Annual Report 2022: Decadal Shifts in Tree Health and Hydrology in Buttonland Swamp, Cache River Watershed, Illinois; SO#94201; Dr. Beth A. Middleton, U.S. Geological Survey, 700 Cajundome Boulevard, Lafayette LA 70506; 337-262-7618; middletonb@usgs.gov;
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REPORT SUMMARY

This annual report updates progress on a study of tree health and hydrology in Buttonland Swamp and Cache River IL swamps during 2022 (Appendix 1). Progress toward project objectives (i.e., hypothesis tests) and the most important finding for each objective includes the following.

Finding 1. Litter production along the Cache River Illinois was site-specific and did not vary by year. Root production was higher in swamps at the drier rather than wetter end of the flooding gradient between 2012-2022. The rate of *T. distichum* growth was higher in Snake Hole with mid-range environments rather than wetter or drier environments.

Finding 2. The hypothesis concerning sediment accumulation and tree growth was not relevant because of the near lack of sediment accumulation detected in Crawford Tract. Regional sediment deposition has been measured since 2005 in Deer Pond and Snake Hole, and the annual deposition in these swamps was higher than Crawford Tract (1 to 20 mm). An analysis of surface elevation change using Surface Elevation Tables (Fig. 2) in Crawford Tract, Eagle Pond, Deer Pond, and Snake Hole indicated that rates of elevation loss were similar in all four regional swamps noting that Deer Pond had a loss of 6 cm of elevation from 2005 to 2021.

Finding 3. There were no observations of seedling and sapling recruitment in the interior of Buttonland Swamp during the tree health survey in June 2022, and seedling recruitment was much less in Crawford Tract in the 2016-2022 study than in the 1990s. For Buttonland Swamp, regional climate data indicated that normal annual precipitation increased in 2011-2020 in comparison to 1991-2000 and 2001-2010 (119.3 to 135.2 cm $year^{-1}$, respectively). July maximum temperature and annual minimum temperature increased from 1991 to 2020.

Finding 4. Stochastic population growth models for Crawford Tract at low- and mid-elevation predicted that future *T. distichum* populations would increase because of the high frequency of seed, seedling, sapling, and tree life stages during the 1990s when conditions were frequently wet but not impounded. Overall, in regional swamps during the various study periods (1990s to 2022), *T. distichum* populations were predicted to be stable in the future. In the interior of Buttonland Swamp, conditions were impounded with 70% of trees either stressed or in decline.

CHANGES FROM THE PROPOSED STUDY FRAMEWORK

It was not possible to test the hypotheses as stated in the proposal because the sedimentation levels and water management differed from those anticipated during the design of the 2019-2022 studies. Evaluation of Hypothesis 2 required variation in sediment accumulation but measurements showed that sediment deposition was negligible at Surface Elevation (SET) Tables in Crawford Tract, with erosion apparent around tree roots in both Crawford Tract and Eagle Pond. The water levels in the interior of Buttonland Swamp were too deep to insert a SET

monument to measure elevation change. Hypothesis 2 was revised to evaluate sediment depth patterns in several areas of Buttonland Swamp.

Another problem for testing the original hypotheses was that year-round impoundment was the only hydrology experienced in the interior of Buttonland Swamp. Hypotheses 1-4 had been set up to test water management approaches related to an SDM report. Tree production, recruitment, and population growth were measured, but could not be related to variation in inundation (i.e., inundated vs. not inundated) during the study period (2016-2022). These hypotheses were recast to examine ecosystem responses of Buttonland Swamp in response to the impounded environments present in the 1990s vs. later decades. To better illuminate the response of tree health to hydrology, similar studies of Cache River swamps were conducted along a wetter to drier gradient from 2002 to 2022. The regional wet-to-dry gradient included: the interior of Buttonland Swamp, Heron Pond, Snake Hole, Wildcat Bluff, Section 8 Woods (2012-2022 only), low elevation Crawford Tract, Eagle Pond, mid-elevation Crawford Tract, Deer Pond, Section 8 Woods (2002-2011 only), and upper elevation Crawford Tract.

