AUSTRALIAN PINE
Casuarina equisetifolia L.
Management Plan for Florida

Recommendations from the Australian Pine Task Force

April 2013

Florida Exotic Pest Plant Council
www.fleppc.org

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# TABLE OF CONTENTS

LIST OF FIGURES .................................................................................................................. 5

LIST OF CONTRIBUTORS ........................................................................................................... 5

EXECUTIVE SUMMARY ............................................................................................................ 7

I. INTRODUCTION ....................................................................................................................... 8

II. PROBLEM STATEMENT .......................................................................................................... 8

III. GOAL ...................................................................................................................................... 9

IV. OBJECTIVES .......................................................................................................................... 9

V. RECOMMENDATIONS ............................................................................................................ 9

VI. BIOLOGY OF AUSTRALIAN PINE (*Casuarina equisetifolia* L.) ........................................... 9

Vernacular Names ...................................................................................................................... 9

Synonyms ..................................................................................................................................... 9

Taxonomy and Morphology ....................................................................................................... 10

Description of Growth .............................................................................................................. 10

Foliage ........................................................................................................................................ 10

Reproduction ............................................................................................................................. 10

Flowering and Fruiting ............................................................................................................ 11

Seed Dispersal and Establishment ............................................................................................. 12

VII. DISTRIBUTION ..................................................................................................................... 13

Distribution and Ecology in Native Range ................................................................................ 13

Distribution in Florida .............................................................................................................. 14

VIII. ECOLOGY ............................................................................................................................ 16

Ecological Impacts in Introduced Range ................................................................................... 16
Impacts on Coastal Beach Ecosystems (Beach Dune, Coastal Strand and Maritime Hammocks) ............................................ 16

Ecological Impacts on Short Hydroperiod Wetlands in the Everglades ................................................. 20

IX. PROPOSED AND ENACTED LAWS ........................................................................................................... 20

X. ECONOMIC IMPACTS ................................................................................................................................. 20

XI. HUMAN HEALTH IMPACTS ..................................................................................................................... 21

XII. HUMAN DIMENSIONS ............................................................................................................................. 21

XIII. MANAGEMENT ........................................................................................................................................ 22

Herbicides and Application Methods ........................................................................................................... 23

Stump application of herbicide .................................................................................................................. 23

Frill or girdle herbicide application ........................................................................................................ 23

Basal bark herbicide application .............................................................................................................. 23

Foliar herbicide application ...................................................................................................................... 24

Soil herbicide application ......................................................................................................................... 24

Marker dyes .................................................................................................................................................. 24

Machinery Used for Mechanical Removal .................................................................................................. 24

Feller-bunchers ............................................................................................................................................. 24

Forestry mowers or mulching heads ........................................................................................................ 24

Biological control ......................................................................................................................................... 25

Manual removal ............................................................................................................................................. 27

XIV. RESTORATION ........................................................................................................................................ 28

XV. CASE STUDY: BILL BAGGS CAPE FLORIDA STATE PARK .................................................................. 28

XVI. CASE STUDY: THOUSANDS ISLANDS, COCOA BEACH .................................................................... 33

XVII. REFERENCES/LITERATURE CITED .................................................................................................... 40
LIST OF FIGURES

Figure 1 *C. equisetifolia* branchlets ............................................................................................................. 11
Figure 2 *C. equisetifolia* seeds ..................................................................................................................... 12
Figure 3 Shallow lateral root system of downed tree (Sanibel Island, Florida) following Hurricane Charley (2004). .................................................................................................................. 13
Figure 4 Windbreak around Persian lime grove in Miami-Dade County ...................................................... 14
Figure 5 Distribution of *Casuarina equisetifolia* in Florida (EDDMapS 2012) ........................................... 15
Figure 6 Beach erosion; Highland Beach, Everglades National Park (1973).................................................. 16
Figure 7 Australian pine understory at Bill Baggs Cape Florida State Park (prior to 1992) ....................... 17
Figure 8 Australian pines threaten crocodile nest in Florida Bay, Everglades National Park ............... 19
Figure 9 Loggerhead turtle trapped in Australian pine roots (Dry Tortugas National Park) ............... 19
Figure 10 Location of Bill Baggs Cape Florida State Park ......................................................................... 29
Figure 11 Bill Baggs Cape Florida State Park (prior to 1992) showing a near-monoculture of Australian pines. ........................................................................................................................................... 30
Figure 12 Bill Baggs Cape Florida following Hurricane Andrew (1992) ..................................................... 31
Figure 13 Bill Baggs Cape Florida in 2012 showing restored native vegetation following Australian pine management .......................................................................................................................... 32
Figure 14 The Thousand Islands, Cocoa Beach, Florida. The Minuteman Causeway ............................. 33
Figure 15 The south Thousand Islands showing the original phased removal plan for exotics. Only Phase 1 has been completed; Phase 2 is pending and has been scaled down .................................... 35
Figure 16 Reynolds 2 (Rey 2) parcel before (above) and after (below) exotics removal by heavy equipment. Note planted southern red cedars (*Juniperus silicicola*) in foreground following removal. Heavy mulch layer in background (below) is the remains of mulched *Casuarina spp.* 37
Figure 17 Crawford Island before (left) and after (right) mechanical removal of *Casuarina* spp. Trees were cut/uprooted and pile-burned. Shrubs shown recruiting (right) are groundsel tree (*Baccharis halimifolia*) and Florida privet (*Forestiera segregata*). Other species planted are not shown .................................................................................................................................................. 38
Figure 18 Yellowtop (*Flaveria linearis*) recruiting in profusion on Crawford 1 following removal of *Casuarina* spp. (Photo: Tim Kuzusko) ........................................................................................................ 38
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Executive Summary

Australian pine (*Casuarina equisetifolia*) is a fast growing tree native to Australia, Southeast Asia, India, Bangladesh and the Pacific Islands that has been introduced to tropical areas throughout the world as an ornamental; to stabilize sand dunes; to form windbreaks around canals, roads, houses, and agricultural fields; and for reforestation due to its capacity to thrive in poor and saline soils.

