot boundary. For each piece, field crews record the large-end diameter (cm, to one decimal place), small-end diameter (cm, to one decimal place; to a minimum small-end diameter of 7.6 cm (3.0 in)), length (m, to two decimal places; large-end to minimum or small-end diameter), decay class (for pine use Table 2 and Figure 1 of Ulyshen et al. (2018); for hardwoods use **Table 6**), and species (four letter code, e.g., PIPA for *Pinus palustris*; **Table 2**). Diameters are measured using calipers, along the axis of the ellipse (parallel to the forest floor). On pieces with pronounced basal flare (i.e., "butt swell," common on uprooted trees), diameter is measured above the flared portion of the piece and length is measured along the entire piece. When species identification is not possible, a piece should be assigned to a genus, species group (hardwood or conifer), or listed as unknown. Field crews record all measurements in metric units.

Table 6. Standing dead tree (snag), downed woody debris (DWD), and stump decay class descriptions used for hardwoods starting with the 2022 inventory of dead wood. Stump decay classes were also used for pines. Descriptions are modifications of those developed by Puhlick (2015) and Waskiewicz et al. (2015).

Snags	
1	Tree recently died. Top is intact but could be freshly snapped. Most fine branching is still present and some foliage may be attached. Bark is intact, wood is hard.
2	Top is intact but could have been snapped at time of death. Foliage is absent and most of the fine branches are absent. More than 50% of the coarse branches are left. Bark may begin to loosen, wood is hard.
3	Top is intact but could have been snapped at time of death. Fewer than 50% of the coarse branches are left. Bark may or may not have sloughed off.
4	Top is always broken. Usually, no coarse branches remain but possibly some of the largest branches are present. Bark may or may not have sloughed off. Some softening of the wood is detectable.
5	Top repeatedly broken. No coarse branches remain. Bark may or may not have sloughed off. Wood soft. Height of tree is severely reduced from its original height.
DWD	
1	Wood is intact and hard. All bark is intact. Twigs (<3 cm) are present. Shape is round. Tree may be elevated by supporting branches. No invading roots.
2	Wood is intact and hard. Bark has begun to fall off. Twigs are absent. Shape is round. Tree may still be elevated but sagging slightly. No invading roots.
3	Wood is hard to partially soft. A trace to no bark remaining. Tree is round. Tree sagging near the ground. Roots invade sapwood.
4	Wood is substantially decayed, and pieces easily slough off. Inner heartwood may be soft but is intact. Round to oval. All of tree is usually on the ground. Roots invade the heartwood.
5	Wood is decayed throughout. May be in many soft portions or powdery and resemble the soil. Oval. Tree is on the ground, partially sunken into the organic layer.
Stumps	
1	Recently cut. Wood is intact and hard. Most bark is intact. No invading roots.
2	Wood is intact and hard. Top of stump shows discoloration. Bark has begun to fall off. No invading roots.
3	Wood is hard to partially soft. Some or no bark remaining. Sapwood is decomposing. Roots invade sapwood.
4	Wood is substantially decayed and pieces easily slough off. Inner heartwood may be soft but is intact. Roots invade the heartwood.
5	Wood is decayed throughout. May be in many soft portions or powdery and resemble the soil.

Stumps

Stumps are measured on the same 0.02 ha (1/20-ac) circular plot that is used to measure DWD. Stumps are measured starting from true north and working in a clockwise direction. For stumps near the plot boundary, the stump is measured if the distance from the plot center (at ground level) to the center of a stump (at ground level) is ≤ 8.02 m (26.3 ft). For each stump, field crews record the diameter at the base (i.e., ground line), at the top of the stump, and at the position estimated to represent the average diameter along the length of the stump (cm, to one decimal place). Calipers are used to measure the base diameter at multiple locations (e.g., the long and short ends of an ellipse); the same is done for the other diameter measurements. Field crews also record stump height (m, to two decimal places; root collar to top of the stump), decay class (**Table 6**), and species (four letter code; **Table 2**). When species identification is not possible, a stump should be assigned to a genus, species group (hardwood or conifer), or listed as unknown. In situations where there is not a clean break at the top of the stump, field crews estimate the location where 50% of the volume occurs from the bottom of the break and the top of the splinter. Usually, this location is closer to the break rather than midway between the break and the top of the splinter. At that location, an estimate of diameter is made had the break not occurred and this value is record as the top diameter. Field crews also record height as the distance between the base of the stump and the location where 50% of the volume occurs from the bottom of the break and the top of the splinter. All measurements are recorded in metric units.