PROGRESS TOWARD PROJECT OBJECTIVES

Findings for Hypothesis 1. Litter production was higher in Crawford Tract in 2019-2022 than during 1992-1999 (i.e., year-round impoundment vs. early summer impoundment, respectively). Water regimes were also examined along a wetter-to-drier gradient from 2002 to 2022 across the Cache River region.

The studies in Buttonland Swamp and other Cache River swamps were set up to match those conducted elsewhere in the southeastern United States within the North American Baldcypress Swamp Network to allow for comparisons of the environment outside of the current conditions in southern Illinois. Year-round impoundment was the only hydrologic environment in the interior of Buttonland Swamp from 2016-2021, as well as during the 1990s. In Crawford Tract (only) litter production (Fig. 1) did not vary between the 1990s and 2016-2021 in Crawford Tract, although litter production was higher in the 1990s at higher elevations (Middleton and McKee, 2005), noting that the wetter end of the Crawford Tract gradient could not be found during the 2016-2021 study. In this study of regional litter production and tree growth along the Cache River, litter and tree production was site-specific and generally did not vary by year. Wood biomass was higher from swamps at the drier end of the flood gradient. Reproductive biomass captured in the litter traps was higher at Section 8 Woods in 2012-2022 after a levee break, when conditions became much wetter (Middleton, this study, unpublished). Root production was higher in swamps at the drier rather than wetter end of the flooding gradient, especially between 2012-2022. The rate of *T. distichum* growth was higher in Snake Hole with environments in the mid-range along the wet-to-dry gradient. Note that the impounded Crawford Tracts sites that were studied in the 1990s had lower levels of litter production at that time (Middleton and McKee, 2004), but these sites could not be located during 2016-2022. The impounded transects were across the old channel from the higher elevation transects of Crawford Tract, and these may have been damaged during dredge removal.

Following the AR4 model, the air temperature may increase by an average of 1.4^{o} C in the next 50 years (IPCC, 2014). Currently, production of *T. distichum* swamps is higher farther south along the White River in Arkansas where air temperatures are warmer (Middleton and McKee, 2005), but not in impounded conditions (Middleton and McKee 2004, 2005). A combination of impoundment and higher temperatures may make the *T. distichum* of southern

Illinois more susceptible to mortality in the future because of the reduced ability of *T. distichum* to access root carbon in hot anaerobic environments (Middleton and McKee, 2005).

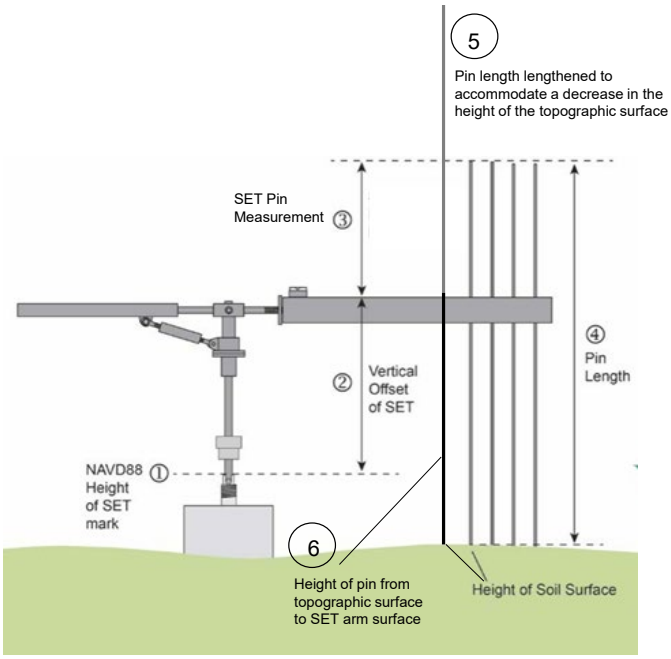
Fig. 1. Floating trap for litterfall from trees including leaves, twigs, and reproductive litter.