As a result of these intentional introductions, Australian pine has become a highly invasive species and is found along most humid tropical or sub-tropical beaches around the world.

In Florida, Australian pine occurs predominantly south of Orlando as it is sensitive to extended periods of freezing temperatures. Australian pine produces copious amounts of wind and water dispersed seeds and is able to colonize a wide variety of habitats including coastal areas, pinelands, disturbed sites and higher areas of elevation in the Everglades. The fast growth, prolific seeding and thick litter accumulation of Australian pine impedes the establishment of native plant species and their associated herbivores, disrupting natural processes. Australian pine readily establishes on sandy shores which leads to increased beach erosion and interference with the nesting of endangered sea turtles and crocodiles.
I. Introduction

Over half of all the land in Florida has been developed or is in agriculture. The remaining natural areas are being lost at an ever increasing rate. Protecting them is vital to preserving our cultural history, native species, water quality and quantity. These remaining natural areas are being detrimentally impacted by invasive plants. Invasive plants are species that have been accidentally or intentionally introduced from outside of their native ranges and cause economic or environmental harm (Clinton, 1999). Invasive plant species cause environmental harm by displacing native plants and associated wildlife, including endangered species. Invasive plants may also alter natural processes such as fire and water flow. In Florida, almost one third of all plant species are non-native and 11% are invasive in natural areas (Pimental et al, 2005).

The Florida Exotic Pest Plant Council was formed in 1984. The mission of the Council is to support the management of invasive exotic plants in Florida's natural areas by providing a forum for the exchange of scientific, educational and technical information. The Australian Pine Management Plan was developed by the Australian Pine Task Force to assist land managers (public and private) in the integrated management of Australian pine in Florida. The Task force is composed of land managers, biologists and academics who have been actively working on the management of Australian pine. The Australian Pine Management Plan is intended to provide comprehensive information regarding the management of Australian pine in Florida.

II. Problem Statement

*Casuarina* species are fast growing evergreen trees that have become serious invasive weeds of coastal areas in central and southern Florida, Hawaii, Puerto Rico and the Virgin Islands (USDA, NRCS 2012). In their Florida adventive range, three species, *C. equisetifolia* (Australian pine), *C. glauca* (suckering Australian pine), and *C. cunninghamiana* (river sheoak), as well as their hybrids, are widely naturalized. This document will only describe the management of Australian pine (*C. equisetifolia*).

*C. equisetifolia* is established and continuing to expand in southern and central Florida. *C. equisetifolia* is unparalleled in its ability to alter coastal habitats due to its rapid growth, dense coverage, thick litter accumulation and ability to increase beach erosion. Of all the exotics that invade coastal areas of Florida (e.g., *Schinus terebinthifolius*), *C. equisetifolia* poses by far the greatest threat to native beach vegetation (Johnson and Barbour 1990). In Florida, *C. equisetifolia* is regulated (possession, propagation, sale, and transportation) as a Noxious Weed by the Florida Department of Agriculture and Consumer Services (5B-57.007 F.A.C.) and is listed as a Category 1 invasive plant by the Florida Exotic Pest Plant Council.

*C. equisetifolia* invades sandy seashores, pinelands, hammocks and short hydroperiod wetlands in all areas of Florida not subject to prolonged freezing temperatures. It has proven to be ill-suited for its original uses as a windbreak sheltering agricultural areas, providing ditch and canal stabilization, and as an ornamental due to its propensity to be blown over in the face of even moderately strong winds (Digiamberardino 1986).
III. Goal

The goal of the Australian pine task force is to protect Florida’s native flora and fauna by developing a state-wide management plan that will assist natural area land managers and the general public in effectively managing Australian pine in Florida.

IV. Objectives

1) To provide information about the taxonomy, ecology, distribution and environmental impacts of Australian pine in Florida.
2) To provide up to date information on control methods for Australian pine in Florida.

V. Recommendations

1) Support research that further quantifies the ecological impacts of Australian pine.
2) Encourage and support Australian pine management efforts throughout Florida.
3) Support efforts to find a suitable biological control agent for Australian pine.
4) Support the development and production of outreach materials that can raise public awareness about the negative environmental impacts of Australian pine.

VI. Biology of Australian Pine (Casuarina equisetifolia L.)

Vernacular Names

The Casuarina family in Australia is called the She-Oak family. The name is likely derived by early settlers as the wood reminded them of oak (Maiden 1917). The prefix “she” is commonly used in Australia to denote paleness of color or inferiority (Maiden 1917).

Casuarina equisetifolia is known around the world. Some of the more common names include: Australian pine, beefwood, casuarina, horsetail casuarina, she-oak, beach she-oak and ironwood.

Synonyms

Casuarina litorea L.
Taxonomy and Morphology

*Casuarina equisetifolia* is in the She-oak family, Casuarinaceae, and assigned to the *Casuarina* genus. Unrelated to the pine family (Pinaceae), Casuarinaceae comprises 4 genera and 90 species from tropical, subtropical dry regions, and warm temperate areas (Wilson 1997). The family is native to Southeast Asia, southern Pacific Islands to Tahiti and Samoa, and Australia. The genus *Casuarina* contains 17 species (Wilson and Johnson 1989). The botanical name *Casuarina* is derived from the resemblance of the branchlets to the feathers of the Cassowary (Maiden 1917). The specific name *equisetifolia* is derived from the resemblance of the needles to horse hair.

In Australia, the species *C. equisetifolia* L. (= *C. litorea* L. ex Fosberg & Sachet) has two subspecies, *C. equisetifolia equisetifolia* and *C. equisetifolia incana*; however, only the former subspecies is known from Florida (Wilson 1997). Additionally in Florida, two other members of this genus are considered invasive, *C. glauca*, and *C. cunninghamiana*.