Fine Woody Debris

Field crews lay out tapes (which define the sampling planes) starting 8.02 m (26.3 ft) from plot center and extend the tapes toward the plot boundary. For each starting location, the sampling plane is 4 m. The starting locations are true N, E, S, and W. Slope is measured along the sampling plane using a Haglöf hypsometer (Haglof Inc.). In the first meter of each transect, field crews record the number of pieces that have a diameter of < 0.6 cm (0.25 in) at the point of intersection with the sampling plane. In the first two meters, field crews record the number of pieces that have a diameter of between 0.6 to 2.5 cm (0.25 to 0.99 in) at the point of intersection with the sampling plane. In the length of the transect (4 m), field crews record the number of pieces that have a diameter of between 2.5 to 7.6 cm (1.0 to 2.99 in) at the point of intersection with the sampling plane. Protocol from Brown (1974) are used: "Particles qualifying for tally include downed, dead woody material (twigs, stems, branches, and bole wood) from trees and shrubs. Dead branches attached to boles of standing trees are omitted because they are not downed vegetation. Cones, bark flakes, needles, leaves, grass, and forbs are not counted."

Standing Dead Trees

Snags with diameter at breast height (DBH) ≥ 11.4 cm (4.5 in) are measured on a 0.08-ha (1/5-ac) circular plot (radius = 16.06 m (52.7 ft)), snags with DBH ≥ 6.4 cm (2.5 in) are measured on a 0.02-ha (1/20-ac) circular plot (radius = 8.02 m (26.3 ft)), and snags with DBH ≥ 1.3 cm (0.5 in) are measured on a 0.008-ha (1/50-ac) circular plot (radius = 5.06 m (16.6 ft)). This is a nested plot design with all plots sharing the same plot center. These plots also share the same plot center as the 0.08-ha (1/5-ac) circular plot for measuring overstory live trees. Snags are measured starting from true north and working in a clockwise direction. For snags near the

plot boundaries, field crews determine if a snag should be recorded by measuring the distance from the plot center pin (at ground level) to the center of the snag (at ground level). For snags that were recorded as live trees during the first inventory in 2017 (i.e., trees with a CC1 of 2, 3, or 4; **Table 5**) or recorded as ingrowth after 2017 (i.e., trees with a CC1 of 5, 6, or 7; **Table 5**), the determination of whether or not to measure the snag should be based on the tree's diameter before time of death using previous tree records. For other snags, the diameter at time of death should be estimated by measuring diameter at groundline and then using an equation by Palik and Pederson (1996) to predict DBH from groundline diameter.

For each snag, a four-letter species code is recorded (**Table 2**). When species identification is not possible, the snag is assigned to a genus, species group (hardwood or conifer), or listed as unknown. Field crews also record the snag's actual DBH (cm, to one decimal place), height (m, to one decimal place), estimated lean (in degrees) from vertical, decay class (for pines use Table 3 of Ulyshen et al. 2018; for hardwoods use **Table 6**), whether it has a broken top, and azimuth and distance (m, to two decimal places) from plot center to the snag. If the snag has lean > 5° from vertical, the horizontal distance from the snag's base to a projected point from the top of the snag to a line that is perpendicular to the base of the snag is measured. The height from the projected point to the top of the snag is also measured and recorded. For splintered snags, the top of the snag should be considered the location where 50% of the volume occurs from the bottom of the break and the top of the splinter. This method should be used for snags with broken tops with breaks that are not perpendicular to the length of the tree. For snags with DBH ≥ 11.4 cm (4.5 in), field crews record the tree condition codes (CC1 and CC2 in **Table 5**) and the tree number (if previously assigned one) or assign the tree a new tree number

(one that has not been previously used for trees on the plot). If the tree tag is missing, the tree number is determined from the previous plot inventory records (if possible).