Findings for Hypothesis 2. Trees had higher production (litter and root) and growth at the higher vs. lower end of a sediment deposition gradient in Buttonland Swamp (2019-2022) if the inundation frequency was lower.

This hypothesis was not relevant to the assessment of tree litter and root production in Crawford Tract because of the near lack of sediment accumulation detected in this study. Sediment deposition was negligible on feldspar markers marked adjacent to the marker posts for SET 86 and 87 in Crawford Tract from 2018-2022 so Hypothesis 2 could not be tested even if restated. Tree roots were exposed at both Crawford Tract and Eagle Pond suggesting erosional environments at least on the edges of Buttonland Swamp. Regional sediment deposition has been measured since 2005 in Deer Pond and Snake Hole, and the annual deposition in these swamps was higher (1 to 20 mm) than in Crawford Tract.

An analysis of surface elevation change using Surface Elevation Tables (Fig. 2) in Crawford Tract, Eagle Pond, Deer Pond, and Snake Hole indicated that rates of elevation loss were similar in all four regional swamps noting that Deer Pond had a loss of 6 cm of elevation from 2005 to 2021.

Fig. 2. The distance of the ground surface to the monument of the Surface Elevation Table (SET) was measured using a leveled SET arm at each of two SETs in Crawford Tract and Eagle Pond from 2020-2022 and in Deer Pond and Snake Hole from 2005-2022. A SET is a specialized land surveying tool used to establish long-term changes in elevation at stationary survey monuments in wetlands (Cahoon et al., 2002). Relative elevations of the SETs were determined at Crawford Tract and Eagle Pond during a flood on April 18, 2022, and determined that the plots at Eagle Pond were about 20 cm lower than those at Crawford Tract along the mid-elevation transect.



Findings for Hypothesis 3. Seedling and sapling regeneration were only present in portions of Buttonland Swamp with growing season drawdown (i.e., higher elevations of the moisture gradient). In a permanently impounded swamp, seedling recruitment occurred only at the edge of the impoundment at the highest elevations (Middleton, 2000). Sapling regeneration was likely related to years of low annual precipitation and/or flooding in the swamp.

Seeds were captured in litter traps, and seedlings and saplings of *T. distichum* were recorded along three transects in 1 m^2 plots marked with wooden posts at 25 m intervals. The *T. distichum* trees nearest each plot were marked with dendrobands (tree growth study) or otherwise noted. These transects were drawn down during the growing season at the shallower edge of the impounded Buttonland Swamp e.g., in Crawford Tract and Eagle Pond during 2018-2022 and 2019-2022, respectively. There were no observations of seedling and sapling recruitment in the interior of Buttonland Swamp during the tree health survey in June 2022. Drawn down but not dry conditions are essential to transitions of seeds, seedlings, and saplings to the adult tree stage, with each stage successively more tolerant of either drought or flooding (Middleton, 2000).

Detailed analyses of seed, seedling, sapling and tree life history stages and transitions for *T. distichum* were made during the 1990s and compared to 2018-2022 in Crawford Tract, and in 2019-2022 in Eagle Pond to other Cache River swamps in 2002-2011 vs. 2012-2022 along a dry to wet gradient including Section 8 Woods, Deer Pond, Wildcat Bluff, Snake Hole, and Heron Pond. The frequency of transition between life history stages (i.e., seed to seedling to sapling to tree) was used to inform the stochastic growth models of projected future population growth in *T. distichum* to examine Hypothesis 4.

Regeneration success for species such as *T. distichum* depends on the presence of drawn down conditions during a part of the growing season (wet but not flooded or dry; Middleton, 2000). Seedlings and saplings were not killed by flooding during the winter season when these life stages are dormant (Middleton, 2000). It is worth noting that precipitation and flooding are increasing in the last 50 years based on a study of regional water gages (Mallakpur and Villarini,

2015). For Buttonland Swamp, regional climate data indicated that normal annual precipitation increased in 2011-2020 in comparison to 1991-2000 and 2001-2010 (119.3 to 135.2 cm $year^{-1}$, respectively). July maximum temperature and annual minimum temperature increased from 1991 to 2020.