Description of Growth

*Casuarina equisetifolia* can grow up to 40 m (131 ft.) in height. The foliage is drab olive to green in color and diffuse with wide-spaced branches. In Florida, trees generally appear flat-topped as the lateral branches that originate low on the stem generally overtake the leader (Woodall and Geary 1985). Growth rates have been reported to be as rapid as 3 m (10 ft.) per year (Rogers 1982).

Foliage

The foliage occurs as branchlets that are slender and jointed, producing short segments or nodes. The segmented branchlets are angular with longitudinal ridges separated by furrows containing stomata. The branchlet furrows are usually filled with dense hairs. Branchlet diameter measures 0.5–0.7 mm, each segment may be 5–8 mm, and the total branchlet length measures 10–25 cm long. The leaves are reduced to erect scale-like teeth (0.3–0.8 mm long) arranged in whorls at the apex of each joint. In *C. equisetifolia*, the leaf teeth number 6–8 and usually become gradually whiter toward the tip and edges (Rogers 1982; Woodall and Geary 1985; Wilson 1997).

Reproduction

*Casuarina* spp. are wind pollinated and *C. equisetifolia* reproduces mostly by seed production. It generally does not form root suckers, coppices weakly from low stumps, but may coppice well from stumps taller than 1 m.

Interspecific hybrids between *C. equisetifolia* and *C. glauca* appear to be common in Florida (Gaskin et al 2009). Similar hybridization has been reported from Taiwan between these two species, and possibly with *C. cunninghamiana* (Ho et al. 2002). These hybrid individuals may be difficult to identify as they have combinations of characteristics consistent with each parental species (Woodall and Geary 1985).
Flowering and Fruiting

Seasonal flowering of *C. equisetifolia* occurs two times each year during the spring and summer (Rogers 1982; Wilson 1997). In Florida, peak flowering occurs from April through June with fruits maturing between September and December (Burns and Honkala, 1990). *C. equisetifolia* produces unisexual flowers and plants are monoecious with both staminate (male) and pistillate (female) flowers. Each male flower is borne in slender, cylindrical spikes at the twig tip, is subtended by 3 or 4 bracts, and consists of a single stamen. The staminate spike terminal is 0.6–2.5 cm long. The female flowers are located in axillary leaf clusters. The fruiting stage of the flowers, or infructescence, is woody and cylindrical. Cones are slightly longer than wide, 9–11 by 12–24 mm, and sparsely pubescent (Wilson 1997). When the cones are fully ripe they range in color from gray green to a reddish brown. When fully mature the two bracteoles that form the individual fruits separate to release a single seed. The solitary seed is a samara, measures 6–8 mm long, is pale brown and possesses a membranous wing (Kondas 1983). *C. equisetifolia* trees are capable of producing viable seeds at two years (Rai 1990). A single Australian pine tree may produce thousands of seeds per year (Morton 1980; Elfers 1988).
Seed Dispersal and Establishment

_Casuarina equisetifolia_ seeds are winged samaras and are dispersed by wind and water (Binggeli 1997). Once released from their cones, the tiny samara can ride on air currents enabling wind dispersal far from the parent tree. Samaras that reach the water can float for over three weeks and are capable of long distance dispersal by ocean and tidal currents. They can germinate in salt water (Pernas and McKinley 2012). To successfully establish, floating seeds/seedlings must be deposited on high ground free of tidal disturbance.

In Florida, mature fruits ripen and are released from cones during the peak of tropical cyclone activity (September–December). This facilitates the establishment of _C. equisetifolia_ far from parent trees after the high winds and tides associated with tropical cyclones, as observed in Everglades National Park following Hurricane Donna in 1960 (Klukas 1969).

Seeds of _C. equisetifolia_ remain viable for up to one year (Elfers, 1988). Seed germination in viable seeds can occur within 14 days with 50% of the viable seeds germinating (Ng and Mat Asri 1979). Floating seeds will germinate within 14 days in fresh or salt water (Pernas and McKinley 2012). Seed germination rates ranged from 41 to 51% when collected from mature, >15 week old fruit. Germination rates decreased to 29% when seeds were collected from younger, immature fruit, 13 weeks old (Rai 1990). _Casuarina_ seed viability can vary dramatically according to the conditions in which seeds are stored. In one example, _C. equisetifolia_ was found
to retain viability for only a few months (Troup 1921). Under controlled environments, when stored at either sub-freezing (-7 C) or close to freezing (3 C) temperatures with seed moisture contents from 6–16 %, *C. equisetifolia* seeds were viable for 2 years (Jones 1967).

**Rooting Habit**

Although *C. equisetifolia* usually has a deep tap root and an extensive shallow lateral root system, poor tap root development occurs on shallow soils or in areas with a high water table (Yadav 1983) such as is found in southern Florida.

![Figure 3 Shallow lateral root system of downed tree (Sanibel Island, Florida) following Hurricane Charley (2004).](image)

**VII. Distribution**

**Distribution and ecology in native range**

*C. equisetifolia* is adapted to sites with relatively high salinity, arid conditions, and low soil fertility. Natural stands occur in temperate to subtropical areas along the east and north coast of Australia from 12–37°S latitude (Midgley et al. 1983; Boland et al. 1984; Wilson and Johnson 1989). This species also ranges from Burma to Vietnam, Malaysia, Melanesia and Polynesia (Wilson and Johnson 1989; Wilson 1997).
Distribution in Florida

*C. equisetifolia* was introduced into Florida in 1898 by U.S. Department of Agriculture plant explorer, Dr. Walter T. Swingle (Morton 1980). It was heavily promoted by John Gifford, pioneer silviculturist in the early 1900s (Gifford 1972). *C. equisetifolia* was extensively planted for ornamental purposes, along roadsides and as windbreaks for citrus groves (Crowder 1974).

In Florida, *C. equisetifolia* colonizes open, sandy habitats, especially along shores and barrier islands. It also colonizes short hydroperiod prairies, tree islands and pine lands (Langeland and Craddock-Burks 1998). This species may occupy ruderal habits, colonizing sites disturbed either by human activity or by storm damage (Morton 1980). A salt tolerant species, *C. equisetifolia* may be found on coastal dunes where it increases beach erosion and interferes in the nesting of endangered sea turtles and American crocodiles (Sealey 1996; Klukas 1969; Doren and Jones 1997).

Infestations of *C. equisetifolia* have been reported in diverse locations with many occurring in very nutrient-poor sites (Rogers 1982). It is reported that these trees are assisted in such conditions by the nitrogen fixing symbiotic fungi (*Frankia* strains) present in the root nodules (Puri 1990).

*C. equisetifolia* in Florida extends north from the Florida Keys mostly along the coasts to central and northern Florida (Wunderlin and Hansen 2008). Along the east coast of the state, *C. equisetifolia* has been reported as far north as Fernandina Beach (30 42° 05’ N latitude), Nassau.
County and on the west coast from St. Marks Refuge (29° 53’ N latitude), Taylor County (EDDMapS 2012).

Throughout Florida Australian pines have been reported from 30 state parks and 8 National Park Service units and are estimated to invade nearly 161,880 ha (400,000 acres) (Cox 1999). Surveys conducted in recent years indicate that Australian pine has colonized large sections of the remaining natural portions of coastline and barrier islands along both the Atlantic and Gulf coasts. On the Gulf coast, approximately 33% of the remaining natural coastline or about 20.1 miles are heavily invaded by Australian pine (Glisson 1997). On the Atlantic coast from Indian River to Dade Counties, 46% of the undeveloped barrier island coastline is heavily infested. In surveys of the Everglades National Park, dense stands of Australian pine were reported from 7,200 ha in the southeastern corner (Doren and Jones 1997).

Figure 5 Distribution of Casuarina equisetifolia in Florida (EDDMapS 2012).
VIII. Ecology

ECOLOGICAL IMPACTS IN INTRODUCED RANGE

Impacts on Coastal Beach Ecosystems (Beach Dune, Coastal Strand and Maritime Hammocks)

Coastal beach ecosystems are one of Florida’s most valuable natural, aesthetic, and economic resources. Coastal beach ecosystems provide valuable habitat for a diverse assemblage of native plant and animals. These unique habitats are disappearing from Florida as they are displaced by real estate development and the encroachment of invasive plant species such as *C. equisetifolia*. Coastal beach ecosystems can be divided into five zones:

1) Beach
2) Upper Beach Zone
3) Foredune
4) Coastal Strand
5) Maritime Hammock

*Figure 6* Beach erosion; Highland Beach, Everglades National Park (1973).
Beaches are created as sand suspended in the wave is deposited on the beach as the wave breaks and is dragged back again in the backwash. Typically the energy of the backwash is less than the initial energy of the wave, resulting in accumulation of sand and the creation of beaches. Storms such as hurricanes often have the opposite effect. The high energy waves produced by the storm erode sands offshore. Plants usually are not able to colonize the beach immediately adjacent to the ocean due to high winds, wave action, and the presence of sea water. The zone above the wrack line or high tide line is called the upper beach zone. In this zone several pioneering plant species are able to establish allowing sand stabilization and the creation of sand dunes. The characteristics of these pioneering plants are rapid growth rates, adaptations to withstand sand movement (accretion and erosion), low nutrients, xeric conditions and inundation. The vegetation in this zone is comprised of drift line annual plants and perennial trailing vines. The zone above the upper beach zone is the foredune. The foredune typically consists of rhizomatous grasses such as sea oats (*Uniola paniculata*) that can survive shifting sands blown off the beach. Above the foredune is the coastal strand. The coastal strand consists of a diverse assemblage of trees and shrubs that are naturally pruned by the salt spray and wind. The upper most zone is the maritime hammock. Maritime hammocks are forests of evergreen broadleaved trees and shrubs (temperate and tropical species).

*Figure 7* Australian pine understory at Bill Baggs Cape Florida State Park (prior to 1992).
The establishment of *C. equisetifolia* in the upper beach zone or foredune disrupts geomorphological and biological processes that create beaches and coastal plant communities. *C. equisetifolia* has been cultivated for erosion control throughout the world (National Research Council 1984). However numerous studies conducted in Florida, the Bahamas, and the Midway Islands show that the establishment of *C. equisetifolia* contributes to the loss of native beach vegetation and beach. Natural processes in the absence of *C. equisetifolia* result in the onshore buildup of sand and dunes by normal wave action (Beavers et al. 1995; Brill et al. 1993). The establishment of Australian pine reduces native vegetation through direct competition for nutrients in the nutrient poor soil. Native vegetation is shaded out by the dense foliage of mature Australian pine and smothered by the dense litter of branchlets (Hammerton 2001). Australian pine is also known to be allelopathic, further inhibiting the growth of native vegetation (Craighead 1978).

The impacts of *C. equisetifolia* are not restricted to the loss of vegetation and beach sand. Beach coastal habitats are complex and support a large number of animal species. Monospecific forests of *C. equisetifolia* eliminate native habitats essential for the survival of wildlife including the American crocodile (*Crocodylus acutus*) and several sea turtle species.

The American crocodile is listed as threatened by the United States Fish and Wildlife Service (USFWS). The three primary nesting colonies of the American crocodile in south Florida are Everglades National Park (Florida Bay Islands), Crocodile Lake National Wildlife Refuge, and Florida Power and Light Turkey Point Power Plant cooling canals (Mazzotti and Cherkiss 2003). The American crocodile constructs earthen nests on creek banks, sandy shores or on canal levees adjacent to water. These sites are all vulnerable to colonization by wind and water dispersed *C. equisetifolia*. Once established, *C. equisetifolia* forms dense superficial roots that disrupt the nesting of the American crocodile.