Hemispherical Photos

For each permanent plot, hemispherical photos are taken directly above plot center and the two subplots for measuring small saplings and regeneration. Photos are taken during July and August after overstory trees are measured in the dormant season. Longleaf pine leaf area is usually at its maximum during the months of July and August. Photos are taken using a Sony α6100 camera with a Regent's fisheye lens (Regent Instruments Inc., Quebec City, QB). Slope and aspect at each photo location are collected using a Haglöf hypsometer (Haglof Inc.) and compass. Slope (in degrees) is measured along the maximum downhill slope direction. Aspect is defined as the orientation of the maximum downhill slope, which the angle in degrees between the maximum slope direction and true north. These values are needed to correctly compute leaf area index and direct radiation values in WinSCANOPY (vPro 2020, Regent Instruments Inc.). Images are taken during uniform sky conditions and when the wind is minimal. Most images are collected approximately 45 minutes before sunrise and after sunset on cloudless mornings and evenings. While photos can be taken during the daytime with overcast sky conditions, it is discouraged because of greater variation in estimates of leaf area index.

Photo Points

Four photos are taken from each plot center after inventories of overstory trees. Photos are usually taken during the summer and fall with a digital camera (Olympus Stylus TG-2). A scale board with height markers is placed 8.02 m (26.3 ft) from plot center for reference (**Figure**

4). The board is first placed true north of plot center, then true east, south, and west. To center the board in the photo, the lower horizontal grid line on the camera screen is aligned with the 1.3-m mark on the board; this places the 2-m mark approximately in the center of the screen. Also, the vertical grid lines on the camera screen are used to position the scale board in the middle of the photo.

Figure 4. Photo taken true north of plot 110 in the control stand of Block C showing the 2-m scale board which centered in the frame of the photo.

Acknowledgements

I thank Scott Taylor for reviewing this report. I also acknowledge work done by Andy Whelan, Mary Frances Nieminen, Lisa Giencke, and other current and former staff at Ichauway to document protocols over time.

References

Brown, J. K. 1974. Handbook for inventorying downed woody material. USDA, For. Serv. Intermountain Forest and Range Experiment Station INT-16. 24 p.

Husch, B., T. Beers, and J. A. Kershaw, Jr. 2003. *Forest mensuration*. John Wiley & Sons, Inc., Hoboken (NJ).

Nagel, L. M., M. K. Janowiak, P. W. Clark, C. L. Peterson, M. R. Vicini, B. J. Palik, A. W. D'Amato, M. A. Battaglia, and C. W. Swanston. 2025. Ten years of Adaptive Silviculture for Climate Change: An applied, coproduced experimental framework. *Bioscience*. https://doi.org/10.1093/biosci/biaf170

Nagel, L. M., B. J. Palik, M. A. Battaglia, A. W. D'Amato, J. M. Guldin, C. W. Swanston, M. K. Janowiak, M. P. Powers, L. A. Joyce, C. I. Millar, D. L. Peterson, L. M. Ganio, C. Kirschbaum, and M. R. Roske. 2017. Adaptive Silviculture for Climate Change: A national experiment in manager-scientist partnerships to apply an adaptation framework. *Journal of Forestry* 115 (3): 167-178. https://doi.org/10.5849/jof.16-039

Palik, B. J., and N. Pederson. 1996. Overstory mortality and canopy disturbances in longleaf pine ecosystems. *Canadian Journal of Forest Research* 26 (11): 2035-2047. https://doi.org/10.1139/x26-229

PRISM Climate Group. 2021. Parameter-elevation regressions on independent slopes model. Available online at www.prism.oregonstate.edu.

Puhlick, J. J. 2015. *How silvicultural treatments and site quality affect carbon storage on the Penobscot Experimental Forest: A 60-year perspective*. Ph.D. dissertation dissertation, University of Maine, Orono, ME. 169 p.

Puhlick, J. J., M. A. Windmuller-Campione, and S. B. Jack. 2026. Adaptive silviculture for climate change in longleaf pine ecosystems. *Journal of Forestry*. https://doi.org/10.1007/s44392-025-00073-6

Ulyshen, M. D., S. Horn, S. Pokswinski, J. V. McHugh, and J. K. Hiers. 2018. A comparison of coarse woody debris volume and variety between old-growth and secondary longleaf pine forests in the southeastern United States. *Forest Ecology and Management* 429: 124-132. https://doi.org/10.1016/j.foreco.2018.07.017

USDA. 2023. The Forest Inventory and Analysis Database: Database Description and User Guide for Phase 2 (version 9.1).