Findings for H\ypothesis 4. Stochastic growth models of *T. distichum* population numbers (Caswell, 2002) showed no change in regeneration and population growth between 2019-2022 vs. 1992-1999 (year-round impoundment vs. early summer impoundment, respectively)**.**

Stochastic growth models can be used to project the stability of populations of species such as *T. distichum* based on the frequency of the transitions of life history stages in various environments (see Hypothesis 3). In Crawford Tract, *T. distichum* population projections were made with data from the 1990s and compared to projections based on data collected in 2018-2022. Projections were also made from life history transition data from regional swamps along a dry-to-wet gradient from 2002 to 2022. No population projection model was possible for the impounded interior of Buttonland Swamp because no regeneration was observed, noting that the original hypotheses related to year-round to early summer impoundment could not be tested.

Population projection models in Crawford Tract at low- and mid-elevation in the 1990s were predicted to increase, which was related to the high frequency of seed, seedling, sapling, and tree life stages at elevations that were frequently wet but not impounded. In regional swamps during the various study periods (1900s to 2022), *T. distichum* populations were predicted to be stable in the future. The exceptions were Section 8 Woods from 2002-2012 and the interior of Buttonland Swamp in 2022; these two swamps had no juvenile-size classes during those periods. The levels of regeneration in some swamps along the Cache River appear to be higher than in other parts of the southeastern baldcypress region where regeneration can be relatively rare.

Tree health of *T. distichum* was assessed in the interior of the Buttonland Swamp in permanently impounded conditions using visual estimates of live canopy cover and tree stress. In these trees within the permanent impoundment, 70% of the trees were either stressed or in decline (Fig. 3). In addition to static water conditions, other factors could drive stress in the *T. distichum* of Buttonland Swamp including chemicals and disease.

Fig. 3. Assessment of *T. distichum* tree health of Tree 6 (of 10) in the interior of Buttonland Swamp based on live crown ratio, leaf condition, tree stress, height, seedling/sapling presence using trees selected using a random toss method in the interior of the Buttonland Swamp.

	**Tree 6** Latitude/Longitude: 37.29508 N / -89.05147 W Height (m): 15.5 Live crown ratio: 15% Herbicide % foliage: 100% Leaf curl: slight Leaf epistasy: slight Leaf yellow: slight Leaf Munsell color: Hue: 5 (GY) Value: 4.5 Chroma: 6 Epicormic sprouting: no Tree health metric: decline Cypress seedlings/saplings: no/no *Lemna* % cover: 0 Notes: Six small cypress trees (10 m tall), 25 m from Tree 6.

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Appendix 1. Location map of the study sites for the decadal comparison of tree health and regeneration of *Taxodium distichum* in Crawford Tract and Eagle Pond in Buttonland Swamp, and long-term sites along the Cache River, Illinois including **A** Mississippi River Swamp Network of the North American Baldypress Swamp Network (NABSCN) with of study swamps, each with 4-7 replicates per location; ***B*** NABSCN swamps along Cache River including Crawford Tract, Eagle Pond, Deer Pond, Wildcat Bluff, Snake Hole, Heron Pond, and Section 8 Woods; ***C*** Location of IDNR/USGS study sites along Lower Cache River in Buttonland Swamp, Illinois including Crawford Tract (CT) site of 1991-2002, which was re-established in 2019 along with a new site at Eagle Pond (EP); ***D*** Plot design in Crawford Tract in 1991-2002 re-established in 2019 with five plots along each of three transects (elevation: ~101.32, 101.57, 102.00 m NBVD. Note that point bar transects within the channel from the 1991-2002 study could not be located (~99.31, 97.84) and may have been removed by dredging.