Five species of sea turtles utilize Florida’s beaches for nesting including the loggerhead, green hawksbill, Kemp’s Ridley and leatherback. Florida is the most important area for turtle nesting in the western Atlantic (Johnson and Barbour 1990). Sea turtles prefer open sandy areas to lay their eggs. The establishment of *C. equisetifolia* on the beach makes the site unusable for turtle nesting due to superficial root growth and thick litter fall (Panday et al. 1998).
Figure 8 Australian pines threaten crocodile nest in Florida Bay, Everglades National Park.

Figure 9 Loggerhead turtle trapped in Australian pine roots (Dry Tortugas National Park).
Ecological Impacts on Short Hydroperiod Wetlands in the Everglades

*C. equisetifolia* has spread into short hydroperiod wetlands in and adjacent to Everglades National Park in Miami-Dade County, Florida. These sparsely vegetated wetlands have an average hydroperiod of two to five months. The wetlands are composed of shallow marl soils with many outcrops of oolitic limestone. The vegetation of these short hydroperiod wetlands consist of sawgrass (*Cladium jamaicense*), muhly grass (*Muhlenberghia capillaris*), panic grasses (*Panicum* spp.) and beak rushes (*Rhynchosperma* spp.) Interspersed within these short hydroperiod wetlands and occurring on higher elevation oolitic rock substrate are tropical hardwood hammocks or tree islands. Larger tree islands on higher ground remain dry throughout the wet season. Lower elevation tree islands may remain inundated or partially inundated during the wet season.

*C. equisetifolia* seeds are dispersed by wind and water and readily germinate on the oolitic limestone outcrops. The fast growing *C. equisetifolia* easily outcompetes native tree island vegetation with its dense shade and thick leaf litter accumulation.

*C. equisetifolia* also directly impacts native wildlife. Established *C. equisetifolia* habitats contained fewer rodents than native tree island habitats (Mazzotti et al. 1981).

The Cape Sable seaside sparrow (*Ammodramus maritimus mirabilis*) is a federally endangered subspecies of the seaside sparrow that is found in short hydroperiod freshwater wetlands in Everglades National Park. The USFWS has identified critical habitat essential for the survival of the sparrow in Everglades National Park. The sparrow prefers large expanses of open graminoid habitat with few or sparse woody trees.

IX. Proposed and Enacted Laws

*C. equisetifolia* is listed as a noxious weed by the state of Florida (Rule 5B-57.004 F.A.C) due to its potential to “…pose a threat to agriculture, beneficial organisms, or the environment or become a public nuisance.” This rule makes it illegal to introduce, multiply, possess, move or release *C. equisetifolia*. Casuarina spp. are also on the Florida Class 1 Prohibited Aquatic Plants List (Rule 5B-64.011) and “Under no circumstances will these species be permitted for possession, collection, transportation, cultivation, and importation except as provided in Rule 5B-64.004, F.A.C.”

X. Economic Impacts

Economic Uses in Native Range

*Casuarina* spp. are not known to be pests in their native range of Australia and many are valued trees that are protected by law (Boland et al. 1984). *C. equisetifolia* is planted as a windbreak for agriculture and utilized as an ornamental tree throughout its native range (Parrotta 1993). *C. equisetifolia* is a heavy hard wood and is utilized for timbers, tools, posts and shingles. The wood is subject to splitting and warping and as a result is not used for furniture or lumber (Ruskin 1984). The wood is also susceptible to infestation by dry wood termites and rots easily
when in contact with the ground (Longwood 1961). *C. equisetifolia* produces a high quality fuel wood that has a low ash content and makes excellent charcoal (Ruskin 1984).

**Economic Impacts in Florida**

*C. equisetifolia* historically has been used for landscape trees, formal hedges, windbreaks for agriculture and firewood but it is no longer used for any of these purposes (except, perhaps, for firewood) in Florida.

Negative economic impacts of *C. equisetifolia* include increased beach erosion that may necessitate costly beach re-nourishment programs (Elfers 1988); the displacement of mangroves resulting in the net loss of nursery and foraging habitat for marine species of economic value. Roots of *C. equisetifolia* can also damage roads, sidewalks and sewer pipes. *C. equisetifolia* has poor resistance to high winds. Although it is composed of strong heavy wood, it does not defoliate making it vulnerable to toppling, trunk snap and major branch breakage (Francis and Gillespie 1989). In Florida the shallow lateral root system coupled with its height also makes it vulnerable to toppling (Burch 2006). Following Hurricane Andrew in 1992, only 4% of *C. equisetifolia* trees were still standing in southern Florida compared to 66% of native trees (Duryea et al. 1996). In 2004, Hurricane Charley struck Sanibel Island where *C. equisetifolia* trees toppled onto roads, utility lines and homes, causing extensive structural damage (Ferriter et al. 2005; Loflin 2004) and hindering relief efforts.

**XI. Human Health Impacts**

Australian pine (*Casuarina* spp.) is wind-pollinated and sheds large amounts of pollen in the spring and early summer. It is classified as an aeropollen that can cause allergic reactions such as respiratory problems, eye irritation, rhinitis, and/or hoarseness (Garcia et al. 1997; Bucholtz et al. 1987).

**XII. Human Dimensions**

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Resource managers or landowners contemplating the removal of Australian pines to restore native habitats need to be prepared for possible reactions both positive and negative. The removal of mature Australian pines particularly can bring critical, deeply emotional reactions from the public. This section is intended to identify the basis for the reactions and to help the resource manager address the public’s concern.
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Controlling or managing invasive species can sometimes be very controversial. Accepting the concept of [controlling] invasive species [as a threat] is not completely dependent on ecological criteria but on human perceptions as well (McNeely 2001). This is particularly true in circumstances where resource managers or biologists are proposing to remove invasive species
that have held a prominent place in the public landscape. In these cases it is important to identify your stakeholders and make an effort at public outreach.

Effective outreach should include information about the impact of invasive species (e.g. Australian pine) on, for example, ecosystem stability and biodiversity. However, the presentation of scientific information is unlikely to be persuasive for many people. This is particularly true in circumstances where resource managers or biologists are proposing to remove species that have held a prominent place in our public landscapes. To be informed that Australian pine is an invasive species that is proposed for removal forces individuals to face a host of losses that can be psychologically costly (e.g., what we thought was natural is not; what we loved was an invasive weed) (McNeely 2001).

Another psychological cost is the loss of a “sense of place.” Floridians generally have a deep sense of place that is usually developed at a young age. They tend to identify with the plants that they grew up with. Australian pines were present in many coastal communities on both public and private lands during the young developmental stage of many Floridians. The value we place on preserving our sense of place is strong. As a consequence, the removal of Australian pine from prominent public places can stir strong emotions and lead to resentment of land managers and biologists.

Effective outreach might include an invitation (an appeal really) to the stakeholders to adopt an alternative “sense of place.” The alternative should be described clearly in order to encourage stakeholders to re-connect psychologically to a new place. The “sense of place” that land managers and biologists envision is an ideal: the natural landscapes and ecosystems that Native Americans and early European settlers and explorers would have experienced.

For stakeholders, adopting a new sense of place is psychologically risky. Perhaps their skepticism is with good reason because many past efforts have lacked long-range planning and, as a result, left bare ground and stumps that were eyesores to the local community. Therefore, outreach efforts should clearly detail planned restoration efforts including detailed re-vegetation plans, assuring the public of a positive vision of the site for the future.

**XIII. Management**

Australian pine is controlled by using a single method or integrating multiple methods into a management program tailored for the specific site. Control methods include killing standing trees by applying an herbicide product that is approved by the U.S. Environmental Protection Agency and the Florida Department of Agriculture and Consumer Services; felling trees with a chain saw or other equipment and treating stumps with herbicide or grinding stumps with specialized equipment; mowing entire trees to the ground with specialized equipment; or removing saplings by hand or using tools designed for the purpose. Use of heavy equipment is not appropriate for most natural areas because of disturbance to soil and damage to non-target vegetation but is useful for removal of Australian pine trees in areas such as right-of-ways. Herbicide can be applied to foliage of seedlings and saplings. Biological controls for Australian pine continue to be in the developmental stages including searches and preliminary screening of prospective agents.
HERBICIDES AND APPLICATION METHODS

Stump application of herbicide. After felling, a 50% aqueous solution of herbicide product that contains 3 lb a.e. triclopyr amine per gallon (e.g. Garlon® 3A) or 10%–20% solution of product that contains 4 lb a.e. triclopyr ester per gallon (e.g Garlon® 4 Ultra) is applied to the surface of the stump. The cut surface should be as level as possible so the herbicide solution does not run off. Sweep off dirt and sawdust because it may adsorb some of the herbicide and prevent it from being taken up by the stump. The herbicide solution is concentrated, as much as possible, on the cambium layer (the layer of living tissue immediately inside the bark) on large stumps. When treating small diameter stumps, the entire stump is treated with herbicide solution. Water- or oil-soluble herbicide formulations can be used. Depending of the size of the project (size and number of stumps), application can be made using dropper bottles, spray bottles, or backpack sprayers. Quart-size spray bottles are often used; they should have chemical resistant seals, especially when applying oil-soluble products. Application of herbicide immediately after felling, especially when using a water-soluble formulation, will provide most consistent results. Oil-soluble formulations can be effective when applied after some time has passed and should then be applied to the bark below the cut surface as well.

Frill or girdle herbicide application. A continuous cut (girdle) or individual cuts (frill) with no more than 3-inches between cut edges is made into the cambium (living tissue immediately inside the bark) completely around the circumference of the tree. Do not make multiple cuts directly above or below each other because this will inhibit movement of the herbicide. Incisions should be angled downward to form a reservoir that will help hold herbicide and must be deep enough to penetrate the bark into the cambium layer. A 50% aqueous solution of herbicide product that contains 3 lb a.e. triclopyr amine per gallon (e.g. Garlon® 3A) or 10%–20% solution of product that contains 4 lb a.e. triclopyr ester per gallon (e.g Garlon® 4 Ultra) is applied to the girdle or each cut until the exposed area is thoroughly wet. Frill or girdle treatments are slow and labor intensive but useful to minimize impact to desirable vegetation in mixed communities. Frill or girdle applications are used when it is aesthetically acceptable or safe to leave dead vegetation standing. Water- or oil-soluble formulations can be used for frill or girdle applications.

Basal bark herbicide application. Undiluted herbicide product that contains triclopyr ester (ready-to-use formulation, e.g. Pathfinder® II) or 10%–20% solution of product that contains 4 lb a.e. triclopyr ester per gallon (e.g. Garlon® 4 Ultra) diluted in a commercial penetrating oil is applied directly to the bark around the circumference of each trunk up to 15 inches above the ground (depending on label instructions). The herbicide must be in an oil-soluble formulation (emulsifiable concentrate). This method is used on trees with a diameter of six inches or less. Bark on larger, older trees becomes scaly and corky and herbicide is not absorbed into the stem. If scaly bark is present it should be removed by scraping. Application can be made using the same type of equipment as for stump application. When using equipment with interchangeable nozzles, the spray tip should be a narrow angle (15–25 degrees) flat fan-tip nozzle such as a TP 1502, TP 1503 or TP 2502/TP 2503, a solid cone nozzle, or an adjustable conejet such as a TeeJet 5500-X4 or 5500-X5 or equivalent. A good alternative is a brass tip shut-off wand such as a Spraying
Systems Model 31 with brass extension and tip shut-off or a Spraying Systems Model 30 GunJet®. A TP-0001/TP-0002 tip or DE-1/DE-2 disc should be used with the Model 30 GunJet®. The GunJet® can be attached to most backpack spray units that produce pressures between 20 and 50 psi. All backpack sprayers and spray guns should have chemical resistant seals for the herbicides and carriers being used.

**Foliar herbicide application.** Herbicide is diluted in water and applied to the leaves of target plants with aerial or ground equipment. Three gallons per acre of a product that contains 3 lb a.e. triclopyr amine per gallon can be applied by helicopter to control large populations of mature trees. While used less frequently than basal bark or stump application, foliage of individual plants or small populations four feet tall or less can be treated on a spray-to-wet basis using a backpack sprayer or hand-held equipment with a 3%–5% solution of herbicide product that contains 3 lb a.e. triclopyr amine per gallon (e.g. Garlon® 3A) or 4 lb a.e. triclopyr ester per gallon (e.g. Garlon® 4 Ultra). Adjuvant, such as surfactant, drift control agent, or other spray modifier is often added to the spray mix as specified on the herbicide label. Application should be carefully directed to the target species to avoid contact of herbicide to non-target species. Do not exceed the maximum allowed application rate for the specified land use (e.g. 9 lb a.e. triclopyr amine/acre/yr on non-cropland sites other than rangeland, pasture, forestry, and grazed areas).

**Soil herbicide application.** Four to six pounds of granular herbicide that contains 75% hexazone (e.g. Velpar® ULW) can be applied to control dense populations of seedlings and/or saplings. A carefully calibrated backpack blower is used for this application. Effects to susceptible non-target vegetation should be considered before using soil active herbicide.

**Marker dyes.** Marker dyes are very useful for keeping track of which vegetation has been treated when making applications to large numbers of individual trees or stumps. Dyes are also a useful indicator of the applicator's efficiency of limiting herbicide contact with non-target vegetation and personal exposure.

**MACHINERY USED FOR MECHANICAL REMOVAL**

**Feller-bunchers,** commonly used in commercial forest harvesting, are machinery heads that grasp, cut, and stack trees. Feller-buncher heads are mounted on tracked skidders (also known as multi-terrain loaders), excavators, or rubber-wheeled articulating loaders.

**Forestry mowers or mulching heads** attach to excavators (also called track-hoes) or four-wheeled loaders and mow trees to the ground. Mowers mounted on excavators are lowered onto trees from above with the use of an articulating arm, while those mounted on wheeled or tracked loaders mow trees from the side, pushing them over before mulching them. Mowers vary in size and power, which determines the size of trees that they can effectively mow. Smaller machines can handle trees up to 2 feet in diameter, while larger mowers, often called chippers because they chip trees as they mow them, handle larger trees. Most mowers and chippers mow the trunk to
ground level while others (e.g. Clear-More chipper/stumper) actually cut the trunk into the ground and destroy the stump. The stump may be killed in the process but regrowth will sometimes occur and the site should be monitored for regrowth.

**BIOLOGICAL CONTROL**

Reports of insects or diseases of *Casuarina* spp. in Florida and other areas where these trees are invasive are uncommon, and mention only a few species that have expanded their host range to include these exotic trees (Wheeler et al. 2011). None causes major damage to the populations of these trees in Florida. For example, the exotic mangrove borer, *Chrysobothris tranquebarica* Gmelin (Coleoptera: Buprestidae), was found feeding on the bark and wood of *C. equisetifolia* in Florida and throughout this beetle’s native range in the Caribbean (Snyder 1919; Ivie and Miller 1984). However, it was also suggested that this species feeds on dead and decaying tissues (Craighead 1971). The *Casuarina* spittlebug, *Clastoptera undulate* Uhlar (Homoptera: Cercopidae), is native to the Caribbean and feeds on leaves of this tree species. However, their impact on tree populations has been negligible (Mead and Bennett 1987). Disease organisms include a native root rot caused by *Clitocybe tabescens* (Scop.) Res. (Morton 1980). Possibly insects from the native range of the *Casuarina* spp. will be a better source of effective biological control agents.

Exploratory surveys were conducted by USDA Australian Biological Control Laboratory (ABCL) staff in South East Queensland, North Queensland, Northern New South Wales and the Northern Territory from 2005 to 2012. In surveys conducted locally around Brisbane and New South Wales, collections were made from *C. equisetifolia*, *C. cunninghamiana* and *C. glauca* trees. Several potential biological control species found are the focus of ongoing research with the goal of finding agents that will be effective and safe for release (Table 1). These species and their status are briefly detailed here.

1) *Selitrichodes* sp. During April 2009, the *C. glauca* plant stock at CSIRO Long Pocket Laboratory became infested with a gall inducing wasp *Selitrichodes* sp. Since 2009, a colony has been established at the ABCL laboratories in Brisbane. Currently biology studies are ongoing but observations so far have seen potted *C. glauca* heavily galled in the colony cages to such a level that several plants have died. Further investigation of *Selitrichodes* sp. observed females ovipositing clusters of eggs on leaf tips. Signs of tissue galling can be seen 7 days after oviposition and adult emergence begins at around 30 days.
2) The torymid wasp, *Bootanelleus orientalis* (left) was one of the first potential agents discovered in feeding on *Casuarina* spp. seeds in Australia. Each attacked seed is hollow and non-viable and over 95% of seeds on a tree can be affected. This insect remains a high priority for biological control given that it appears highly damaging, specific and it avoids potential conflicts of interest with the general public by impacting the reproductive potential of trees without damaging foliage. Since wasps rely on developing fruits, cage testing could be problematic as species will have to be reproductive. Australian pine trees can take up to 3–4 years to produce fruits and producing test plants at a similar stage of development could be difficult. Preliminary evidence, however, indicates that these wasps will attack mature fruit which would expedite the testing. Additionally, wasp specimens from *C. equisetifolia* and *C. cunninghamiana* will be genetically characterized to determine if additional species are present that remain undetected by traditional morphological methods.

