pepper (*Schinus terebinthifolius)* is found at the edges and carrotwood (*Cupaniopsis anacardioides*) is beginning to colonize openings. Once established, coastal hammock might resist invasion by non-natives, somewhat relieving land managers of expense on non-native treatment.

Land management decisions concerning expenditure of resources in the TI should take anticipated sea level rise into account. The TI are generally less than 1 m NAVD 1988, making them especially susceptible to sea level rise. Vulnerability to sea level rise is depicted in Figure 5. Sea level rise predicted by IPCC (2007) for end of this century (18–59 cm) would result in loss of from about half the area of the hammocks to all of Salmela and most of Provost. However, some workers point out that the IPCC estimates are likely to be too conservative, and that sea level might rise by more than a meter by the end of this century (Jevrejeva, Moore, & Grinsted, 2010).

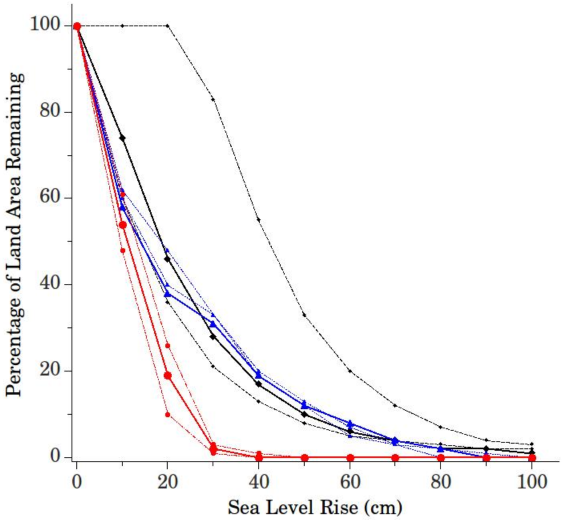

Fig. 5. Representation of hammock areas in relation to sea level rise. Black=TI, blue=Provost, red=Salmela. Faint lines represent 95% confidence intervals.

As is evident in the figure, only 20 cm of sea level rise significantly diminishes the area of the hammocks, and this amount has been projected to occur by 2050 (Vermeer & Rahmstorf, 2009). A rise of 50 cm submerges the majority of the TI. This grim prospect for long-term survival of the TI suggests consideration be given prior to investment of scarce resources if upland restorations are competing for funds. Future research will compare dredge spoil to hammock soil, and investigate recruitment rates on dredge spoil.

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Tropical Hammock Vegetation in the Thousand Islands, Brevard County, Florida: Species Composition and Susceptibility to Sea Level Rise.

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Abstract: Coastal hammock vegetation in the Thousand Islands (TI) is associated with two pre-Columbian shell middens, named Provost and Salmela Hammock. These middens provide a source population of tropical and subtropical coastal hammock species for recruitment to islands modified by dredge spoil during mosquito control efforts and housing development in the late 1950s through early 1970s. Significant recruitment has taken place in some dredged areas. I suggest that this coastal hammock community be considered a viable restoration goal following removal of invasive non-native vegetation in the TI.

The TI are located in the Banana River Lagoon, Brevard County, east-central Florida (Fig. 1). Morphology and sediment stratigraphy indicate that these islands comprise the relict shoals of an approximately 350 ha flood tide delta deposit generated during what must have been a significant storm (R. Parkinson, 2005, pers. commun.).

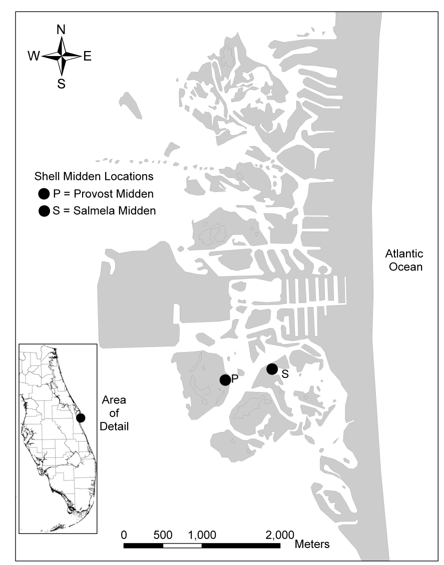

Fig. 1. Location of the Thousand Islands, Provost and Salmela shell middens, Brevard County, East-Central Florida. (source: `http://www.fgdl.org/metadataexplorer/explorer.jsp`)

Prior to development, vegetation of the TI was principally mangrove and succulent salt marsh (Fig. 2). Beginning in the late 1950s, small ditches were dug through the islands to allow water movement and fish access to inner areas of the succulent marsh for mosquito control (J. Salmela, 2000, pers. commun.). During the late 1960s Brevard County Mosquito Control began dredging the TI south of Minutemen Causeway, resulting in conversion of salt marsh to upland dredge spoil (J. Beidler, 2011, pers. commun). In 1972 construction of the C-34 impoundment began on approximately 100 acres of state-owned islands. This section of islands was completely impounded with a perimeter dike to allow mechanical flooding of the marsh during mosquito breeding season to prevent oviposition (Provost, 1971). The C-34 impoundment has not been managed in this way since the 1980s (S. Taylor, 2000, pers. commun.).

Fig. 2. Example of mangrove and succulent marsh, adjacent to Provost Hammock.

Prior to construction of the C-34 perimeter dike, vegetation surveys were conducted by the Florida Medical Entomological Research Center, as part of permitting for construction (Salmela, 1972). During the survey Bidlingmayer (1970) noted the existence of an area of shell midden hammock (recently named for Provost). The C-34 perimeter dike was constructed inside the hammock, (Fig. 3) to avoid flooding it (Provost, 1971). A similar hammock I found nearby and named Salmela was not mentioned in any documentation, but was also left unmodified.

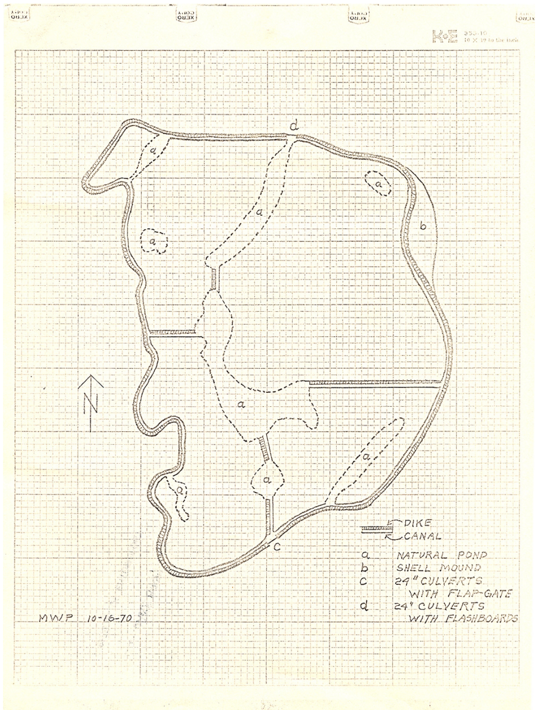

Fig. 3. Figure from Provost, 1971, depicting proposed construction of C-34 impoundment. Note location of perimeter dike and "shell mound."

Materials and Methods—This research was conducted to determine the relative abundance of tropical plant species in two coastal hammocks located on shell middens in the TI, evaluate similarity between the TI and Maritime Hammock Sanctuary/Turtle Mound hammocks, and to determine their susceptibility to sea level rise expected to occur this century.

I established long-term monitoring transects in March, 2012 to characterize hammock vegetation and track future response to rising sea level. No voucher specimens were collected. Historic hammock areas were delineated by aerial photographs, LiDAR-based elevation data, and soils. Aerial photographs were acquired from the University of Florida (`http://web.uflib.ufl.edu/maps/Aerials/MAPNEWAERIAL.HTML`) and georeferenced in a GIS. Dredge spoil is readily distinguished from sandy hammock soil by presence of benthic material, e.g. bivalve and gastropod shells.

I sampled vegetation using point intercept (Mueller-Dombois and Ellenberg, 1974). Transects were 10 m long and placed haphazardly so as to represent the entire hammock while minimizing disturbance. Points were taken at 1 m intervals along each transect. I marked endpoints with PVC poles and recorded positions using a Trimble GPS unit with differential correction. I calculated percent cover by dividing the number of points at which a species occurred in each transect ($n = 25$ for each hammock) by the total number of points per transect (11).

To determine minimum elevation of hammock vegetation (NAVD 1988) I collected 86 GPS points at the transition of saltmarsh to hammock vegetation, avoiding steep banks where even submeter horizontal error would result in larger vertical error. Mean value and 95% confidence interval were used in calculations. Plant classification follows Wunderlin and Hansen (2011).

Results—A typical view of hammock vegetation is shown in Figure 4. Both hammocks had an approximate area of 2500 m^2 prior to modification, as estimated from GIS. All subtropical/tropical hammock species listed by Bidlingmayer (1970) are still found in the TI except Florida fiddlewood (*Citharexylum fruticosum* now *C. spinosum*) which I have not seen in the TI.

Fig. 4. Typical view of hammock vegetation, depicting sparse understory and dense stem counts.

Species occurring at Provost and Salmela hammocks now but not listed by Bidlingmayer include Jamaican capertree (*Capparis jamaicensis*), giant airplant (*Tillandsia utriculata*), marlberry (*Ardisia escallonoides*), and pigeon plum (*Coccoloba diversifolia*) (Table 1). *Randia aculeata* exhibited the greatest relative abundance at Provost with 30.91% cover (± 10.24 at 95% confidence). *Eugenia foetida* exhibited the greatest relative abundance at Salmela with 49.82% cover (± 8.44 at 95% confidence). Salmela hammock had seven species not found at Provost. Possible explanations include Salmela hammock being somewhat closer to the barrier island and its having a greater amount of shells than Provost.

Table 1. Percent cover (%C) of tropical hammock species by location with standard error (SE).

Species	% C (Prov.)	SE	% C (Sal.)	SE
Randia aculeata	31.27	5.12	24.36	4.22
Eugenia foetida	21.45	4.81	50.18	4.33
Eugenia axillaris	16.36	3.36	24.00	4.19
Myrcianthes fragrans	7.27	3.40	11.64	5.05
Capparis flexuosa	6.18	1.65	10.18	2.84
Chiococca alba	2.91	1.14	4.00	1.40
Amyris elemifera	2.55	1.34[a]	11.64	2.75
Erythrina herbacea	1.45	0.86[a]	3.27	1.38
Capparis jamaicense	0.36	0.36[a]	2.55	0.98
Coccoloba diversifolia	0.00	N/A	9.09	4.07
Krugiodendron ferreum	0.00	N/A	6.91	2.18
Guapira discolor	0.00	N/A	5.09	2.63[a]
Sideroxylon celastrinum	0.00	N/A	2.91	1.46[a]
Bursera simaruba	0.00	N/A	1.82	1.29[a]
Zanthoxylum fagara	0.00	N/A	1.09	1.09[a]
Ardisia escallonioides	0.00	N/A	0.36	0.36[a]
Bare	7.64	2.08	1.82	0.91

[a] Indicates 95% confidence interval contains zero.

Associated plants found at these hammocks are listed in Table 2, and include live oak (*Quercus virginiana*), saw palmetto (*Serenoa repens*), privet (*Foresteria segregata*), and southern red cedar (*Juniperus virginiana*). The hammocks also contain the following epiphytes: *Tillandsia recurvata*, *T. usneoides*, and *T. utriculata*. Privet is common in dredged areas throughout the TI. Wax myrtle (*Myrica cerifera*) is also common in dredged areas of the TI but is lacking in the hammocks.

Table 2. Percent cover (%C) of associated tropical hammock species by location with standard error (SE).

Species	% C (Prov.)	SE	% C (Sal.)	SE
Forestiera segregata	4.36	1.50	4.36	1.58
Juniperus virginiana	3.64	1.96[a]	0.00	N/A
Serenoa repens	0.00	N/A	4.73	2.47[a]
Quercus virginiana	0.00	N/A	1.82	1.82[a]
Opuntia stricta	0.00	N/A	0.36	0.36[a]
Tillandsia recurvata	4.00	1.49	2.91	1.26
Tillandsia usneoides	1.82	0.74	2.55	0.98
Tillandsia utriculata	0.00	N/A	1.09	1.09[a]

[a] Indicates 95% confidence interval contains zero.

Jaccard similarity coefficients for tropical vegetation are given in Table 3 for the Thousand Islands (TI) as a whole, Maritime hammock in south Brevard County, and Turtle Mound in Volusia County. Both are also coastal hammocks. Tropical vegetation is defined as having a distribution limited to coastal Florida. Tropical vegetation in the Thousand Islands more closely resembles that found in the Maritime Hammock Sanctuary, located approximately 40 km south of the TI, than at Turtle Mound, located approximately 70 km north of the TI.

Table 3. Jaccard similarity coefficients for Thousand Islands, Maritime Hammock Sanctuary, and Turtle Mound.

Baseline Location	Maritime Hammock Sanctuary	Turtle Mound
Thousand Islands	0.69	0.31

[a] $J(TI, MHS) = \frac{|TI \bigcap MHS|}{|TI \bigcup MHS|}$

Discussion—The presence of $CaCO_3$ in shell middens is known to affect soil chemistry and thought to influence thermal properties, which might give a competitive advantage to tropical vegetation found in these coastal hammocks. For example, Smith and McGrath (2011) found significantly higher soil pH, cation exchange capacity, concentrations of calcium, total nitrogen, and various micronutrients associated with shell middens in St. Catherines Island in Georgia. Norman and Hawley (1995) found alkaline pH in the soil of Turtle Mound, Canaveral National Seashore, Florida. Norman (1976) and Norman and Hawley (1995) found significantly higher soil temperature in Turtle Mound than in surrounding soils, but also noted a greater temperature range. It is not clear if this effect is due to the shell directly, to the influence of the hammock itself on soil moisture (Norman and Hawley, 1995) or proximity to the Atlantic Ocean (Stalter and Kincaid, 2004).

The dredged soils in TI contain more clay than the sandy shell midden soils. The benthic material in these soils might mimic effects of calcium carbonate in the shell middens, allowing the hammock vegetation to colonize the modified islands. I have not investigated soil chemistry, temperature, or composition in the TI. However, it is reasonable to believe that the physical and chemical characteristics of dredge spoil make the modified islands suitable for coastal hammock species.

Many of the tropical species found in the TI are near the northern limits of their ranges, and little suitable habitat remains elsewhere in central Brevard County, making the TI an important location for remnant coastal hammock. The ability of coastal hammock species to colonize dredge spoil, particularly after removal of Australian pine and Brazilian pepper (Kozusko, unpublished) would seem to make this community type a suitable restoration goal as removal of non-native vegetation continues.

Additionally, non-native vegetation is rare within Provost and Salmela hammocks, although Brazilian