Forensic Wetland and Deepwater Habitat Mapping for Setting Pre-development Conditions

Stephanie Lawlor, Kai Rains, Shawn Landry, and Mark Rains
School of Geosciences, University of South Florida, Tampa, FL, USA
Email: krains@usf.edu

ABSTRACT

Mapping wetlands and deepwater habitats prior to modern settlement is difficult due to the difficulty of obtaining sufficient, spatially explicit data on conditions prior to the middle of the 20th century. We overcame this barrier by using Public Land Survey System data and other ancillary historical data to map wetlands and deepwater habitats in the 1850s in the mainland portion of St. Lucie County, Florida. Using just the Public Land Survey System data, a first draft map indicated there was 754 km^2 of wetlands and deepwater habitats covering 52% of the study area. After two iterations using other ancillary historical data, a third and final draft map indicated there was 1,222 km^2 of wetlands and deepwater habitats covering 84% of the study area, and overall increase of 62%. These results show that PLSS data can be used to map wetlands and deepwater habitats prior to modern settlement, but the use of other ancillary historical data can make maps more accurate and trustworthy. The outcome is a first-of-its-kind map of wetlands and deepwater habitats in the mainland portion of St. Lucie County, which is now representing baseline conditions in ongoing projects seeking to both quantify and mitigate for widespread land use-land cover change.

INTRODUCTION

In quantifying the effects of global change, we must start by setting the baseline conditions from which global change began (Knowlton and Jackson 2008). Lacking an appropriate baseline, we cannot quantify the loss of tropical forest from a study of the pasture, the loss of mangroves from a study of the condominium complex, or the loss of nearshore benthos from a study of the port. However, setting such a baseline is typically an optimization problem, in which we balance a desired baseline date, which might be in the distant past, and the availability of adequate historical data, which might only be available in the more recent past (e.g., Rains et al. 2013). In the case of wetlands, which have been ditched, drained, and converted to other land uses almost from the beginning of modern time, these adequate historical data are particularly difficult to acquire (Siemens 1983).

There is widespread availability of satellite imagery, but readily available, high-quality imagery dates only back to the late 20th century (Loveland and Dwyer 2012), so wetland change analyses that set baselines from satellite imagery cover only the most recent decades (Murray et al. 2022). There also is widespread availability of aerial imagery, but readily available, high-quality imagery dates only back to the mid-20th century (Morgan et al. 2010) such information was often acquired through manual interpretation of aerial photographs. As traditional methods of analyzing aerial photographs can be time-consuming, subjective, and can require well-trained interpreters (who are currently in short supply, so wetland change analyses that set baselines from aerial imagery cover only a few additional decades (Rains et al. 2013). For most of the conterminous United States, neither time is deep enough to quantify the widespread global change that has occurred since modern settlement (Waisanen and Bliss 2002).

Data dating back to the beginning of modern settlement in the conterminous United States are sparse (Waisanen and Bliss 2002). Dahl (1990) famously set baseline conditions to conduct a wetland change analysis for the conterminous United States since colonial settlement, using a variety of data sources but relying heavily on estimates of drained land in agricultural settings (e.g., Roe and Ayers 1954). However, Dahl (1990) also included an abundance of caveats regarding the general lack of accurate and trustworthy data. In the conterminous United States, this challenge is exacerbated by the prolonged history of land acquisition of each newly acquired territory, starting with the original 13 states being ceded to the newly founded United States by Great Britain in 1783 and continuing until the acquisition of portions of southern Arizona and New Mexico from Mexico through the Gadsen Purchase in 1853 (Burns 2017).

Surveying natural resources and partitioning ownership were among the first tasks set forth by the federal government. Survey records can be particularly valuable for constructing historical maps because they represent first-hand historical observations made by standard methods that can be used for both qualitative and quantitative analyses (Bourdo 1956). There were a variety of survey methods used historically but the most common was the Public Land Survey System (PLSS), particularly once territories achieved statehood (White 1983). PLSS data include both hand-drawn maps and hand-written notes and have proven to be useful in mapping pre-settlement vegetation (Schulte and Mladenoff 2001; Christy and Alverson 2011; Liu et al. 2011; Marcoe and Pilson 2017) Oregon. Of the 202 townships included in our study area, 148 (73%, though with caveats about the potential for inconsistency among individual surveys (Schulte and Mladenoff 2001; Liu et al. 2011)especially in the context of growing environmental change. However, historical records may have associated bias and error because their original purpose may not have been for scientific use. The Public Land Survey (PLS and the need for empirical calibration to overcome undermapping of pre-settlement wetlands and other hydrological features (Wang 2005). Therefore, we hypothesized that we could make a sufficiently accurate and trustworthy map of pre-settlement wetlands and deepwater habitats using the early PLSS survey data along with other ancillary historical data, at least where such features were large and widespread.

SITE DESCRIPTION

The study area was the 146,155-ha mainland portion of St. Lucie County, Florida (Figure 1). The climate is humid and subtropical, with a mean annual temperature of 23°C and a mean annual precipitation of 1300 mm (National Weather Service 2023). Surficial deposits are predominantly marine terrace sands and shelly sands that comprise a shallow, unconfined surficial aquifer, which overlie the discontinuously confined Floridan Aquifer (Miller 1997; Reese 2003). The landscape is low-lying and has a nearly level topography, rising gently from 0 to 20 m and with a mean elevation of approximately 7 m (Watts and Stankey 1980). Prior to settlement, most of the County's extensive wetlands and deepwater habitats were collectively named the Alpatiokee Swamp and most likely did not have a strong or permanent surface-water connection to down gradient waters (Bachmann 1861).

Florida was acquired from Spain through the Adams-Onis Treaty of 1819 and achieved statehood in 1845. Some of the earliest settlement in South Florida followed the Armed Occupation Act of 1842, which was "*an act to provide for the armed occupation and settlement of the unsettled portions of peninsular of East Florida*" (5 U.S. Statutes at Large 502; Covington 1961). In response, approximately 40 pioneers settled in the area along the Indian River Lagoon (Saint Lucie Historical Society 2023). A second attempt at widespread settlement in South Florida followed the Homestead Act of 1862, which was enacted to encourage "*actual settlement and cultivation*" (12 U.S. Statutes at Large 392; Clark and Marshall 1975). However, despite the government's best attempts, this section of Florida was only sparsely settled as a mere 93 land patents were granted within the 18 townships that make up the County in the 75 years between 1842-1927 (General Land Office 2023). Since that early settlement time, extensive drainage and the advent of air conditioning and other modern conveniences has led to widespread change, and the County had a population of 329,226 in 2020 (U.S. Census Bureau 2023). The County is now characterized by agriculture, especially citrus in the interior, and urbanization, including the cities of Port St. Lucie and Fort Pierce, on the coast.

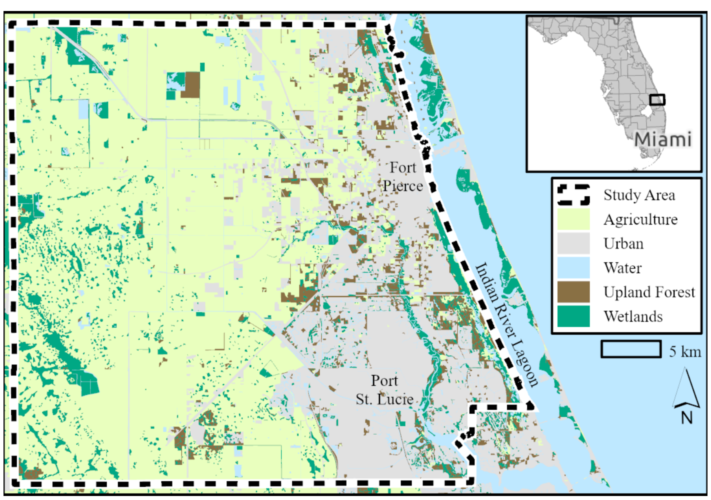
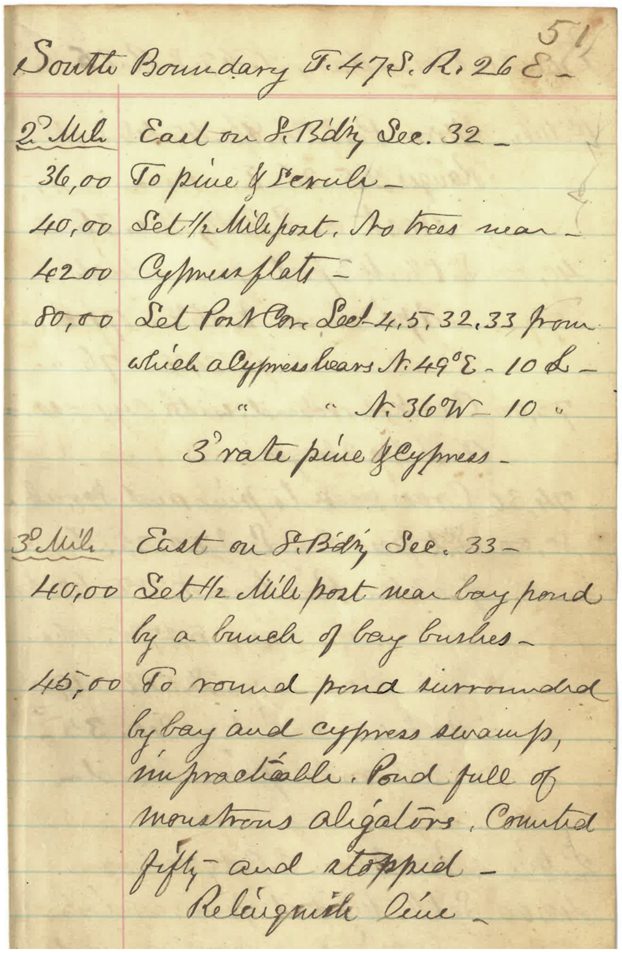


Figure 1. The study area is the 146,155-ha mainland portion of St. Lucie County, Florida. The north, west, and south borders are coincident with the County boundaries while the east border is defined by the mainland coastline of the Indian River Lagoon, which is an Outstanding Florida Water and an Estuary of National Significance. Barrier islands separate the Indian River Lagoon from the Atlantic Ocean, but they were not included in the study area. Data are from Florida Department of Environmental Protection (2023).

PLSS BACKGROUND

The PLSS divides all surveyed lands into 36 mi^2 townships, each comprised of 36 1 mi^2 sections. Surveyors, along with two chainmen, walked, measured, and mapped along the section lines, repeatedly laying a 66-ft, 100-link chain to mark distance, direction, and features along the section line. They mapped notable features intersected by the chain, including vegetation, timber, possible sources of ore, arable land, and prominent water features, taking detailed field notes of both the surveys and of their general observations (Dodds 1943) (Figure 2). Final cadastral land survey plats were then drafted from the field map sketches and surveyor notes back at headquarters. Cadastral land survey plats are standardized and spatially coordinated and can therefore be georeferenced, digitized, and analyzed quantitatively.

The early PLSS surveys of the mainland portion of the County took place between 1844-1859. During this time, the PLSS was overseen by the Bureau of Land Management (BLM) General Land Office (GLO), and the standards were being formed and refined (White 1983). Nevertheless, the mapping of hydrologic features, including what we now call wetlands and deepwater habitats, was always a priority. Prior to 1851, each State Surveyor General would issue general instructions and would then issue further specific instructions to surveyors for every survey contract. In 1845, the Florida Office of the Surveyor General issued general instructions to surveyors which included the following directive: *"You will carefully note the distances from your last corner post to the point where you meet with or leave any lakes, rivers, creeks, brooks, swamps, prairies, hills, roads, canals, or any other natural or artificial object, with their general course; and also take their bearings, so as to establish the position of any important object which you may see on either side of your line, that your field notes*


51
South Boundary T.47 S. R.26 E.
2d Mile East on S. Bdy Sec. 32
36,00 To pine & Scrub
40,00 Set 1/2 Mile post. No trees near
42.00 Cypress flats
80,00 Set Post Cor. Secs 4.5.32.33 from which a Cypress bears N.49°E. 10 L.
" " N.36 W. 10 "
3d rate pine & cypress
3d Mile East on S. Bdy Sec. 33
40,00 Set 1/2 Mile post near bay pond by a bunch of bay bushes
45,00 To round pond surrounded by bay and cypress swamp, impracticable. Pond full of monstrous aligators. Counted fifty and stopped.
Relinquish line.

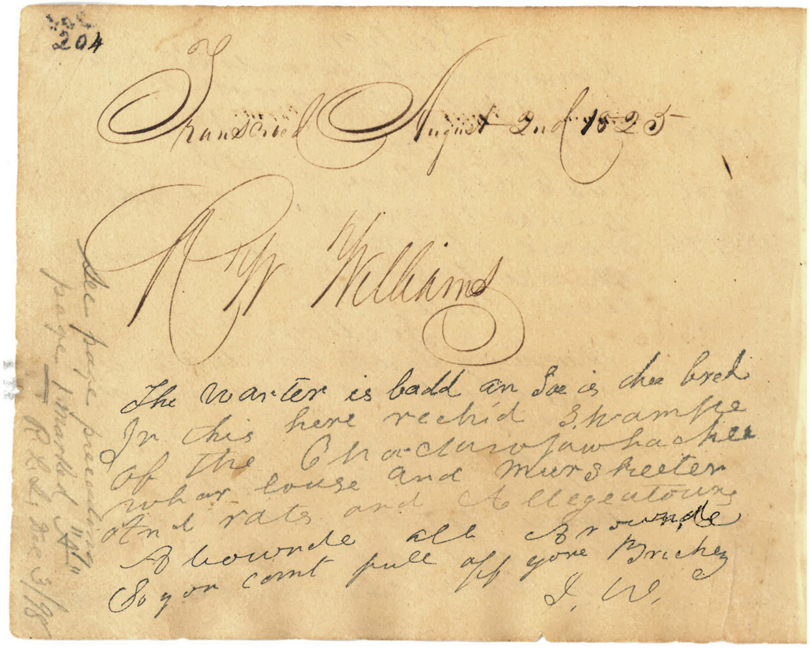

204
Transcribed August 2nd 1825
R W Williams
The warter is badd an Soe is the brek
In this here rechid Swampe
of the Choctawhatchee
whar louse and murskeeter
And rats and Allegators
Abownde all arownde
So yor cant pull off yore Briches
J. W.

Figure 2. Examples of surveyor's notes, from left-to-right, Township 47 South, Range 26 East in Lee County, FL (1872, W. L. Apthorp) and Township 3 North, Range 16 West in Washington County, FL (1825, J. Wright).

may afford a full and accurate topographical description of the country surveyed by you" (Surveyor General of Florida 1845). Instructions like these were soon codified nationwide. In 1851, the Commissioner of the GLO issued similar general instructions to surveyors in Oregon (Commissioner of the General Land Office 1851), which were quickly adopted by many states (White 1983). Subsequently, in 1855, the Commissioner of the GLO once again issued similar general instructions, this time to all surveyors nationwide (Commissioner of the General Land Office 1855). Meanwhile, the Swamp Land Act of 1850 (9 U.S. Statutes at Large 519) ceded federal land deemed wet or unfit for cultivation to the states, which further underscored the need for accurate surveys of these features.

METHODS

We acquired the 18 cadastral land survey plats and tract book (General Land Office 2018), survey notes (Florida Department of Environmental Protection 2018), and georeferenced PLSS boundaries (Bureau of Land Management 2018) for the mainland portion of the County. We also acquired *The Survey of Steamboat Routes from the St. Johns River, 1882* (Williamson 1882). We used standard tools in ArcGIS (ESRI, Redlands, California) to view, edit, and analyze map-related datasets throughout this process. We used the PLSS township and section corners as control points (minimum 5 per plat) to georeference the plats. We created the first draft map of wetlands and deepwater features in the 1850s by using the ArcGIS edit toolset to digitize pond, marsh, swamp, and wet prairie features (1:5,000) depicted on the georeferenced cadastral land survey plats while referencing the associated survey notes.

To assess the accuracy of this first draft map, we compared it to two historical ancillary data sources: 1) the tract book records of the acreages of land deemed wet or unfit for cultivation and thus ceded to the state as per the Swamp Land Act of 1850 and 2) the depiction of the general locations of wetlands and deepwater habitats in *The Survey of Steamboat Routes from the St. Johns River, 1882* (Williamson 1882). The tract book records indicated that a total of 1,131 km^2 of land in the mainland portion of the County was deemed wet or unfit for cultivation and was therefore ceded to the state. This exceeded the total area of wetlands and deepwater habitats in our first draft map. Similarly, *The Survey of Steamboat Routes from the St. Johns River, 1882* (Williamson 1882) depicted a geographically extensive system of wetlands and deepwater habitats in the southeast portion of the County that was otherwise missing from our first draft map. We digitized and added this to our first draft map, thus creating a second draft map.

To assess the accuracy of this second draft map, we compared it to a digitized map (1:5000) of wetlands and deepwater habitats as depicted in aerial imagery in the 1950s (Rains et al. in preparation). By 1950, there were only 20,073 inhabitants in the County (U.S. Department of Commerce 1950), and most of the limited development at

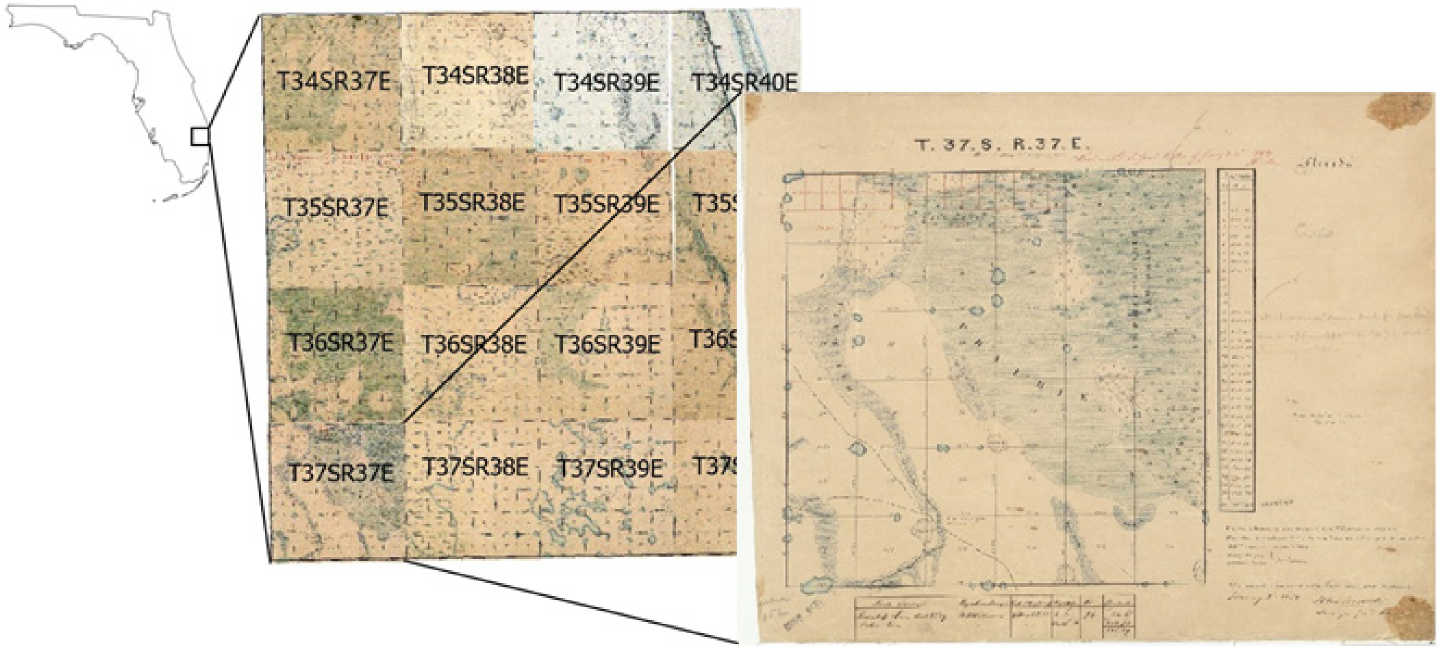


Figure 3. The 18 cadastral land survey plats covering the mainland portion of the County, with the cadastral land survey plat for Township 37 South, Range 37 East expanded.

that time was concentrated near the mainland coastline of the Indian River Lagoon, leaving large tracts of wetlands and deepwater habitats intact elsewhere in the County. During this review, we determined there were additional wetland and deepwater habitats missing from our second draft map, particularly in the southeast portion of the County. We added these features to the second draft map to create a third and final draft map of the wetlands and deepwater habitat map in the 1850s.

We assessed the internal consistency of the final draft of the map of wetlands and deepwater habitats in the 1850s by comparing the frequency of occurrence of wetlands and deepwater habitats the surveyors mapped along the section lines (i.e., expressed as a proportion of the total section line length within the mainland portion of the County) to the total area of the wetlands and deepwater habitats mapped in our final map of wetlands and deepwater habitats in the 1850s (i.e., expressed as a proportion of the total area of the mainland portion of the County). We also assessed the accuracy of the final draft map of wetlands and deepwater habitats in the 1850s by comparing the areas mapped to the areas ceded to the state as per the Swamp Act of 1850.

RESULTS

Our map of the wetlands and deepwater habitats in the 1850s went through three iterations: the first draft map of wetlands and deepwater habitats in the 1850s created directly from the PLSS data, the second draft map of wetlands and deepwater habitats in the 1850s created from the PLSS data and contemporary historical ancillary data, and the final map of wetlands and deepwater habitats in the 1850s created from the PLSS data, contemporary historical ancillary data, and the 1950s aerial imagery (Figure 4).

In the 1850s, wetlands and deepwater habitats were widespread. Total wetland and deepwater habitat area was 1,222 km^2, or 84% of the mainland portion of the County. Almost the entirety of the western interior portion of the County was wetlands and deepwater habitats. This is the geographically expansive, low-gradient, poorly drained

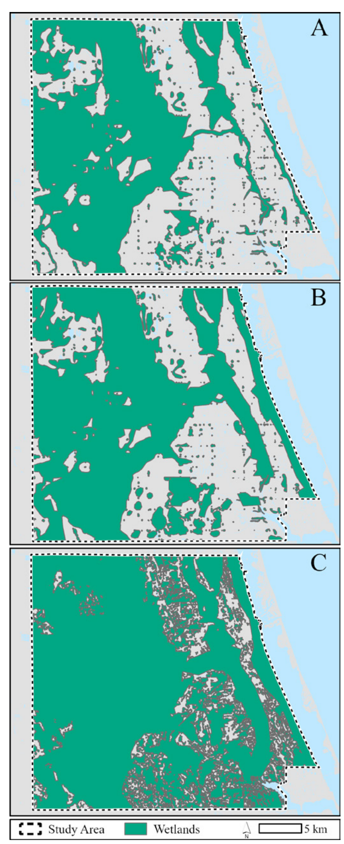


Figure 4. The development of a map of wetlands and deepwater habitats in the 1850s: (A) the first draft, with 754 km2 covering 52% of the mainland portion of the County, (B) the second draft, with 882 km2 covering 60% of the mainland portion of the County, and (C) the final draft, with 1,222 km2 covering 84% of the mainland portion of the County.

Eastern Valley geomorphic province (see Williams et al. 2022). Non-wetland and non-deepwater habitat areas were scattered but were predominantly located in the eastern portion of the County. This is the location of the north-by-northwest to south-by-southeast trending coastal dune ridges that occur along the Atlantic Coastal Ridge geomorphic province (see Williams et al. 2022).

Our validation gives us a high degree of confidence in the internal consistency and accuracy of our mapping. The best data are along the section lines, which the original surveyors walked. The frequency of wetlands and deepwater habitats (i.e., what the surveyors depicted as marshes, swamps, ponds, and wet prairies on their maps and surveyor notes) along these section lines was 83% of the mainland portion of the County. This is similar to our final map estimate of 84% of the mainland portion of the County. Furthermore, our final map estimate of 1,222 km^2 is within 10% of the 1,131 km^2 of land that was deemed wet or otherwise unfit for cultivation and was therefore ceded to the state, in accordance with the Swamp Act of 1850.

DISCUSSION

Mapping by inference from incomplete data is common throughout many fields and at all scales, from physicists using tools like electron tomography to map at the atomic scale (Ophus 2019), to geologists using mineralogy and biostratigraphy to map historical continental positions at the global scale (PALEOMAP Project and Scotese 2016), to astronomers using radio telescopes to map the universe at the galactic and extragalactic scales (Verschuur and Kellerman 1988). Here, we mapped wetlands and deepwater habitats by inference from incomplete data, developing the first detailed maps of the pre-development wetlands and deepwater habitats in the mainland portion of St. Lucie County, Florida (Figure 4).

The best-known baseline data for wetland and deepwater habitat area in the conterminous United States is from Dahl (1990). He used a variety of data sources but relied heavily on estimates of drained land in agricultural settings (e.g., Roe and Ayers 1954). This resulted in numerical estimates of total wetland and deepwater habitat area but did not result in a map, as much of the underlying data were aspatial. Our technique improves upon this and results in both numerical estimates of total wetland and deepwater habitat area and a map. It relies on the mapping products created when Florida achieved statehood, when surveying the resources and partitioning ownership were among the first tasks. We relied particularly on the PLSS survey data, which include both hand-drawn maps and hand-written notes, all of which are publicly available from the GLO (Figures 2 and 3).

PLSS data have been used previously to map historical vegetation (Schulte and Mladenoff 2001; Christy and Alverson 2011; Liu et al. 2011; Marcoe and Pilson 2017) Oregon. Of the 202 townships included in our study area, 148 (73%, though the data are notoriously inconsistent in quality, varying between individual surveys and even individual surveyors (Schulte and Mladenoff 2001; Liu et al. 2011). This was true in our case, as our PLSS data were comprised of 35 separate surveys conducted under seven different surveyors and completed over the course of 16 years (Figure 5). The early environment in Florida may have additionally led to mapping inconsistencies among surveyors. These individuals faced numerous hardships, including swamps and saw palmettos, alligators and snakes, and diseases like dysentery, malaria, and yellow fever, the diseases alone killing many surveyors in those earliest years (Knetsch 2006). These experiences were routinely logged in the surveyor notes. These were often included as formal notes in the survey data themselves, including from the survey along the south boundary of Section 33, Township 47 South, Range 26 East (Figure 2, left): "*45.00: To round pond surrounded by bay and cypress swamp, impracticable. Pond full of monstrous alligators. Counted fifty and stopped. Relinquished line.*" These were occasionally also included as informal notes which reflect more general observations, including what appears to be a poem from the survey of Township 3 North, Range 16 West in Washington County (Figure 2, right): "*The warter is badd and soe is the bred in this here rechid swampe of the Choctawhatchee, whar louse and murskeeters and rats and allegeatours abounde all arounde, so you cant pull off yore brichez.*"

We overcame the challenges of using PLSS data by also using other ancillary historical data. This was particularly important in the southeast portion of the County, which was largely lacking in wetlands and deepwater habitats in the first draft map of wetlands and deepwater habitats (Figure 4A). Ancillary historical data indicated our first draft had underrepresented wetlands and deepwater habitats. We reconsulted the surveyor notes and learned that surveyors in the southeast portion of the County commonly used the term "prairie" for features surveyors elsewhere in the County called "wet prairie." We retrained ourselves and created a second draft map of wetlands and deepwater habitats, increasing the mapped area of wetlands and deepwater habitats by 17% (Figure 4B). Additional ancillary historical data indicated our second draft continued to underrepresent wetlands and deepwater habitats, especially in the southeast portion of the County. Using these additional ancillary historical data, we created a final draft map of wetlands and deepwater habitats, increasing the mapped area of wetlands and deepwater habitats by an additional 39% (Figure 4C). The area of wetlands and deepwater habitats in our final map is within 10% of the area of land that was deemed wet or unfit for cultivation and was therefore ceded to the state in accordance with the Swamp Act of 1850. This underscores the importance of using the PLSS data along with other ancillary historical data to achieve a sufficiently

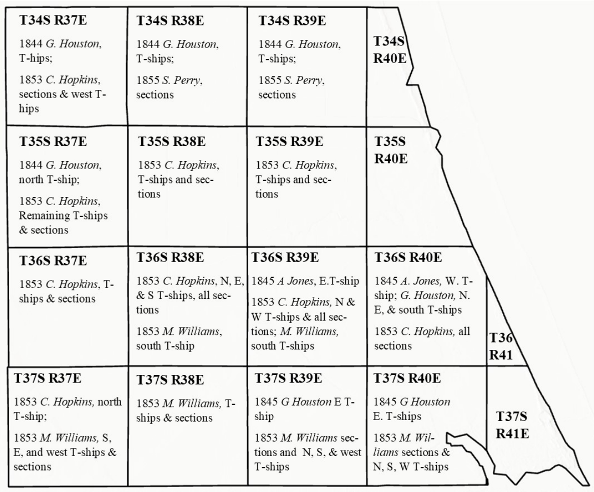


Figure 5. Dates and surveyors for the 18 PLSS cadastral land survey plats in the mainland portion of the County. There were 35 separate surveys conducted along township and section boundaries under seven different surveyors and completed over the course of 16 years. Survey details for the partial townships: T34S R40E (1844) G. Houston, Township boundaries; (1859) S. Harris, sections and resurvey of Townships. T35S R40E (1845) R. Jones, W Township boundary and G. Houston, section boundaries and the N and E Township boundaries; (1851) A. Randolph, N Township and some section boundaries; (1853) C. Hopkins, remaining section boundaries. T36S R41E (1845) G. Houston, Townships and sections. T37S R41E (1845) G. Houston, Township boundaries, A. Randolph, section boundaries.

accurate and trustworthy map of pre-development wetlands and deepwater habitats.

PLSS data are available in all or parts of 30 states that, collectively, comprise approximately 80% of the total land in the U.S. (National Research Council 1983). The remaining lands include most of the eastern states, Texas, Hawai'i, and parts of many other states. These were surveyed under different systems, ranging from the metes and bounds system in Maine (Brady 2019) to the Kingdom of Hawai'i system in Hawai'i (Williamson 1977), each of which can be used to various degrees to map historical conditions (e.g., Srinath and Millington 2016). Particularly useful datasets in coastal areas nationwide are historical NOAA Shoreline Surveys, which are also called T-Sheets. T-Sheets provide the authoritative definition of the U.S. high-water line and commonly include detailed maps of coastal features (Grossinger et al. 2005; Grossinger et al. 2011). These have been used to map coastal wetlands and deepwater habitats throughout the U.S. (Basso et al. 2015; Marcoe and Pilson 2017). However, whatever the base dataset, ancillary data are always essential to achieve desired accuracy and trustworthiness (Wang 2005), as wetland mapping is quite challenging even with today's best technology (Tiner 2015).

Our final map indicates that wetlands and deepwater habitats covered almost the entirety of the mainland portion of the County in the 1850s (Figure 4). The County is low-lying and has nearly level topography and few natural channels (Watts and Stankey 1980), so depressional, flat, and slope wetlands and deepwater habitats (sensu Brinson 1993) likely predominated (cf. Rains et al. 2011). Stated simply, rainfall probably did not move far across this landscape before it moved up into the atmosphere by evapotranspiration or down into the underlying Floridan aquifer by groundwater recharge. Therefore, like much of Florida, the mainland portion of the County has undergone extensive drainage and economic development since Florida achieved statehood in 1845 (Grunwald 2006), and looks very different today (Figure 1). Our final map is now available to represent baseline conditions as projects seek to both quantify and mitigate for these changes. These include a wetland change analysis between the 1850s, 1950s, 2000s, and 2020s (Rains et al. in preparation) and the development of a prioritization tool for planning wetland restoration for water-quality improvement funded to date by the U.S. Environmental Protection Agency and St. Lucie County and with support from the Florida Department of Environmental Protection and the Indian River Lagoon National Estuary Program. It also is serving to heighten stakeholder awareness of baseline conditions, and the extent to which Florida has changed as it has gone from a largely natural to a largely built landscape in the span of less than 200 years.

ACKNOWLEDGMENTS

This project was partially funded by Wetland Program Development Grant 02D16522 from the U.S. Environmental Protection Agency, a grant from St. Lucie County, a scholarship from the Fred L. and Helen M. Tharp Endowed Scholarship Fund, and exploratory funds from University of South Florida's Ecohydrology Research Group. The project was greatly enhanced by in-kind services and support from the St. Lucie County Environmental Resources Department, especially Amy Griffith, Jennifer McGee, Mike Middlebrook, and Aimee Cooper. The scanned surveyor notes in Figure 2 were provided by Karen McMillan, Program Manager in the Division of State Lands of the Florida Department of Environmental Protection.

REFERENCES

Bachmann J. 1861. Birds eye view of Florida and part of Georgia and Alabama [Map]. Library of Congress, Geography and Map Division, Washington, D.C. [accessed 2023 Aug 19]. http://hdl.loc.gov/loc.gmd/g3931a.cw0117200.

Basso, G., K. O'Brien, M.A. Hegeman, and V. O'Neill. 2015. Status and Trends of Wetlands in the Long Island Sound Area: 130 Year Assessment. Washington, DC: U.S. Department of the Interior, Fish and Wildlife Service.

Bourdo, E.A. 1956. A review of the General Land Office Survey and of its use in quantitative studies of former forests. *Ecology* 37(4):754–768. doi:10.2307/1933067.

Brady, M.E. 2019. The forgotten history of metes and bounds. *Yale Law J.* 128(4):872–953.

Brinson, M.M. 1993. A Hydrogeomorphic Classification for Wetlands. U.S. Army Corps of Engineers, Waterways Experiment Station, Wetlands Research Program Technical Report WRP-DE-4. Vicksburg: U.S. Army Corps of Engineers.

Bureau of Land Management. 2018. Bureau of Land Management Geospatial Business Platform: BLM ES PLSSFirstDivision. [accessed 2018]. https://gbp-blm-egis.hub.arcgis.com/datasets/BLM-EGIS::blm-es-plssfirstdivision/about.

Burns, A. 2017. *American Imperialism: The Territorial Expansion of the United States, 1783-2013*. Edinburgh: Edinburgh University Press.

Christy, J.A., and E,R, Alverson. 2011. Historical vegetation of the Willamette Valley, Oregon, circa 1850. *Northwest Sci.* 85(2):93–107. doi:10.3955/046.085.0202.

Clark, P.P., and J.F.B. Marshall. 1975. J. F. B. Marshall: A New England emigrant aid company agent in post-war Florida, 1867. *Fla Hist Q.* 54(1):39–60.

Commissioner of the General Land Office. 1851. Instructions to the Surveyor General of Oregon. General Land Office. [accessed 2023 Aug 21]. https://www.ntc.blm.gov/krc/system/files?file=legacy/uploads/14242/1851_Instructions_Oregon.pdf.

Commissioner of the General Land Office. 1855. Instructions to the Surveyors General of Public Lands of the United States. General Land Office. [accessed 2023 Aug 21]. https://www.ntc.blm.gov/krc/system/files?file=legacy/uploads/14246/1871_Instructions_to_the_S_G.pdf.

Covington, J. 1961. The Armed Occupation Act of 1842. *Fla Hist Q.* 40(1):41–52.

Dahl, T.E. 1990. Wetlands Losses in the United States, 1780's to 1980's. Washington, DC: U.S. Department of the Interior, Fish and Wildlife Service.

Dodds, J.S. 1943. Original Instructions Governing Public Land Surveys of Iowa. University of Wisconsin - Madison: Iowa Engineering Society.

Florida Department of Environmental Protection. 2018. Land Boundary Information System Records Search. [accessed 2018]. https://www.labins.org/survey_data/landrecords/landrecords.cfm.

Florida Department of Environmental Protection. 2023. Statewide Land Use Land Cover. [accessed 2023 Aug 21]. https://geodata.dep.state.fl.us/datasets/FDEP::statewide-land-use-land-cover/about.

General Land Office. 2018. General Land Office Records Search. [accessed 2018]. https://glorecords.blm.gov/search/.

General Land Office. 2023. General Land Office Records Search. [accessed 2023 Aug 6]. https://glorecords.blm.gov/search/.

Grossinger, R., R.A. Askevold, and J.N. Collins. 2005. T-Sheet Users Guide: Application of the Historical U.S. Coastal Survey Maps to Environmental Management in the San Francisco Bay Area. San Francisco Estuary Institute, SFEI Report No. 427.

Grossinger, R., E.D. Stein, K. Cayce, R. Askevold, S. Dark, and A. Whipple. 2011. Historical Wetlands of the Southern California Coast. San Francisco Estuary Institute, SFEI Contribution No. 586/Southern California Coastal Water Research Project, SCCWRP Technical Report No. 589.

Grunwald, M. 2006. *The Swamp: The Everglades, Florida, and the Politics of Paradise*. New York: Simon & Shuster.

Knetsch, J. 2006. *Faces on the Frontier: Florida Surveyors and Developers in the 19th Century*. Cocoa: The Florida Historical Society Press.

Knowlton, N., and J.B.C. Jackson. 2008. Shifting baselines, local impacts, and global change on coral reefs. *PLoS Biol.* 6(2):e54. doi:10.1371/journal.pbio.0060054.

Liu, F., D.J. Mladenoff, N.S. Keuler, and L.S. Moore. 2011. Broad-scale variability in tree data of the historical Public Land Survey and its consequences for ecological studies. *Ecol Monogr.* 81(2):259–275. doi:10.1890/10-0232.1.

Loveland, T.R., and J.L. Dwyer. 2012. Landsat: Building a strong future. *Remote Sens Environ.* 122:22–29. doi:10.1016/j.rse.2011.09.022.

Marcoe, K., and S. Pilson. 2017. Habitat change in the lower Columbia River estuary, 1870–2009. *J. Coast Conserv.* 21(4):505–525. doi:10.1007/s11852-017-0523-7.

Miller, J.A. 1997. The hydrogeology of Florida. In: *The Geology of Florida*. Gainesville: University Press of Florida. p. 69–88.

Morgan, J.L., S.E. Gergel, and N.C. Coops. 2010. Aerial photography: A rapidly evolving tool for ecological management. *BioScience* 60(1):47–59. doi:10.1525/bio.2010.60.1.9.

Murray, N.J., T.A. Worthington, P. Bunting, S., Duce, V., Hagger, C.E. Lovelock, R. Lucas, M.I. Saunders, M. Sheaves, M. Spalding, N.J. Waltham, and M.B. Lyons. 2022. High-resolution mapping of losses and gains of Earth's tidal wetlands. *Science* 376:744–749.

National Research Council. 1983. Procedures and Standards for a Multipurpose Cadastre. Washington, D.C.: National Academies Press. [accessed 2023 Aug 20]. http://www.nap.edu/catalog/11803.

National Weather Service. 2023. Monthly Climate Normals (1991-2020) – Fort Pierce St. Lucie County Intl Ap, FL. [accessed 2023 Aug 26]. https://www.weather.gov/wrh/Climate?wfo=mlb.

Ophus, C. 2019. Four-dimensional scanning transmission electron microscopy (4D-STEM): From scanning nanodiffraction to ptychography and beyond. *Microsc Microanal.* 25(3):563–582. doi:10.1017/S1431927619000497.

PALEOMAP Project, and Scotese, C. 2016. PALEOMAP PaleoAtlas for GPlates and the PaleoData Plotter Program. [accessed 2023 Apr 29]. https://gsa.confex.com/gsa/2016NC/webprogram/Paper275387.html.

Rains, K., S. Lawlor, E. Guerron-Orejuela, W. Kleindl, S. Landry, and M. Rains. In preparation. More channels, fewer wetlands: The stunning transformation of Florida's waterscape between the 1850s-2020.

Rains, M.C., S. Landry, K.C. Rains, V. Seidel, and T.L. Crisman. 2013. Using net wetland loss, current wetland condition, and planned future watershed condition for wetland conservation planning and prioritization, Tampa Bay watershed, Florida. *Wetlands* 33(5):949–963. doi:10.1007/s13157-013-0455-4.

Rains, M.C., K.C. Rains, W.J. Kleindl, S. Landry, T.L. Crisman, A. Brown, and L. Vanmaurik. 2011. Wetland Inventory and Evaluation, St. Lucie County, Florida. Tampa: University of South Florida.

Reese, R.S. 2003. Hydrogeology, Water Quality, and Distribution and Sources of Salinity in the Floridan Aquifer System, Martin and St. Lucie Counties, Florida. U.S. Geological Survey, Water-Resources Investigations Report 03-4242. Washington, DC: U.S. Geological Survey.

Roe, H.B., and Q.C. Ayers. 1954. *Engineering for Agricultural Drainage*. New York: McGraw-Hill Book Company.

Saint Lucie Historical Society. 2023. Indian River Colony. [accessed 2023 Aug 26]. https://stluciehistoricalsociety.net/indian-river-colony/.

Schulte, L.A., and D.J. Mladenoff, 2001. The original U.S. Public Land Survey records: Their use and limitations in reconstructing presettlement vegetation. *J For.* October:5–10.

Siemens, A.H. 1983. Wetland agriculture in pre-Hispanic Mesoamerica. *Geogr. Rev.* 73(2):166. doi:10.2307/214642.

Srinath, I., and A. Millington. 2016. Evaluating the potential of the original Texas Land Survey for mapping historical land and vegetation cover. *Land* 5(1):4. doi:10.3390/land5010004.

Surveyor General of Florida. 1845. General Instructions to Deputy Surveyors. Florida Office of the Surveyor General. [accessed 2023 Aug 21]. https://ftp.labins.org/GLO/glo_instructions_pdfs/GLOGPP1845.pdf.

Tiner, R.W. 2015. Introduction to wetland mapping and its challenges. In: *Remote Sensing of Wetlands: Advances and Applications*. Boca Raton, Florida: CRC Press. p. 43–65.

U.S. Census Bureau. 2023. QuickFacts: St. Lucie County, Florida. [accessed 2023 Aug 21]. https://www.census.gov/quickfacts/stluciecounty-florida.

U.S. Department of Commerce. 1950. 1950 Census of Population. Series PC-2, No. 9. Washington, DC: U.S. Department of Commerce.

Verschuur, G.L., and K.I. Kellerman. 1988. *Galactic and Extragalactic Radio Astronomy*. Berlin: Springer Science & Business Media.

Waisanen, P.J., and N.B. Bliss. 2002. Changes in population and agricultural land in conterminous United States counties, 1790 to 1997. *Glob. Biogeochem. Cycles* 16(4):84-1-84–19. doi:10.1029/2001GB001843.