Waskiewicz, J. D., L. S. Kenefic, N. S. Rogers, J. J. Puhlick, J. C. Brissette, and R. J. Dionne. 2015. Sampling and measurement protocols for long-term silvicultural studies on the Penobscot Experimental Forest. USDA Forest Service Gen. Tech. Rep. NRS-147. 32 p.

Example of a field sheet provided to field crews in 2026 for measuring overstory trees. Values for "ingrowth" trees are recorded on additional rows, and azimuth and distance from plot center to ingrowth trees are recorded in the notes.

Block: A Treatment: Transition Plot: 3 Page 1 of 1

Tree	Species	CC1	DBH	LLB	CP	TH	Tag Needed	Notes
171	PIPA							
172	PIPA							
173	PIPA							
174	PIPA							
175	PIPA							

Block: A Treatment: Transition Plot: 3 Page 1 of 1 **2022 ENTRIES**

Tree	Species	CC1	DBH	LLB	CP	TH	Distance	Degrees
171	PIPA	D					13.41	46
172	PIPA	2	50.7	9.9	15.7	25.5	10.12	91
173	PIPA	2	61.6	10.7	12.5	20.8	3.51	258
174	PIPA	D					15.57	273
175	PIPA	2	56.5	10.0	15.4	27.4	13.42	343

Downed Woody Debris Field Sheet

Date: _____ Block: _____ Treatment: _____

Plot: _____ Crew: _____

DLE (cm)	**DSE** (cm)	**Length** (m)	**DC**	**Species** (letter code)	**Azimuth to LE** (true)	**Distance to LE** (m)	**Notes**

Stump Field Sheet

Date: _____ Block: _____ Treatment: _____

Plot: _____ Crew: _____

Ground line diameter (cm)	**Top diameter** (cm)	**Average diameter** (cm)	**Height** (m)	**DC**	**Species** (letter code)	**Azimuth** (true)	**Distance** (m)	**Notes**

Page ____ of ____

Fine Woody Debris Field Sheet

Date: _________ Block: _________ Treatment: ______________________________________

Plot: __________ Crew: ____

Transect (starting point true N, E, S, or W of plot center): _____
Slope (%, along the sampling plane): _____________________
Piece Count:

< 0.6 cm (0.25 in) first 1 meter	0.6 to 2.5 cm (0.25 to 0.99 in) first 2 meters	2.5 to 7.6 cm (1.0 to 2.99 in) total length (4 meters)

Transect (starting point true N, E, S, or W of plot center): _____
Slope (%, along the sampling plane): _____________________
Piece Count:

< 0.6 cm (0.25 in) first 1 meter	0.6 to 2.5 cm (0.25 to 0.99 in) first 2 meters	2.5 to 7.6 cm (1.0 to 2.99 in) total length (4 meters)

Transect (starting point true N, E, S, or W of plot center): _____
Slope (%, along the sampling plane): _____________________
Piece Count:

< 0.6 cm (0.25 in) first 1 meter	0.6 to 2.5 cm (0.25 to 0.99 in) first 2 meters	2.5 to 7.6 cm (1.0 to 2.99 in) total length (4 meters)

Transect (starting point true N, E, S, or W of plot center): _____
Slope (%, along the sampling plane): _____________________
Piece Count:

< 0.6 cm (0.25 in) first 1 meter	0.6 to 2.5 cm (0.25 to 0.99 in) first 2 meters	2.5 to 7.6 cm (1.0 to 2.99 in) total length (4 meters)

Standing Dead Wood Field Sheet

Date: _____ Block: _____ Treatment: _____

Plot: _____ Crew: _____

species (letter code)	**DBH** (cm)	**broken top** (Y/N)	**degrees from vert. ***	**height** (m) **	**horiz. distance** (m) *	**decay class**	**azimuth** (true)	**distance** (m)	**CC1**	**CC2**	**tree #**

* Only if lean is > 5º from vertical.

** If lean is > 5º from vertical, record the height from the "projected point" to the top of the snag.

Notes: