Notes on the Ecology of the Thousand Islands for Master Naturalist Class

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A Kayaks & Compasses© Presentation from www.thousand-islands.org by Tim and Laura Kozusko. All photos by Tim Kozusko, unless otherwise noted.

Introduction

Any given landform that one considers in Florida will have been shaped by one or more of three major forces: dissolution of limestone (not a major impact in the Thousand Islands), erosional/depositional forces of the sea, and of course the impacts of humans. The Thousand Islands comprise a young landform that demonstrates the ability of the sea and humans to shape the land. These islands are a special place that joins temperate to subtropical, bears witness to the beginnings of the environmental movement, and provides habitat and recreational opportunities.

Sediment cores tell us that the Thousand Islands were formed when a storm-driven sea broke through the barrier island, leaving behind a deposit known as a flood tide delta. Additionally, from the 1960s to the early 1970s the islands were significantly reshaped by efforts to control mosquitoes as the population of Brevard swelled during the race to the moon.

AN INLET ONCE WHERE COCOA BEACH IS NOW

Sometime in the past a storm battered the coast of Brevard, as many have before and since. Winds lashed at the vegetation, and waves pounded the beach. Somewhere along the dune there might have been a weakened section in the dune or sparse vegetation. Indigenous people lived in this area and may have cleared some of the palmetto and scrubby oaks, or there might have been a topographical low in the barrier island that made it susceptible to the sea. In any case, waves sliced at the beach until water punched through the dune, uprooting palmettos at first, and then the entire barrier island was cleaved in two as the heaving sea poured through the opening into the lagoon, pushing sand into shoals rather like those of a river delta. The storm waves receded and the shoals became land. Plants colonized the shoals, and the shifting of sand by longshore currents gradually closed the inlet. This cycle has repeated itself all along the barrier island over the centuries.

After many centuries people came to Brevard in droves and soon learned why this area was originally part of Mosquito County. Knowing that the saltmarsh mosquito won't lay its eggs in standing water, biologists learned to control them by “source reduction.” To achieve this goal, large sections of the islands were either ditched or diked to remove the moist sand that the mosquitoes require to lay eggs on. Together with chemical controls it yields a qualified success, although mosquitoes can be quite bad in the islands during summer and late autumn.

Today these islands are not pristine. Large areas of wetland have been converted to upland, supporting a suite of plants not normally associated with each other. But the Thousand Islands still function as habitat, provide a “living laboratory” for students eager to explore the mazes of mosquito canals, and give us a place to escape the rigors of life. These islands remind us that the power of the ocean to shape the land must not be ignored. They are worthy of our continued efforts to preserve and restore them. Thankfully the entire Thousand Islands landscape now rests in public ownership. This will enable us to restore and manage these islands to improve their ecological function. Removal of invasive non-native plants is crucial to restoration efforts, and this can be unpopular with lay-people. As Master Naturalists you serve as a bridge between biologists and the lay-public. This booklet is intended as one source among many to help you in this role.

Depositional History

The Thousand Islands landform is the result of a flood tide delta deposit. Two lines of evidence support this conclusion. Visual evidence from aerial photographs points to a similarity in morphology between the Thousand Islands and known flood tide delta deposits. Additionally, physical evidence from sediment cores indicates the presence of a sand layer consistent with a flood tide delta deposit. Though most of these islands have been modified by dredging, the Thousand Islands formation is natural.

In Figure 1, aerial views of the Thousand Islands prior to significant modification and a recently deposited flood tide delta in North Carolina are compared. Similarities in general form can be seen. Longshore transport has since closed the inlet at Cocoa Beach, though a topographical low area still exists where the inlet probably once was.

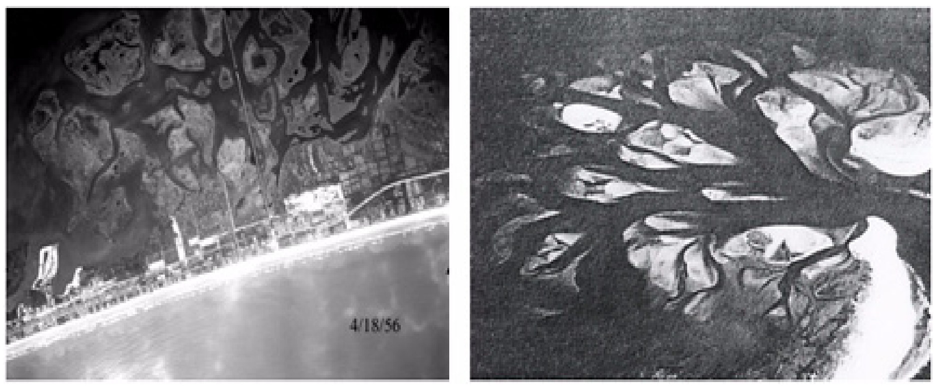

FIGURE 1. The Thousand Islands (left) in 1956, before significant dredging, compared to a flood tide delta behind a barrier island in North Carolina. Cocoa Beach photo courtesy Brevard County Mosquito Control. Flood tide delta picture from *Barrier Islands*, S.P. Leatherman Ed., page 216.

Lasater and Nevin (1973) took several shallow cores in the Thousand Islands as part of a report to a property owner. Though some of their sampling locations were close to dredging sites and their analysis was limited, the cores did exhibit characteristics consistent with a flood tide delta deposit. This is principally the existence of a layer of sand, free of the shells that are indicative of deposition in a normal benthic environment (Cooper, 1994; Armon, 1979; Moslow and Heron, 1979). The present author has also done some shallow core work (<1m) in the islands south of Minutemen Causeway, finding the same general trends. Shells representing a benthic community are present in the upper approximately 10cm of sediment. Below this is a layer of varying thickness, composed of sand, sometimes interspersed with fragments of woody vegetation. Below the sand layer, the cores generally exhibit the shell sand/silt layer similar to the benthic community found at the core surface. This uneven sand layer lacking shells suggests an interruption in the normal accretion of benthic sediments by a rapid deposition of material being washed in by wave action (Randy Parkinson, personal communication). The date of this event is unknown.

ACTIONS OF MAN

Anthropogenic Impacts

Aboriginal people inhabited Brevard County for centuries before the arrival of Europeans (Cultural Resource Management, 1978). Shell middens are present in at least two areas of the islands and the author found pottery sherds along the west barrier shore prior to the construction of condominiums near 8th Street south in the early 1970's. Sherds were not found within the Thousand Islands proper. As an aside, it is a common mistake to refer to pre-Columbian inhabitants of Brevard as Ais; they were only called that after Europeans arrived on the scene. We don't know who the pre-Columbian people were, so they should not be called Ais (Vera Zimmerman, personal communication).

MOSQUITO CONTROL

Since World War II, the Thousand Islands have been heavily impacted by development and mosquito control (Figure 2). Few people understand the capacity of a central Florida salt marsh to produce mosquitoes. In the late 1940's on Sanibel Island Dr. Maurice Provost measured mosquito egg densities of 45,000 per square foot (Patterson, 2004). This translates to about 2,000,000,000 per acre. The saltmarsh mosquito doesn't lay its eggs in standing water as do other species of mosquito. Instead they choose moist sand or mud, waiting for high water to flood the eggs which then hatch. Eggs can persist for months, although the percentage of viable eggs decreases over time (Scott Taylor, personal communication).

Beginning in the late 1950s, small ditches were dug through the islands to facilitate fish access to inner areas of the *Sarcocornia* marsh for mosquito control (Scott Taylor, personal communication). At approximately the same time, dredge and fill activities were begun in Cocoa Beach for housing development. This involved dredging of canals to provide fill material for houses. And during the late 1960s deeper ditching by dragline was begun in the south Thousand Islands in a stronger effort to control mosquitoes (Figure 3). The islands south of Minutemen Causeway were more heavily impacted in this way than those islands to the north. As the environmental movement began following publication of Rachel Carson's seminal book *Silent Spring*, the value of salt marshes gradually began to be appreciated. Dredging of mosquito canals was suspended in the early 1970's, largely due to concerns about impacts of this practice to the ecology of salt marshes. Additionally, as the Apollo program was cancelled demand for houses waned, reducing pressure to develop any more of the islands.

In 1972 the impoundment known as C-34 was begun on 105 acres of state-owned islands near the high school. This section of islands was completely impounded with a perimeter dike to allow mechanical flooding of the marsh during mosquito breeding season, thereby preventing oviposition by female mosquitoes. Flooding stress can be damaging to mangroves, and this impoundment was studied by NASA using infrared aerial photography in one of the earlier examples of remote sensing. This impoundment is no longer actively managed in this way (Scott Taylor, personal communication). Contrary to popular belief, C-34 is the only impounded area in the Thousand Islands. It is also known as "Gumbo-Limbo" due to a very large tree of that species once found there.

Before it was impounded, C-34 was the island used in the Freedom 7 "Operation Stretch" program where students were left on their own to spend a night and day as a sort of ordeal somewhat like Outward Bound.

FIGURE 2. Aerial photograph of Thousand Islands and Cocoa Beach, 1994 US Geological Survey.

FIGURE 3. Photograph of dragline at work in the Thousand Islands, 1973

DEVELOPMENT OF SHORELINES AND HABITAT COMPRESSION

Housing development and mosquito control have had several effects on habitat within the Thousand Islands. The construction of Minutemen Causeway has probably disrupted water movement through the islands, particularly those to the south of the road. This impedes flushing and solute exchange between the wetlands within the islands and the Banana River Lagoon.

To eliminate mosquito breeding habitat, the naturally shallow angle of repose of the shore/water interface has been greatly increased. This affects hydrology and interferes with several of the ecosystem processes that normally take place at this interface. Species that breed (e.g. saltmarsh mosquitoes, horseshoe crabs) or forage (e.g. roseate spoonbills) have been adversely affected by these changes. This must be viewed as a loss of habitat, with widely-ranging, although largely unquantified effects on various species, both plants and animals.

The effect of changing the angle of the shore/water interface is depicted in Figure 4. The amount of land between normal high and low water levels is identified by the vertical black lines. This transitional area provides foraging and breeding habitat. When the shoreline angle is made to be more steep, the areal extent of this transitional habitat is horizontally compressed. This is the concept of habitat compression seen in so many transitional habitats near development. The dune habitat is another example of habitat compression. Beachfront developments typically install lawns right up to the dune, eliminating most of the specialized vegetation found there.

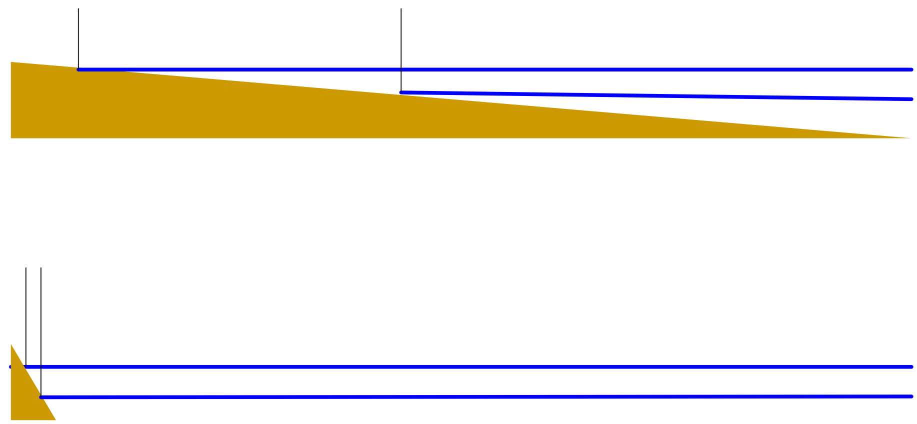

FIGURE 4. As the angle of the shore/water interface is increased, the transitional zone between land and water is compressed. In this figure the horizontal extent of land affected by the same change in water level is depicted by vertical lines, corresponding to two shore/water angles. The decrease in horizontal extent between the bars is habitat compression.

MAKING WETLANDS DRY

In the process of dredging for mosquito control, soils have been raised above the water table, allowing upland plant species to move in, changing the species composition of the islands and allowing plants that are not normally associated with each other to invade the former wetlands (Figure 5). Paradoxically, this has increased the species diversity of vascular plants there. Construction of dikes has apparently decreased the breeding habitat of the horseshoe crab (*Limulus polyphemus*), and the diamondback terrapin (*Malaclemys terrapin*) and has probably allowed easier access for raccoons to nests, increasing predation on turtle eggs.

Despite the grim prediction of Lasater and Nevin (1973), the Thousand Islands have not become "ecologically dead". To the contrary, the area supports large numbers of migratory birds, native wading birds, ospreys, alligators, small mammals, and even an occasional otter is seen there. However, restoration is needed - particularly with regard to invasive non-native plants such as Brazilian pepper and Australian pine. Natural shoreline angles also should be restored where possible.

Additionally, the Thousand Islands have become quite popular with eco-tourism and educational events. The acquisition of the remaining Thousand Islands ensures that they will remain as an area for passive recreation, a "living laboratory," habitat, and a strong reminder of the dynamic nature of the barrier island. It is irresponsible for any resident of the barrier island either to ignore or deny the ability of the sea to create an inlet and new flood tide delta deposit anywhere along the barrier island, during any given hurricane season. We know this sort of event has happened in the past and can happen again. It is only a matter of time.

FIGURE 5. Erect prickly pear cactus (*Opuntia stricta*) growing on modified shoreline among obligate hydrophytes glasswort (*Sarcocornia perennis*), saltwort (*Batis maritima*), and white mangrove (*Laguncularia racemosa*).

PLANTS

Vegetation Communities

The vegetation communities of the Thousand Islands can be classified in three habitat types: salt marsh, dredge-spoil, and tropical maritime hammock (generally associated with shell middens). Of these three, the dredge-spoil community contains the highest plant diversity and suffers the greatest degree of invasion by non-native plant species.

The succulent *Sarcocornia* marsh habitat is found inside the C-34 impoundment and along most of the edges of the islands. The margins of the islands and their interiors along ditches are typically fringed with mangroves (Figure 6). A ground-level view is presented in Figure 7. Unaltered islands have mangroves inland if they are inundated sufficiently to allow propagule dispersal to the interior. Once established the mangroves can begin to expand until killed back by freezes. The dead wood of freeze-killed mangroves is a common sight.

The dominant plants of the unaltered interior marshes appear to be glasswort (*Sarcocornia perennis*) and saltwort (*Batis maritima*) where mangrove cover is sparse enough to permit sufficient light to support glasswort and saltwort growth (Kozusko, unpublished data). These marshes generally range from damp in the dry season to “spongy” wet or flooded in the wet season. They are also known as succulent or *Sarcocornia* marsh to distinguish them from the more northern salt marsh composed of *Spartina* and *Juncus.*

NATURAL WETLANDS

FIGURE 6. Aerial view of succulent marsh (*Sarcocornia* and *Batis*) with mangroves established along mosquito control ditches.

FIGURE 7. Ground-level view of succulent marsh with mangroves on unaltered island. Note dead mangroves in various states of decay.

In Brevard County mangroves are near the northern limits of their ranges and suffer mortality and disturbance from freezes. When mangroves die back, *Sarcocornia* and *Batis* are allowed to expand. These plants will persist until mangroves become established and shade them out. This typically takes place until the next freeze kills the mangroves back (Figure 8). There are several areas where saltmarsh cordgrass (*Spartina alterniflora*) maintains stands that have persisted for several decades. This species is well known in northern salt marshes and begins to dominate in Volusia County. Blackrush (*Juncus roemerianus*) is not found in the Thousand Islands. Saltgrass (*Distichlis spicata*) exhibits only limited coverage.

FIGURE 8. Freeze-killed mangroves, succulent marsh and mangrove recruits in unaltered marsh.

ALTERED LANDS

Dredge spoil harbors the most species diverse vegetation community in the Thousand Islands. The change in soil regime from wetland to upland resulting from spoil deposits allows disturbance invaders to colonize areas previously tolerated only by species with adaptations to water-logged saline soils. The major non-native species found in this habitat are Brazilian pepper (*Schinus terebinthifolius*) and Australian pine (*Casuarina glauca*, *C. equisetifolia*, and an intermediate thought to be a hybrid between *C. glauca* and *C. equisetifolia*). However, the native species swampprivet (*Forestiera segregata*), wax myrtle (*Myrica cerifera*), and salt bush (*Baccharis halimifolia*) probably exhibit the greatest coverage (Kozusko, unpublished data). An aerial view of typical dredge spoil habitat is given in Figure 9 and a ground-level view is presented in Figure 10.

FIGURE 9. Aerial view of dredge spoil habitat: Brazilian pepper (*Schinus terebinthifolius*), Florida swampprivet (*Forestiera segregata*), and Salt myrtle (*Baccharis halimifolia*) and Wax myrtle (*Myrica cerifera*) dominate.

FIGURE 10. Ground-level view of typical dredge spoil habitat: Florida swampprivet (*Forestiera segregata*), Salt myrtle (*Baccharis halimifolia*), Erect prickly pear cactus (*Opuntia stricta*), and Buttonwood (*Conocarpus erectus*).

TROPICAL PLANTS

Tropical vegetation is found in several locations in the southern Thousand Islands. The two major areas are both associated with shell middens. A small area near 4th Street South (the main Crawford Island) and areas near the midden along Jones Creek consist of a few plants that have volunteered in dredge spoil substrate.

Tropical Genera present in the C-34 hammock before dike work included *Amyris, Bursera, Capparis, Chiococca, Erythrina, Eugenia, Ficus, Randia*, and *Torrubia* (Bidlingmayer, unpublished vegetation survey, 1971). Many of these species are listed by Wunderlin and Hansen (2003) as having the northern limit of their range in or near Brevard County.

In 1999 (unpublished report) the vegetation of the Thousand Islands was listed by this author, and the C-34 hammock area was photographed by him from the air in July of the same year (Figure 11). All the species found by Bidlingmayer (1971, unpublished) were found. Several tropical species were noted on the perimeter dike near the shell midden suggesting successful expansion of this vegetation type onto dredge spoil. Another tropical hammock associated with a shell midden was discovered by this author on an island southeast of C-34, along Jones Creek.

FIGURE 11. Aerial view of C-34 hammock area, looking west, July, 1999. Notice how the perimeter dike was constructed around the inside of the hammock to exclude it from the impoundment and thus prevent it from flooding (Jack Salmela, personal communication).

Several factors might account for the association of tropical species with shell middens. Two likely factors are the increased soil aeration, and the ability of calcium carbonate from shells to ameliorate soil acidity usually associated with the oxidation of sulfides created by anaerobic metabolism (Norman, 1976). Additionally, the volume of water in the Banana River acts as a thermal mass, mitigating detrimental effects from cold fronts. Dredge spoil material also contains shells and might be chemically similar to soils of shell middens. Some tropical species have volunteered at a site approximately 500m from the nearest seed source. In the C-34 impoundment the tropical hammock has spread out onto the perimeter dike. Several species have dispersed to the south of the eastern hammock on Jones Creek. It seems likely that this plant association might be induced to colonize the areas of upland habitat in the Thousand Islands as noxious invasive species such as Brazilian pepper and Australian pine are removed.

Any restoration effort should include aggressive removal of non-natives, natural recruitment augmented by some patchy planting to provide seed sources, and should maintain the open habitat aspect that has formed over the past 40 years. This open habitat will benefit the once plentiful six-lined racerunner (*Cnemidophorus sexlineatus*) now vanishing in Cocoa Beach due to habitat loss.

ACKNOWLEDGEMENTS

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Roseate Spoonbill

Notes

Indian River Lagoon

THE LAGOON AS A BODY OF WATER AND MORE

Physical Characteristics

The Indian River Lagoon system (IRL) is a body of water on the central east coast of Florida. It is approximately 155 miles long, delineated by Ponce de Leon Inlet to the north and Jupiter Inlet to the south (Figure 1). More importantly, the IRL extends from latitude 29°03'N to 26°57'N. This length of just over 2 degrees latitude straddles the divide between the temperate Carolinean Province north of Cape Canaveral, and the sub-tropical Caribbean Province to the south. This change in latitude has a tremendous effect on species diversity and species composition at either end of the IRL (Woodward and Clyde, 1994; Richard Turner, personal communication).

The IRL is composed of three lagoons: the Indian River Lagoon, Banana River Lagoon, and Mosquito Lagoon. The portions of the Indian River Lagoon south of St. Lucie inlet are commonly referred to as Hobe Sound and Jupiter Sound. Due to its long narrow morphology, more than two thirds of the IRL lies beyond the greatest tidal excursion distance, suggesting limited direct exchange between the IRL and the Atlantic (Woodward and Clyde, 1994).

There is significant exchange of water between the three lagoons. In the Banana River and Mosquito Lagoons, evaporation and seepage through the porous sands of the barrier island into the Atlantic exceed inputs from surface flow and rainfall. This indicates that the Banana River Lagoon probably acts as a sink for water from the Indian River Lagoon, and Mosquito Lagoon acts as a sink for the Indian River Lagoon through the Banana River Lagoon (Woodward and Clyde, 1994). This large exchange with the Atlantic by seepage is one of several factors that distinguish the lagoon from the classic definition of an estuary.

The IRL can not be properly thought of as just the water body; it must be considered as the lagoon complex and the watershed that supplies its water; the water body and the watershed can not be decoupled. A watershed can be described as all the land that water falls on, flows over, through, and under on its way to some receiving body of water, in this case the IRL. The IRL watershed has been heavily impacted by human activities. Fortunately work has been under way to restore some aspects of the IRL watershed (Bob Day, personal communication).

Stormwater runoff from impervious surfaces carries chemicals into the lagoon and speeds the velocity of water entering the lagoon. Rainfall that once took from days to weeks to enter the lagoon now arrives in minutes to hours following large rainstorms. As the velocity of water is increased by impervious surfaces, its ability to carry sediments is also increased, and large areas of wetlands that once slowed the runoff have been destroyed, allowing large amounts of silt to enter the lagoon.

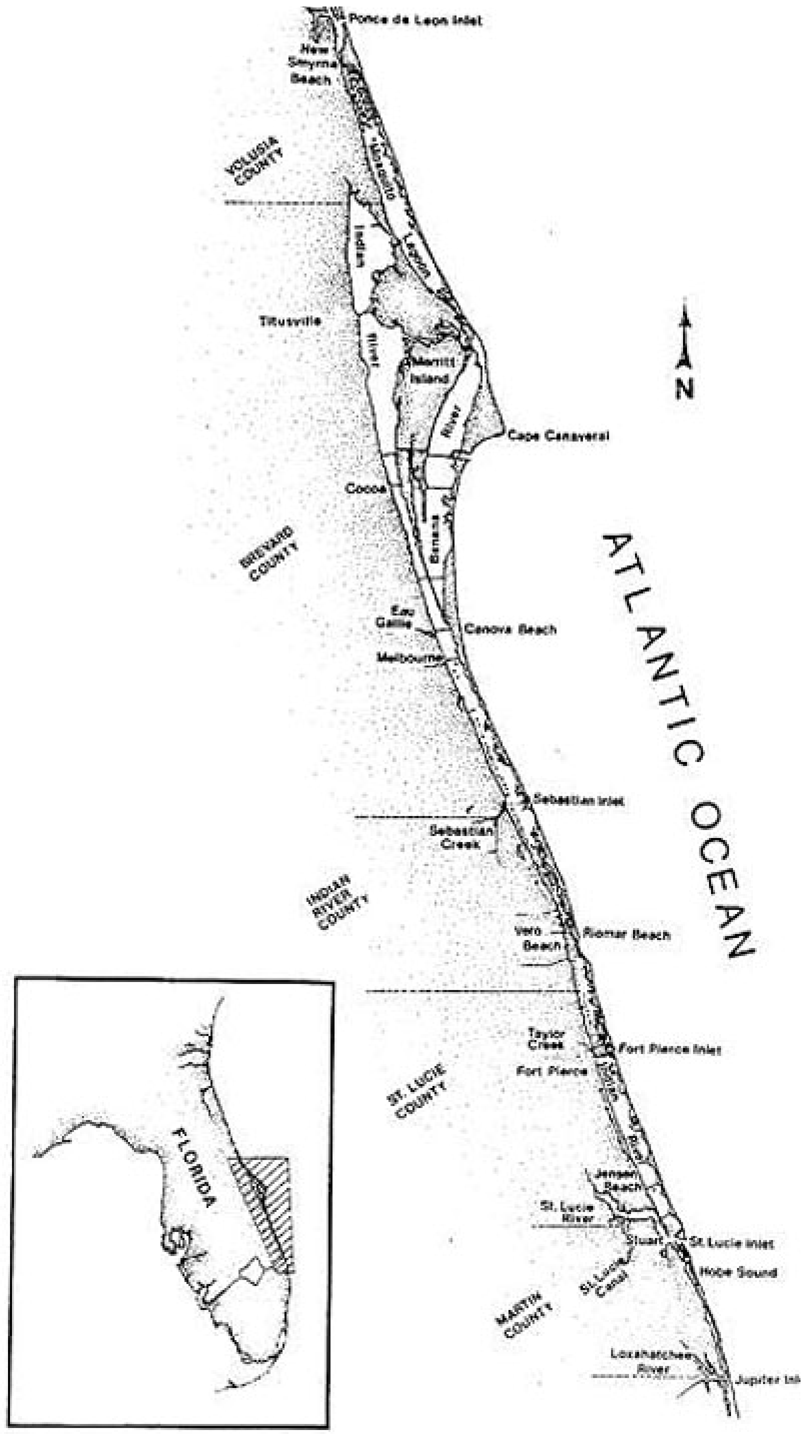


FIGURE 1. Map of the Indian River Lagoon system, east-central Florida. Source: Swain et al. 1995. *Bull. Mar. Sci.* 57: 1-7.

WATERSHED IMPACTS

The pre-development IRL watershed was bound to the east by the barrier island and to the west by the Atlantic Coastal Ridge, a relict shoreline from a Pleistocene high stand when sea level was higher than at present (Cook, 1945). South of Melbourne the ridge becomes discontinuous, allowing the Sebastian and St. Lucie rivers to drain inland areas into the IRL (White, 1958). In many areas the watershed has been increased by drainage canals, which divert water from the St. Johns watershed into the IRL, more than doubling the total watershed area and significantly increasing surface water inflows (Woodward and Clyde, 1994). Additionally, utilities import ground and surface water from the St. Johns watershed into the IRL watershed. In Banana River Lagoon for example, discharges from wastewater treatment facilities, the ultimate source of which is the St. Johns watershed, exceed inflows from runoff (Woodward and Clyde, 1994).

In addition to changes to the watershed, the IRL has been modified by dredge and fill, resulting in horizontal compression of the land-water interface and unnaturally deep areas where boat channels and mosquito canals have been cut. In many places these canals have lowered the benthic interface to well below the compensation depth, effectively eliminating submerged aquatic vegetation and favoring planktonic algae in the role of primary production, and probably changing the interstitial chemical characteristics of the sediments as oxygenated rhyzopheres associated with rooted vascular plants decline.

These canals act as sediment traps, allowing dissolved organic matter to flocculate. Deeper canals can tap into ground water, acting as thermal refugia, affecting the migration of the West Indian Manatee (Lisa Sette, personal communication). The canals also tend to be very low in dissolved oxygen and can have zooplankton densities up to two orders of magnitude less than what is found in natural areas (Kozusko, unpublished data).

ESTUARY OR LAGOON?

The IRL is often referred to as an estuary. Although the IRL has many physicochemical processes in common with an estuary, it should be considered to be morphologically distinct. These definitions are complicated by the need to somewhat arbitrarily delineate a continuum of coastal morphological features ranging from an open river mouth through embayment to a closed lagoon (Moore, 1992).

Simply put, an estuary is a place where a river meets the sea. It will have a diurnal or semi-diurnal astronomical tide, a flow primarily driven by gravity that might change direction with the tide, and a salinity gradient ranging from fresh at one end to seawater at the other end (Stickney, 1984). The connection to the sea is significant in comparison to the volume of the estuary.

The IRL has none of these aspects, and referring to it as an estuary trivializes the features that make it so unique. Its tides are meteorological and whatever flow is present is also wind-driven. The salinity is relatively constant throughout and there is little direct exchange of water between the IRL and Atlantic due to insignificant connection between the two. Approximately three quarters of the IRL is at least 5 miles from any inlet, and the five inlets that are present are artificially sustained by jetties and dredging. Historically inlets closed after 200 to 300 years and then another opened elsewhere due to hydrodynamic forces (Randy Parkinson, personal communication). The remnants of relict inlets can be seen as flood tide deltas in many areas along the west side of the barrier island (Figure 2). The Thousand Islands area in Cocoa Beach is the best example of a flood tide delta on the east coast (Randy Parkinson, personal communication).

FIGURE 2. Aerial image (2004) of the Sebastian Inlet area and adjacent flood tide delta. Note white lines of impoundment dikes. Source: St. Johns River Water Management District: http://sjr.state.fl.us/programs/data.html

BAR-BUILT ESTUARY

The area surrounding the St. Lucie River can be thought of as a true bar-built estuary, although its inlet is held open and its function has been dramatically altered by artificial connection of the St. Lucie River to Lake Okeechobee. Following large storms or during years with high rainfall, massive water releases can take place through the St. Lucie, resulting in severe declines in water quality and damage to any species unable to tolerate fresh water. When water is withheld for storage to satisfy agricultural and urban water supply needs, brackish water moves too far up the river, killing species unable to tolerate the increased salinity.

FORMATION

Physical Development

The IRL developed as Holocene sea level rose to fill a topographical depression 5000 to 6000 years ago (Bader and Parkinson, 1991). The western boundary of the IRL watershed, the Atlantic Coastal Ridge, formed during the Pamlico high stand 120,000 to 140,000 years ago when sea level was approximately 9 meters higher than at present (Cook, 1945; Bader and Parkinson, 1991). Sea level began to fall some 100,000 years ago as climate cooled, pausing to form the Merritt Island complex, finally ending up more than 100 meters lower than at present (Osmond, May, and Tanner, 1970).

A second high stand about 2 meters higher than present sea level occurred approximately 30,000 years ago. By 20,000 years ago sea level was approximately 100 meters lower than present and what is now the IRL was dry land (Bader and Parkinson 1990). As sea level again began to rise, the present coast of Florida began to take its current shape.

The present barrier island might have formed in one or a combination of two ways: spit growth across an embayment by longshore sand transport, or flooding of coastal areas behind relict beach ridges, as many barriers are thought to have formed (Cooper, 1994). The IRL probably began as an embayment that was gradually enclosed by a lengthening of the barrier island due to longshore transport of sands eroded farther north along Florida's east coast.

We know that sea level is rising. And as sea level continues to rise, barrier islands respond by migrating toward the mainland. All east-coast barrier islands are moving landward as storm-driven overwash and flood tide delta formation transport beach and dune material into the lagoon (Parkinson, 1995). These deposits can be seen along the west sides of the barrier at the southern and northern ends of Brevard County (Figure 3). As these deposits continue to be transported into the lagoon, the open lagoon water gradually fills in to become marsh or mangrove swamp, as is seen at the northern end of IRL in Figure 3.

The west side of the barrier island in central Brevard County shows a strong cuspate spit formation (Figure 4), indicating a stable barrier with little or no inlet or washover formation (Bader and Parkinson, 1990). The reason for this is not known but it might result from offshore deposits of beach rock or the vagaries of ocean currents and storms, or some combination of these or other factors.

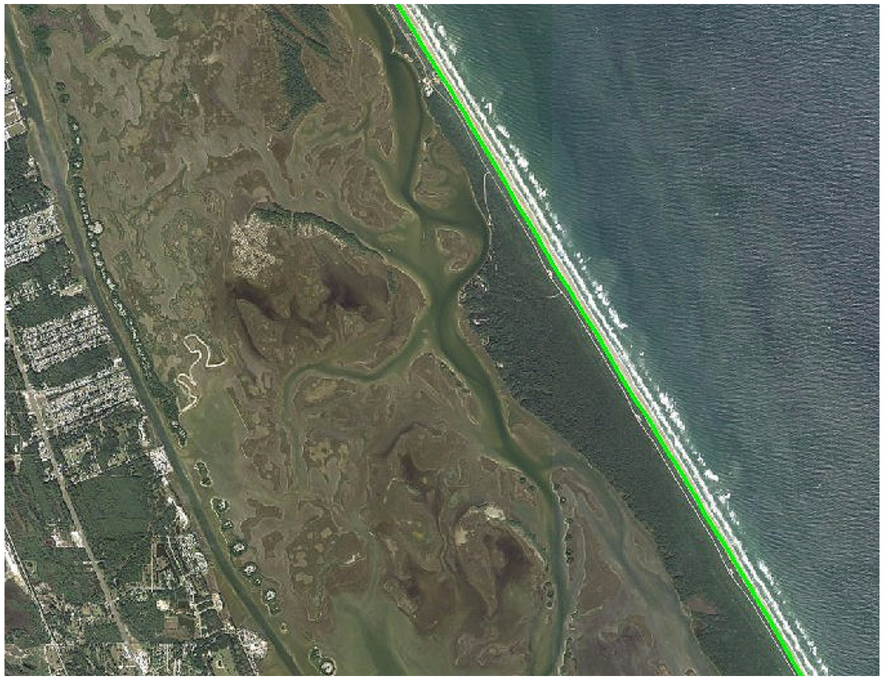


FIGURE 3. Mosquito Lagoon near Turtle Mound, depicting filling in of lagoon by overwash and flood tide delta deposits. Source: St. Johns River Water Management District. http://sjr.state.fl.us/programs/data.html

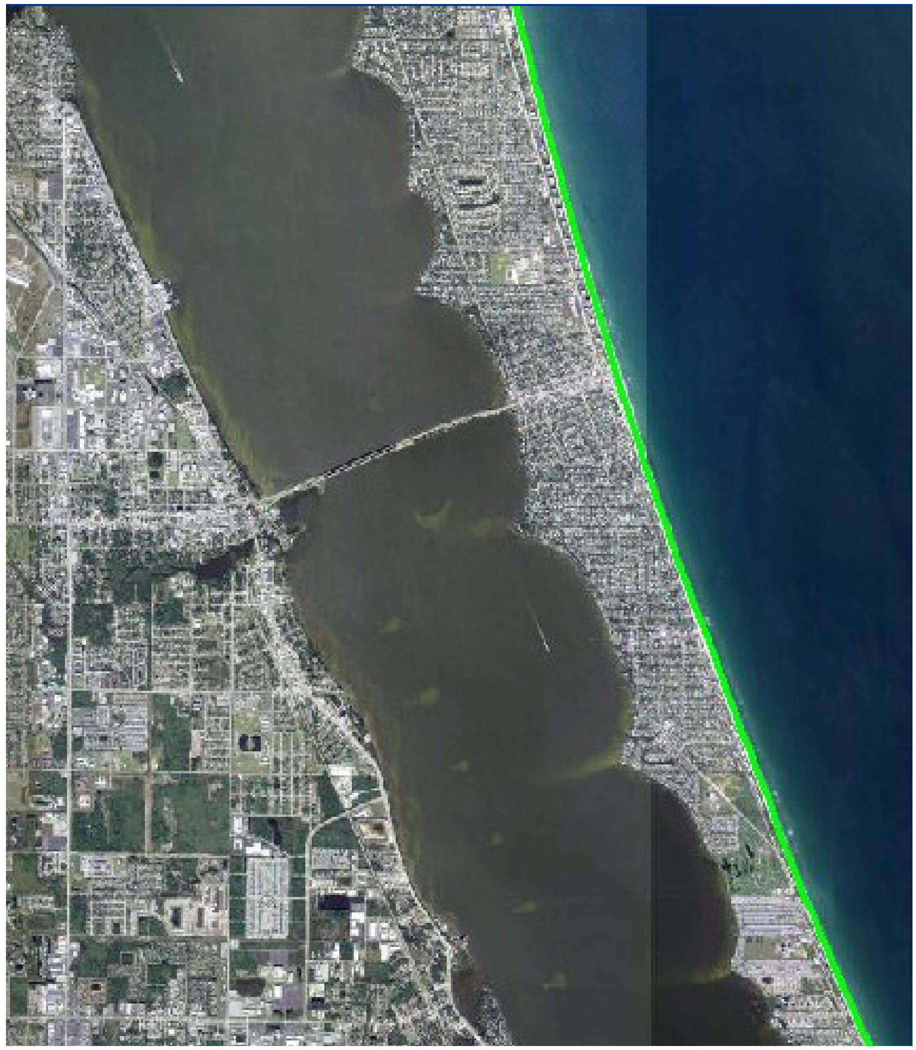


FIGURE 4. Indian River Lagoon, Melbourne Beach, depicting cuspate spit formation on west side of barrier island. Source: St. Johns River Water Management District. http://sjr.state.fl.us/programs/data.html

Beach rock, also called coquina, is known as the Anastasia Formation by geologists. It consists of weakly cemented shell fragments, whole shells, and sand. Coquina forms when sea level falls, leaving the shore line behind. The natural acidity of rainfall dissolves some of the calcium carbonate in the shell and it is gradually re-deposited, cementing the particles together. Iron can also be involved in the process. The rock has been used for construction, particularly the Castillo de San Marcos, built 1672-1695. The soft nature of the coquina rock made it well suited to absorbing the energy of cannon balls.

PLANTS AND HABITATS

Biological Characteristics

Vegetation communities associated with the IRL include seagrass beds, freshwater marsh and salt marsh, mangrove swamp, hardwood hammocks, pine flatwoods, coastal scrub, maritime hammock, tropical hammock, beach dune, and dredge spoil. Each of these communities has a suite of indicator species that can be used to identify it.

There are seven species of seagrass found in the IRL. Seagrass beds provide habitat structure and are a major source of primary productivity in the IRL. The main threats they face arise from poor water quality. As the transparency of water declines, seagrasses do not receive enough light to thrive and the system switches over to one dominated by planktonic and drift algae, which are not seen as having as much ecological value as seagrasses. The algae then intercept more sunlight, causing seagrass to decline further.

Nutrient loading also damages seagrass by promoting growth of algae, which compete with seagrass for light. Tons of nutrients are brought into the IRL watershed every year by humans in the form of food and fertilizers. As population continues to rise, this problem will get worse. Additionally, scarring from recreational boating damages seagrass beds.

Freshwater marshes are found along tributaries and swale marshes between relict beach ridges within the IRL. Indicator species include Carolina Willow (*Salix caroliniana*) in disturbed areas, pickerelweed (*Pontederia cordata*), and various emergent grasses and sedges.

Salt marshes in the IRL north of Cape Canaveral are dominated by non-woody vegetation, primarily smooth cordgrass (*Spartina alterniflora*) and needle rush (*Juncus roemerianus*). These plants usually exhibit a taller growth form near open water and a shorter form approaching land (Montague and Wiegert, 1991). South of Cape Canaveral these plants begin to be replaced by mangroves. Saltgrass (*Distichlis spicata*), annual and perennial glasswort (*Salicornia bigelovii* and *Sarcocornia perennis* respectively) are found throughout the lagoon. Non-woody saltmarsh plants typically exhibit strong zonation that might be explained by factors such as environmental gradients or vegetative reproduction (Montague and Wiegert, 1991).

Mangrove swamps, together with salt marshes, are exceedingly productive systems that supply energy to the lagoon, and adjacent marine and terrestrial systems, and provide habitat structure. There are three species of mangrove in the IRL. To varying degree, all possess three primary adaptations that distinguish them from other trees: the ability to excrete and exclude salt, roots modified to serve as aerial gas exchange organs, and a method of reproduction referred to as “vivipary” in which the embryo either germinates on the tree or while floating (Odum and McIvor. 1990).

IMPOUNDMENTS

Between 1954 and the early 1970’s the majority of saltmarsh and mangrove swamp associated with the IRL was impounded in efforts to control saltmarsh mosquitoes (Rey, Kain, and Stahl, 1991). The female saltmarsh mosquito will not lay its eggs in standing water. Instead it chooses to oviposit in moist sand or mud. By 1950 these mosquitoes were showing considerable resistance to DDT, and mosquito control efforts began to focus on "source reduction" (Patterson, 2004). The most effective means of source reduction is to impound the marsh by construction of a perimeter dike to isolate the marsh (Figure 5). The impoundment was then flooded during breeding season to prevent oviposition by mosquitoes.

FIGURE 5. Aerial view of impounded salt marsh, Blackpoint Wildlife Drive. Note difference in water quality between impoundment (left) and lagoon (right).

A major drawback of impoundments is their interference with exchange between the marsh and lagoon. This lack of exchange particularly affects any species that uses the marsh for habitat in its juvenile stage. Many impoundments have been opened to allow exchange with the lagoon. For impoundments remaining closed, water drawdown is important to wading birds (Rosier, 1993). Opening impoundments has been shown to benefit fish populations (Poulakis, 1996), and zooplankton densities have been shown to remain similar to open lagoon if the impoundment is open at least during the winter (Rey, Kain, Crossman, Peterson, Shaffer, and Vose, 1991).

HABITATS

Hardwood hammocks are found where hydroperiod, disturbance regimes such as fire and storm frequency, and other variables allow their development. Hardwood hammocks generally occur adjacent to freshwater or in swales between relict beach ridges. Indicator species include the laurel oak (*Quercus laurifolia*), red maple (*Acer rubrum*), sweetgum (*Liquidambar styraciflua*) Carolina willow (*Salix caroliniana*), and buttonbush (*Cephalanthus occidentalis*).

Pine flatwoods are found on marine terraces – flat areas of land once offshore when sea level was higher. The typical vegetation is slash pine (*Pinus elliottii*) and longleaf pine (*Pinus palustris*) with an understory of saw palmetto (*Serenoa repens*) and ericaceous shrubs.

Coastal scrub/maritime hammocks are generally found landward of the back-dune area (Johnson and Barbour, 1990). Depending on disturbances such as fire and storms, these communities can be dominated by saw palmetto (*Serenoa repens*) or oaks (*Quercus* spp.). Ericaceous shrubs become more abundant west from the dune (Paul Schmalzer, personal communication). The farther west from the dune one goes, the older the sediments. Older sediments have been more strongly leached, resulting in less calcium carbonate available to maintain a circum-neutral pH. This gradient of decreasing soil pH favors Ericaceous shrubs which are able to out-compete other plants in acidic soils.

Maritime hammock is dominated by live oak (*Quercus virginiana*). Mixed in the understory are plants such as beautyberry (*Callicarpa americana*), marlberry (*Ardisia escallonioides*), myrsine (*Rapanea punctata*), wild coffee (*Psychotria nervosa*), snowberry (*Chioccoca alba*), and stoppers (*Eugenia axillaris*, and *E. foetida*), (Johnson and Barbour, 1990).

Tropical hammock is often associated with shell middens (Norman, 1976). Tropical species are found much farther north along the east coast of Florida than in the center of the peninsula due to the moderating effect of the ocean and lagoon on climate (Henry, Portier, and Coyne, 1994). Vegetation is similar to that found in maritime hammocks with additional species such as the Jamaican capertree (*Capparis cynophallophora*) and torchwood (*Amyris elemifera*).

The beach dune community is inhabited by species able to tolerate salt, wind, and dry sandy conditions. These species include seaoats (*Uniola paniculata*), bitter panicgrass (*Panicum amarum*), seacoast marshelder (*Iva imbricata*), and railroad vine (*Ipomoea pes-caprae*).

Dredge spoil communities are found along the perimeters of impoundments and along dredged channels. This community suffers the greatest invasion by non-native plants such as Brazilian pepper (*Schinus terebinthifolius*) due to the disturbance of dredging and the pioneer species traits held by many such invasive non-native plants. Common species include salt myrtle (*Baccharis halimifolia*), Florida swampprivet (*Forestiera segregata*), wax myrtle (*Myrica cerifera*), and red cedar (*Juniperus virginiana*).

CLIMATE

Non-native Plants in the Thousand Islands

One of the characteristics of the Thousand Islands that makes them so worthy of our efforts to preserve them is the fact that the Thousand Islands lie right on a transition zone between two climate regions, subtropical to the south and temperate to the north. In Figure 1 we see a plot of each calendar day's maximum temperature, averaged over the past few decades, for Cape Canaveral Air Force Station in blue, Orlando in green, and Patrick Air Force Base in red. From the graph we see what everyone knows who's been in Orlando in the summer – it's hotter in the middle of the state than it is near the ocean. Water moderates climate because it takes so much energy to heat it, and it retains this heat a long time. This is easy to experience when walking on hot sand in the middle of a summer day. The sand gains and loses heat much more rapidly than does water. At night the sand cools quickly, the water remains essentially the same temperature.

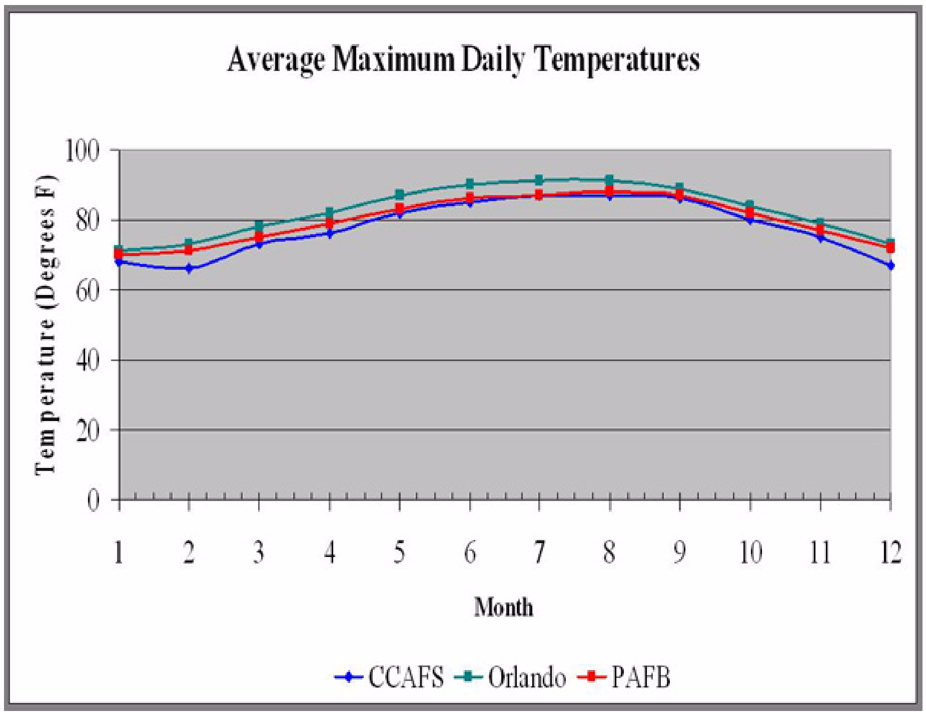


FIGURE 1. Maximum daily temperature, averaged over the past few decades, for Cape Canaveral Air Force Station in blue, Orlando in green, and Patrick Air Force Base in red. Source: 45th Space Wing.

Figure 2 depicts the average low temperature, for each calendar day over the past few decades. The results are surprising; Cape Canaveral Air Force Station, just 15 miles north of Patrick Air Force Base, has average daily low temperatures much more similar to Orlando than it does to Patrick Air Force Base. The difference in average low temperature between Cape Canaveral Air Force Station and Patrick Air Force Base demonstrates that these two locations straddle a climatic transition zone between temperate to the north, and subtropical to the south. The Thousand Islands lie right in the middle of this transition zone. Transition zones are often very important places, in an ecological context.

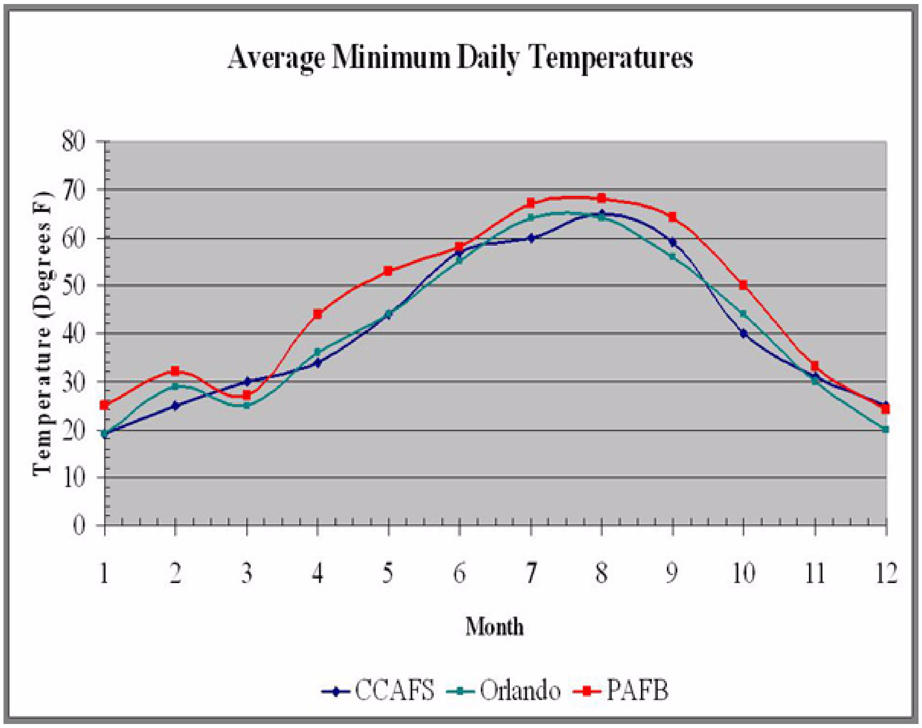


FIGURE 2. Minimum daily temperature, averaged over the past few decades, for Cape Canaveral Air Force Station in blue, Orlando in green, and Patrick Air Force Base in red. Source: 45th Space Wing.

INVADERS

The location of the Thousand Islands in a subtropical climate zone renders them more susceptible to invasion by non-native plants and animals from tropical regions. Many of the most troublesome invasive non-native species originate from tropical areas. Three out of five of the problematic invasive non-native plants found in the Thousand Islands are designated as Class I Prohibited Aquatic Plants by the Florida Department of Environmental Protection. This makes it illegal to posses, collect, transport, cultivate, or import them without a permit from the Department.

The Florida Exotic Pest Plant Council rates all five of these plants as Category I invasives. This category is defined as an "invasive exotic that is altering native plant communities by displacing native species, changing community structures or ecological functions, or hybridizing with natives." This definition relies on scientifically documented ecological damage caused by the plant in question. These classifications do not come lightly, and reflect the grave concern biologists have over the ability of these trees to invade, degrade, and even destroy natural systems.

BRAZILIAN PEPPER

This is Brazilian pepper (Figure 3). Its scientific name is *Schinus terebinthifolius*. It is also commonly known as Florida holly due to its red fruits, but it is not from Florida and it is not a holly. The male and female flowers are on different trees in this species, so not every tree that you see will produce the fruits that are seen in the figure below. This plant sets its fruit twice a year, which coincides with both legs of the migration of neo-tropical birds, providing an excellent dispersal mechanism for its seeds.

FIGURE 3. Brazilian pepper (*Schinus terebinthifolius*) with fruits.

Brazilian pepper was first introduced into Florida in the early mid 19th Century and it languished in a kind of ecological obscurity until the 1960's. When Davis wrote his landmark paper on the vegetation of the Everglades he didn't mention Brazilian pepper. Then, just 20 years later land managers were challenged by the expansion of this tree. So what changed that allowed this invasion to happen?

DISTURBANCE FOR DEVELOPMENT

These trees are known as pioneer species. This means that they tend to colonize new habitats or recently cleared areas. We can blame the sudden invasion by Brazilian pepper on increases in land clearing following demand for housing that attended the introduction of air conditioning, mosquito control, and the rapid development that followed the space program into our area (Figure 4).

Figures 5 through 8 trace the development of Crawford Island in aerial photos from 1951, 1969, and 2004, and its subsequent invasion by Brazilian Pepper and Australian pine. Figure 9 depicts the island with a plat of a proposed development from the 1960s that never took place.

FIGURE 4. Brazilian pepper with space shuttle in the background.

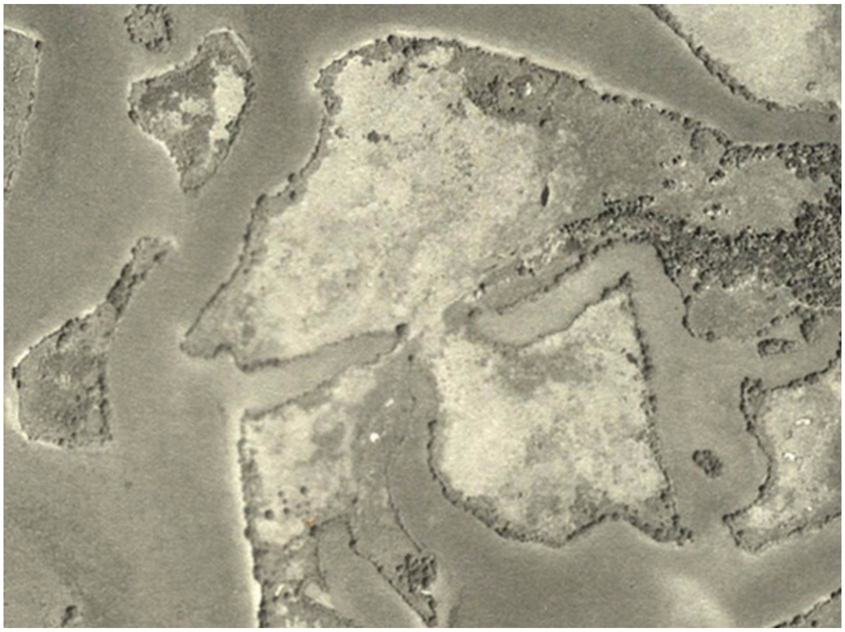


FIGURE 5. Aerial view of Crawford Island, 1951. Photo courtesy Ted Roever.

FIGURE 6. Aerial view of Crawford Island, 1969. Photo courtesy Ted Roever.

FIGURE 7. Aerial view of Crawford Island, 2004. Source: www.labins.org.

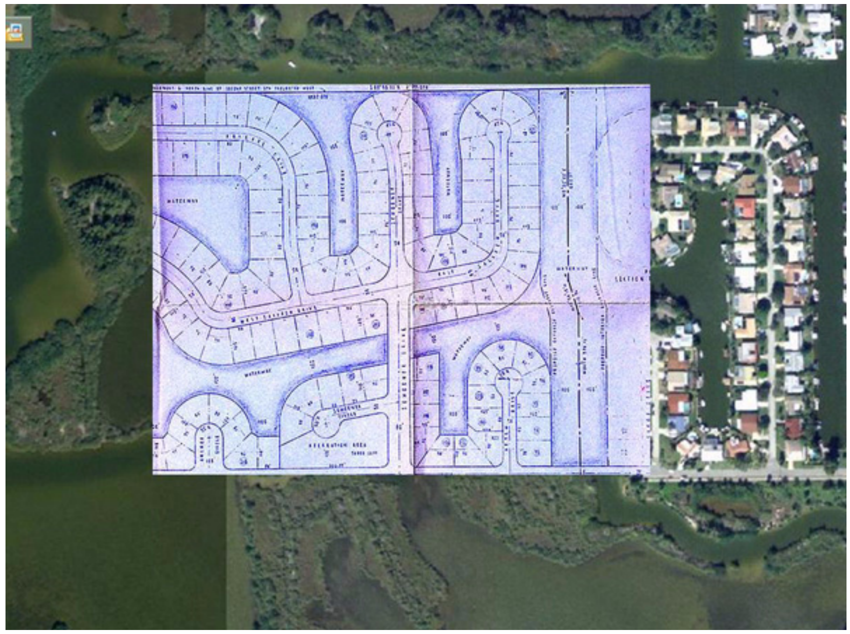


FIGURE 8. Aerial view of Crawford Island, 2004. Source: www.labins.org. Plat courtesy of Joanie Regan, City of Cocoa Beach.

AUSTRALIAN PINE

Australian pine (Figure 9) rates special consideration here due to the controversy often surrounding its removal. It is vital for people to understand the damage that this tree causes to the ecology of areas it invades. It is not a true pine, but rather a flowering plant. In true pines the needle is the leaf; in Australian pine what appears to be a needle is actually a stem, and the leaves are about 1 mm long in small whorls at joints along the length of the needle-like stem (Figure 10). The number of these small leaves per whorl, and the presence or absence of a brown band in the leaves is part of how the various species are distinguished. There are three species of Australian pine in Florida, and two of these are found in the Thousand Islands, along with a third type that is thought to be a hybrid.

Australian Pine is native to Australia, Southeast Asia and the south Pacific Islands. It was first brought to the United States beginning in the late 1880s, and was spreading in Florida by the turn of the century (Morton, 1980). It was widely used as a windbreak, especially for citrus trees, and was planted in the mistaken belief that the trees could prevent erosion.

Its Generic name *Casuarina* comes from the Malay word *kasuari*, their word for the cassowary, referring to the resemblance of the tree's “needles” to the Cassowary’s plumage. The specific name *equisetifolia* is derived from the resemblance of the needles to horse hair, and *glauca* refers to a bluish waxy coating on the “needles.”

FIGURE 9. Australian pine, Crawford Island. *Casuarina glauca* is center and left, *C. equisetifolia* is tree at extreme right.

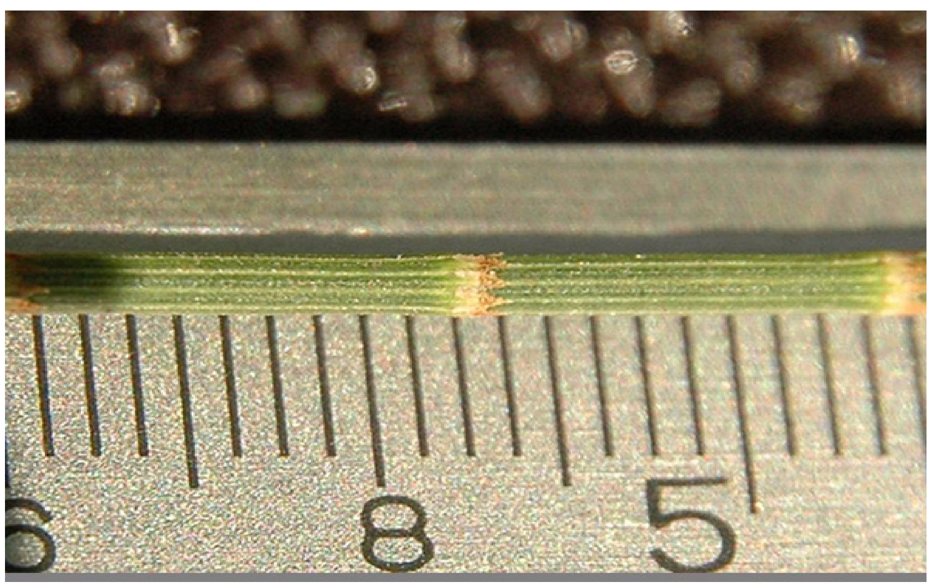


FIGURE 10. Close-up of whorled leaves of Australian pine. Scale is millimeters.

Below are male flowers of *C. glauca* (Figure 11). Male and female flowers are found on separate trees in this species, with no female trees in North America. This tree reproduces by sending out root suckers, new trees sprout from the root (Figure 12). It appears to be able to reproduce by fragmentation; even a small needle-like branch can sprout if it is blown off a parent plant and it lands on soil under the right conditions.

FIGURE 11. Close-up of male flowers of *Casuarina glauca*.

FIGURE 12. Close-up of uncovered suckering root of *Casuarina glauca* with new trees sprouting.

Casuarina equisetifolia and the hybrid have female and male flowers on the same plant. The fruits of these trees resemble cones (Figure 13). *C. equisetifolia* doesn't sucker and the hybrid has traits of both species: suckering, seeds, and it appears to be cold tolerant.

FIGURE 13. Close-up of cone-like fruits of *Casuarina equisetifolia.*

AUSTRALIAN PINES IN COCOA BEACH

Australian pines were originally planted in Cocoa Beach to provide windbreaks around citrus groves where Cocoa Isles is now. In the aerial from 1956 below (Figure 14), the rectangular windbreaks can be seen at the arrows.

Australian pine has shallow roots that rarely penetrate very deep into the soil. Planted in many areas to prevent erosion, this tree actually increases erosion by eliminating native vegetation with deeper roots, or mangroves with roots that absorb wave energy, as seen in the view of Crawford Island presented in Figure 15. The shallow root systems of these trees make them susceptible to wind-throw during storms (Figure 16).

A reasonable question to ask is what impact do these trees have on native plants? One way to answer this question is to measure how much of the ground is covered by each species of plant so their percentages of ground cover can be compared. The task is simple; just imagine a line across an island, in this case Crawford Island (Figure 17). We call this line a transect. We then stretch a tape measure across it as in Figure 18, and simply record how many centimeters are intercepted above and below by each species at zero to 1, 1 to 2, 2 to 3, and greater than 3 meters in height. We took size data so we can measure how many new plants are growing, and describe the understory vegetation beneath different types of trees.

FIGURE 14. Australian pines as windbreaks to protect fruit trees. Photo courtesy Brevard County Mosquito Control.

FIGURE 15. Australian pines with the shoreline eroding out from beneath them. The tree trunk just left of center is actually suspended over water now.

FIGURE 16. This tree was blown down in 2004. No roots had penetrated into the soil deeper than 20 cm. Photo was taken in 2006, and the tree had not died.

FIGURE 17. Aerial view of Crawford Island with one transect line depicted by red line.

FIGURE 18. Actual transect line with tape measure loosely in place prior to measurements being taken.

QUANTITATIVE LOOK AT ELIMINATION OF NATIVE SPECIES BY AUSTRALIAN PINE

When the data from a transect line intercept are plotted on a graph, we can get a clear idea of just how ecologically destructive these trees are. In Figure 19 the actual data from a transect line through a stand of Australian pines are presented. On the horizontal axis is the width of the island in meters. On the vertical axis is the percentage of each meter covered by native vegetation less than 1 meter tall, and by non-native vegetation greater than 3 meters in height. Native vegetation was depicted at this height because it represents replacement plants. Three important factors are apparent from this graph:

1. Native vegetation is more open, allowing access by ground-foraging animals like birds and reptiles.
2. Non-native vegetation tends to dominate at 100% cover, choking out all other species.
3. Where non-native plants comprise the canopy, there is almost no native vegetation beneath it. For approximately 100 meters, nearly half the width of the island, there is no native vegetation replacing itself. This area is utterly dominated by Australian pine, to the detriment of every other species found on the island.

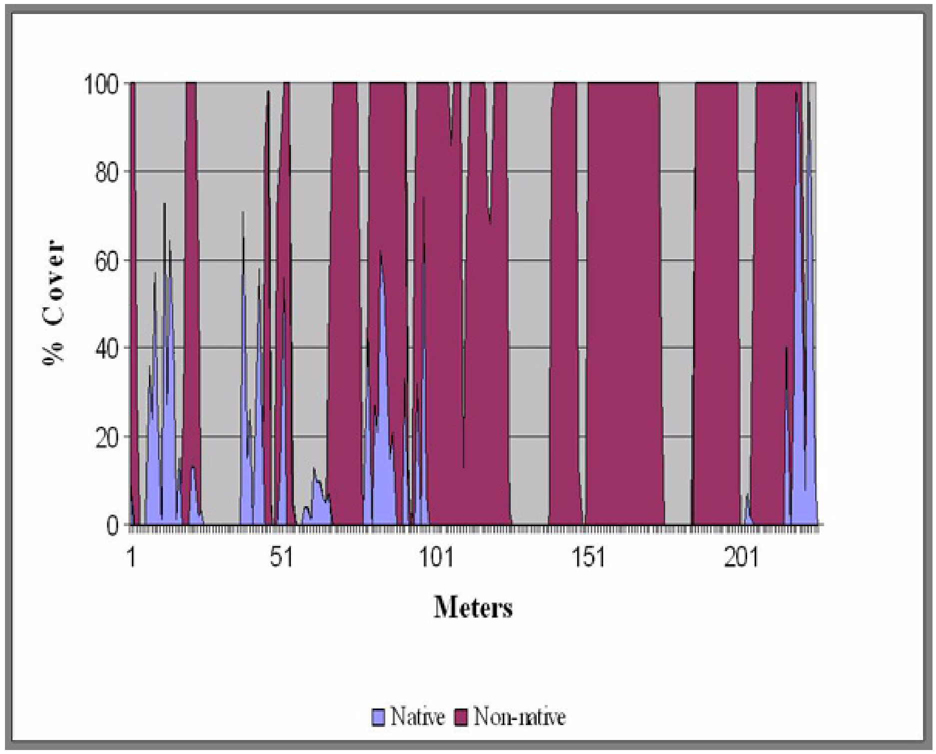


FIGURE 19. Line intercept data from one transect at Crawford Island, 2006. Transect length in meters is given on the X axis, and percent cover is given on the Y axis.

A ground-level photograph of this destroyed habitat near meter number 165 is presented in Figure 20. In this picture, one can see how Australian pine completely dominates the landscape. Notice how the fallen needle-like branches cover the ground like a carpet. These branches release toxic chemicals into the soil that prevent other plants from being able to grow beneath the Australian pines. This is called allelopathy, and in this way the Australian pines control or eliminate competition by other plants. The chemicals released by Australian pines are known to be carcinogenic. The effect of these chemicals leaching into the lagoon is unknown.

Australian pine is very effective at controlling which plants it has to compete against for light and nutrients. When established it alters the temperature, light, and chemistry of soils, which drastically affects the native plants and animals beneath it. *Casuarina glauca* is thought to posses allelopathic properties. Allelopathy is the ability to exude chemicals that inhibit growth of other species beneath it. The chemicals called tannins that are leached from its “needles” are carcinogenic and can kill cattle that forage on them (Elfers, 1988). Australian pines are known to decrease soil pH, which has a dramatic effect on the capacity of the soil to retain nutrients (Ussiri, Lal, and Jacinthe, 2006).

FIGURE 20. Substrate beneath Australian pine, depicting how needle fall effectively eliminates competition from understory vegetation.

MORE ECOLOGICAL EFFECTS

Australian pine has the ability to fix soil nitrogen at rates comparable to nodulated legumes. This explains the ability of Australian pine to occupy nitrogen-poor sites such as coastal dunes, and allows these trees to grow densely and quickly (Ng 1987). The dense growth habit of Australian pine reduces light reaching the ground, and the high litter fall prevents germination of seeds. In the way these trees block sunlight and usurp the soil surface with litter fall, they are the ecological equivalent of a shaded parking lot. The ground beneath stands of these trees is ecologically depleted, often utterly devoid of vegetation and any animals except for a few arthropods. Most native species, plant and animal, are eliminated by this tree due to its ability to suppress recruitment of native plant species. For these reasons Australian pines can be considered a “keystone weed” (Gordon, 1998).

Australian pine destroys nesting habitat for many species not seen in the Thousand Islands such as sea turtles and crocodiles. These trees change the profile of dunes, making them steeper and horizontally compressed (Doren and Jones, 1997). Locally, they might affect nesting habitat needed by the diamondback terrapin (*Malaclemys terrapin*), a unique species unfortunately in decline. According to Klukas (1969), Australian pine is also known to exclude the gopher tortoise (*Gopherus polyphemus*), which has been introduced on at least one island.

Mazzotti, Ostrenko, and Smith (1981) studied the effects of Australian pine on small mammals and found that these trees effectively eliminated breeding animals from the landscape. The entire small mammal population under study demonstrated a strong preference for native vegetation. This finding is especially important because small mammals are a vital link between plants and predatory animals in ecosystem-level energy pathways. This systematic degradation of upper-trophic level biodiversity is the main reason these trees are seen as having no place in a Florida landscape. They should be aggressively removed as part of any restoration.

EDITORIAL COMMENT

It is worth pointing out that the Environmentally Endangered Lands Program is not, and never was intended to be a landscaping program. Its stated mission is "Protecting and Preserving Biological Diversity Through Responsible Stewardship of Brevard County's Natural Resources." Responsible stewardship is further defined as being "…guided by scientific principles for conservation and the best available practices for resources, stewardship and ecosystem management." It is difficult to fathom how the willful protection of any non-native species, be it stray cat, Brazilian pepper, or Australian pine, could possibly be a part of that mission.

Many biologists, myself included, view non-native species as an even bigger threat to the ecological diversity of Florida than development because these invaders threaten lands already protected from the bulldozer. The State is currently involved in a pitched battle against species such as Australian pine, spending millions of dollars trying to bring them under control. State funds were given toward the acquisition of the Thousand Islands; it is simply unreasonable to expect anyone to sanction the protection of these trees.

No one likes change. And as these trees are removed the islands will look different. But we must not see this in the darkness of something that has been lost, rather we should think of it in the light of what has been gained. This is restoration.

The next time you look at a stand of Australian pines I challenge you to see them not as stately trees swaying gently in the sea breeze, but as trespassers that are taking something from us. I challenge you to understand that the pelicans resting on branches hanging over the water will find other places to rest – just as they did for thousands of years before these trees were brought to Florida. I challenge you to consider all the native species, the ones we're trying to protect, that will be able to reclaim the land currently held against its will by these trees. And I challenge you not to be selfish about how you feel the land should look, but rather to accept the removal of these trees as a science-based act of ecological healing, fulfilling the mission of our Environmentally Endangered Lands program. By every contextually relevant definition of the word "right", aggressive removal of Australian pines is the right thing to do. We must not allow sentimentality to overrule science.

Notes

Closing Thoughts

Some Rules to Remember

FIRST LAW OF ECOLOGY

You can never do just one thing. Understand what this means and know that it always applies. For example, when salt marshes were impounded or dredged for mosquito control, the action that took away breeding habitat for mosquitoes also impacted breeding habitat for horseshoe crabs and foraging habitat for birds. Always look for examples of this when you do interpretive work.

EXPERTS DISAGREE

Don't let disagreement or lack of consensus confuse you. Read all sides, take a look in the mirror and if you feel you understand the subject well enough to have an opinion, have it. If you don't, then report the various opinions. For example, I generally report the number of sea level oscillations as varying, according to experts.

BEWARE OF SAYING "NEVER" OR "ALWAYS"

Plants and animals don't read books. Remember Davis coming to Florida, taking a quick look and reporting that mangroves built land, which we now know not to be the case. Have a look at this white mangrove (Figure 1) and remember it next time you read that they don't have aerial roots. It never read that book.

FIGURE 1. Aerial roots on white mangrove (*Laguncularia racemosa*).

CONTEXT AND DEFINITIONS

Beware of using scientific terms that have been misused/overused in the popular press. Often terms like “biodiversity” carry little or no meaning without a definition and context. For example, biodiversity at what taxonomic level, Species, Genus or Family? Does it mean anything to compare species diversity values from two different habitats, or is that ecological chauvinism?

Consider the two marshes below in Figures 2 and 3. Figure 2 is a *Sarcocornia* marsh in the Thousand Islands. The island is approximately 1 acre and there are 8 plant species on the island (Kozusko, unpublished data). The freshwater marsh in Figure 3 is in the Kissimmee Prairie and has 15 to 25 plant species per square meter. Is the freshwater marsh intrinsically more valuable than the salt marsh in the Thousand Islands? The salt marsh is probably more productive. So be careful using unqualified or vaguely qualified terms to describe habitats that exist in different contexts.

A term like biodiversity is best used as a measure within a context. For example, we can use species diversity to track the health of a specific ecosystem over time, or in response to some form of disturbance. But remember, the dredging of the Thousand Islands for mosquito control increased the plant species diversity dramatically, in spite of significant loss of wetlands. So be careful with terms.

FIGURE 2. Salt marsh in Thousand Islands, approximately 8 plant species per acre.

FIGURE 3. Freshwater marsh at Kissimmee Prairie, approximately 150 plant species per acre.

HUMAN CONSTRUCTS AS REALITY

You've learned names for various habitat types. Names like scrub and pine flatwoods should evoke distinct images of places you have walked through and can recognize and name. But when powerful multivariate statistical tools such a cluster analysis and ordination are brought to bear on plant distribution data, we see that these names we use to describe collections of plants don't actually exist. Names like scrub and pine flatwoods are really just a matter of convenience - they are human constructs to help us understand and describe our world. And though they are very helpful, even essential, they are not *real*. The boundaries between habitat types such as scrub and pine flatwoods can be very abrupt. However, the existence of a habitat called scrubby flatwoods should be a clue that often this clear boundary is not the case, and it can be impossible to tell where one habitat type ends and the next begins.

This is probably something of a shock, to read that there's no such thing as scrub. But that's not what I'm saying. My point is to understand that scrub is a label, not something real. Remember, when you look at a plant community you are looking at a living response to a set of environmental factors that vary over time and space, often in a continuous manner (Mitsch and Gosselink, 1993). The overlapping sets of plants that we see in the landscape sometimes are arranged as recognizable communities. Other times they are not. Changing gradients of environmental factors drive plant species distributions, not the associations themselves that we see and name. So the message here is don't let the category get in the way of what it is meant to describe. See the landscape, not the name we use to describe the landscape. Don't cloud your vision with expectations that attend labels.

Let's consider an example that will hopefully illustrate this. To do this we need to introduce some ecological concepts. Ecologists generally study the distributions of species and their interactions with each other and environment in which they live. A few key concepts in this are the role of predation, competition, and disturbance in determining the distributions of species in time and space. We will leave predation and competition to further reading or perhaps a later version of this booklet, as they can be very complicated subjects. For now we will consider the role of disturbance in creating a continuum of plant species based on soil moisture at the edge of a pond, and how this continuum affects plant species diversity and dominance. For further reading see succession in Mitsch and Gosselink, (1993).

THE ROLE OF DISTURBANCE

To grow, plants need nutrients, light, water, carbon dioxide, oxygen, etc. And they need these in the right amounts. We all know that plants evolve oxygen in photosynthesis, but they also need oxygen for the same reason we do. Most plants get their oxygen primarily through their roots. But as soils become waterlogged, oxygen moves into the soil more slowly than the plant needs it (Mitsch and Gosselink, 2003). To live in waterlogged soils plants must have adaptations to get the oxygen they require in other ways. You might have learned about some of the adaptations mangroves have evolved to deal with their flooded environments. The flooding of soil and the accompanying depletion of oxygen can be thought of as a form of disturbance.

Another form of disturbance that we will consider is the effect that salt in water has on the cells of an organism. Technically the salt in water around the Thousand Islands is not a disturbance as it is more or less constant in time. But increased water levels during the summer can bring salt water into contact with plant roots. In this fashion salt can act as a sort of disturbance, even if it is a stretch to consider it that way. As an aside, central Florida is a study in disturbance ecology. We have infrequent freezes, fire of varying frequency, and hurricanes, just to name a few. As you continue your studies of the ecology of central Florida you will encounter the role of disturbance again.

If the amount of salt dissolved in the water surrounding root cells is higher than the salt concentration in the cells, water will try to leave the cells to go into the surrounding water in an attempt to equalize the concentration. This is osmosis. It means that plants growing in salt water have to work to keep water inside their cells, in spite of growing in flooded soil. This is the paradox of life in a salt marsh.

SOIL MOISTURE GRADIENT

Let's return to the figure concerning the slope of the land-water interface (Figure 4). In a wetland where the typical water level varies between the two blue lines, the vertical black lines represent the habitat where soil water content will be most variable. The frequency and duration of saturated soil conditions is termed hydroperiod. From the deepest part of the pond that is always flooded, to the outer edges where it never floods, this landscape can be said to experience a continuum of average hydroperiod, varying from 365 days where the pond doesn't dry out in an average year, to 0 days where soil is not flooded in an average year. Just below Figure 4 is a photograph of a flatwoods pond in the same orientation, with the pond center to the left (Figure 5). The beginning of wooded uplands is obvious in this photograph and there is some concentric zonation of the wetland plants, which is a response to the continuum of hydroperiod.

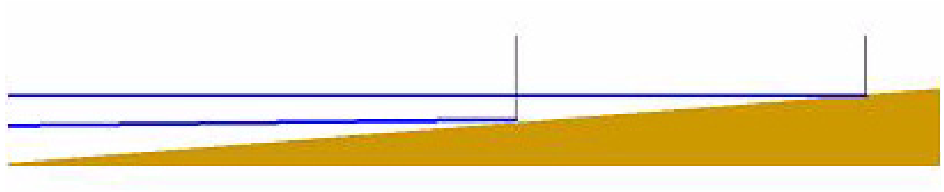


FIGURE 4. In this figure the horizontal extent of land affected by a change in water level (blue lines) is depicted by vertical black lines.

FIGURE 5. A flatwoods pond depicting a continuum of hydroperiod from flooded on the left, to dry uplands on the right and foreground.

So how does this relate to the Thousand Islands? Recall that the plant species diversity we considered earlier was very low in the native *Sarcocornia* marsh compared to a wetland in the Kissimmee Prairie. In Figure 6 we see a view of a prairie pond just after the application of prescribed fire in 1998. This makes the extent of the pond obvious as the wetland vegetation did not burn. Recall that the plant species diversity is listed as 150 to 200 species per acre (Paul Gray, personal communication). In the center of the pond (left) note the dark green of pickerelweed (*Pontederia cordata*). In the center of the pond the disturbance is so constant as not to be a disturbance - it is the normal condition. The conditions are harsh, but if a plant has the necessary adaptations to deal with these conditions, competition will be low and the plant species can thrive. Farther from the center the hydroperiod begins to be more variable and we see maidencane grass (*Panicum hemitomon*) with a few species of sedge, etc. As the hydroperiod becomes much more variable, we can see 15 to 20 or more plant species per square meter. This is the key to understanding the role of an environmental continuum to plant distribution. As hydroperiod becomes more variable, no single species can dominate the variable habitat and species diversity is high. The continuum of hydroperiod is a major influence on the species composition there. Contrast this with Figure 7, *Sarcocornia* marsh in the Thousand Islands, with just a few species per acre, and no continuum.

FIGURE 6. View of a Kissimmee Prairie pond just after prescribed fire. Note concentric zonation of plants, shown by different shades of green.

FIGURE 7. *Sarcocornia* marsh in the Thousand Islands.

In this salt marsh the conditions are harsh, but nearly constant so there is little competition for species able to cope with the conditions. This relates to low species diversity, although productivity can still be quite high. Here there is no gradient so there is no change in species composition. In the prairie pond the continuum was one of highly variable hydroperiod, resulting in higher species diversity. This is a complex and abstract subject, presented here only briefly. But it is worthy of further investigation.

RESILIENCE

One last point. Nature, particularly near the tropics where energy supplied from the sun and rainfall are abundant, can be quite resilient. In my forty years of experience with the Thousand Islands I have seen them dredged and repeatedly damaged by freezes. Yet they always manage to bounce back. Consider Figure 8. This aerial was taken in December 1969 when mosquito canal dredging had begun in the south Thousand Islands. Note the white bare sand where salt marsh was destroyed and converted to uplands. Figure 9 is a picture I took in this same area, just over 3 years later. Notice how rapidly the Australian pines had invaded the disturbed soils, and how quickly the mangroves regrew. Remember this concept in the context of restoration.

FIGURE 8. Aerial view of south Cocoa Beach, December, 1969. Photo courtesy Ted Roever.

FIGURE 9. View of regrowth just less than 4 years after dredging in the Thousand Islands, summer, 1973.

In closing, view this booklet as but one source of many. Make it a point to be as well-read as you can on the natural history and ecology of our area. And remember, no book can be a substitute for your own observations! I'll end with an example that in one move demonstrates the tenacity of life that you should be on the lookout for, and the downright nastiness of Australian pine.

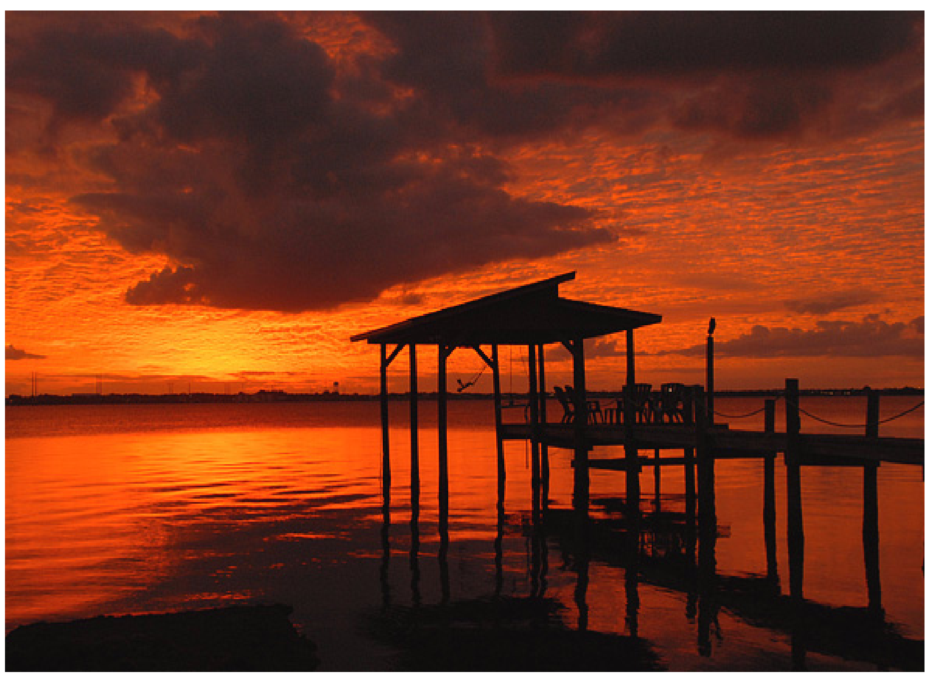
In Figure 10 we see an Australian pine at Long Point Park that was blown over in the hurricanes of 2004. In the center of the photograph you can see the root system as a vertical brown mass with new green growth arising from the now horizontal original trunk of the tree. In Figure 11 we see the *underside* of the root system. Note the two green branches on the right side of the root system. As can be seen in Figure 12, these green, photosynthetic branches have arisen from what had been the *underside* of the root system. A part of the tree that had been formerly underground, has the ability to become a photosynthetic branch just by virtue of now being exposed to sunlight.

FIGURE 10. Wind-thrown Australian pine at Long Point, February, 2008.

FIGURE 11. View of underside of root system, now exposed. Note new growth.

FIGURE 12. Close-up view of a former root that, under exposure to sunlight, has sprouted a photosynthetic branch.

Never lose your sense of amazement at examples of nature such as this, non-native or not.



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Born in 1959, Tim Kozusko is a native of Cocoa Beach and lifelong barrier island resident. Educated locally, he has an M.S. in biology from the University of Central Florida and is currently a doctoral student at FIT in science education (biology), interested in the public perception of what constitutes methods of science. He works at Kennedy Space Center and resides in Melbourne Beach with wife Laura.

He is a member of the American Society of Limnology and Oceanography, Florida Academy of Sciences, Indian River Anthropological Society, Native Plant Society, Sierra Club, Society of Wetland Scientists, Surfrider Foundation, and the Union of Concerned Scientists. In May 2007 he was honored to receive Keep Brevard Beautiful's Education Award for community service.

The author applying prescribed fire at the Ordway-Whittel Kissimmee Prairie Sanctuary, now part of Kissimmee Prairie State Preserve, July, 1997.

Notes