3) The defoliating moth, *Cryptophasa irrorata*, was first colonized after field collections in May 2011 at Yeppoon in North Queensland. Field collected *C. irrorata* larvae were reared to adult in the laboratory and a sustainable colony has been established. Host specificity and biology studies are currently ongoing. Laboratory observations found early instar larvae of *C. irrorata* begin feeding at the new foliage and form silken webbed shelters at leaf basal attachments. As the larvae develop they move into thicker stemmed material, burrowing out the core of the stem at branching points to shelter within a retreat. They covered the exit hole with a mass of webbed frass and the larvae disperse while dragging foliage into burrows. Biology studies have found time from egg hatch to adult emergence to be typically 134 days when larvae were reared on cut foliage at 25 degrees Celsius in the laboratory.

4) A defoliating moth *Calathusa maritime* collected from Archer Point in North Queensland on *Casuarina equisetifolia* was colonized during 2010. Larvae were observed feeding on foliage typically starting from the apical tip of leaves and moving down towards the main stem. The externally feeding larvae may avoid predation by camouflage, appearing similar to the shape and coloration of the leaves. Several cages holding large larval numbers completely defoliated *C. equisetifolia* plants. When close to pupation, larvae constructed cocoons made from webbed silk and frass which were attached to leaf branches. Emerging females mated and typically laid eggs singly on the foliage and stem rather than in clusters. The life cycle from egg to adult was typically 30 days but in one case a field collected pupa did not emerge as an adult until after 3 months suggesting *C. maritime* may diapause.
5) *Ophelmodiplosis clavata*. A cecidomyiid gall midge infested *C. glauca* plant stocks at ABCL during early 2011. The cecid galls affect the tips of branchlets, forming a small pink swelling (Figure left). Each gall contains a single immature midge. The attack results in deformed branch growth. Thus far, this midge has only attacked stocks of *C. glauca*; whereas neither *C. equisetifolia* nor *C. cunninghamiana* growing in the same area have been infested. Therefore it appears to be species specific to *C. glauca*. Leaf galling *O. clavata* individuals were found heavily parasitized in the field and as such were difficult to colonize as only several adults emerged from collected galls. Observations of *O. clavata* found adults would lay eggs within the ribbed channels of the leaf tip surface. Once larvae hatch from eggs they enter into the leaf tip and begin feeding on the growing point. Eventually larvae create a chamber within soft leaf tip tissue and the tip begins to swell slightly.

6) An unidentified seed feeding Cecidomyiidae fly (left) was collected from the fruits of *C. equisetifolia* from Archer Point near Cooktown in Far North Queensland in 2007. Flies emerged from fruits and upon dissection the seeds appeared to be damaged. During January 2012, collections of *Casuarina equisetifolia* seed cones from Redcliffe in South East Queensland, yielded these same Cecidomyiidae adults.

Table 1. Potential biological control agents associated with *Casuarina* spp. in Australia.

<table>
<thead>
<tr>
<th>Genus</th>
<th>Species</th>
<th>Order</th>
<th>Family</th>
<th>Tissue attacked</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Selitrichodes</td>
<td>n. sp.</td>
<td>Hymenoptera</td>
<td>Eulophidae</td>
<td>gall branchlet tips</td>
</tr>
<tr>
<td>2 Bootanelleus</td>
<td>orientalis</td>
<td>Hymenoptera</td>
<td>Torymidae</td>
<td>seeds</td>
</tr>
<tr>
<td>3 Cryptophasa</td>
<td>irrorata</td>
<td>Lepidoptera</td>
<td>Xyloryctidae</td>
<td>branchlets</td>
</tr>
<tr>
<td>4 Calathusa</td>
<td>maritime</td>
<td>Lepidoptera</td>
<td>Noctuidae</td>
<td>branchlets</td>
</tr>
<tr>
<td>5 Ophelmodiplosis</td>
<td>clavata</td>
<td>Diptera</td>
<td>Cecidomyiidae</td>
<td>branchlet tips</td>
</tr>
<tr>
<td>6 unknown</td>
<td></td>
<td>Diptera</td>
<td>Cecidomyiidae</td>
<td>seeds</td>
</tr>
</tbody>
</table>

**MANUAL REMOVAL**

Individual saplings can be removed by hand pulling or using tools such as an Extractigator ([www.extractigator.com](http://www.extractigator.com)) or Weed Wrench ([www.weedwrench.com](http://www.weedwrench.com)). The site should be monitored for regrowth from plant parts left in the soil. Regrowth should be manually removed or treated with herbicide.
XIV. Restoration

Established Australian pine monocultures may alter ecosystem properties requiring active restoration (Gordon 1998). The level of restoration will vary depending on the pre-invasion native plant community. Restoration efforts may include the removal of accumulated litter and/or the planting of suitable native plant species.

At John D. MacArthur Beach State Park in Palm Beach County, Florida Australian pine dominated the county park since its establishment in 1981. Large stands of Australian pine occupied the coastal dunes, maritime hammocks and roadsides. On Munyon Island over 95% of the island was covered in Australian pine. From 1981–1991 considerable numbers of Australian pines were removed from the park by park staff, utility companies and through mitigation projects. In 1991, the Palm Beach County Department of Environmental Resources Management (DERM) implemented a plan to restore the Lake Worth Lagoon system including Munyon Island. The project completed in 1997 provided for the removal of Australian pine, removal of spoil and the creation/restoration of coastal plant communities now home to a diverse assemblage of native plants and animals (Fillyaw 1997).

At Dry Tortugas National Park, Australian pine almost completely covered 30 acre Loggerhead Key, replacing the islands natural vegetation communities as well as reducing sea turtle nesting habitat. The thick roots systems of the Australian pines hindered nesting sea turtles (Reardon 2000) and created steep embankments. In 1995 the National Park Service developed and implemented a management plan with the intent of restoring the island back to its pre-settlement conditions. Control efforts included manual pulling of seedlings, basal bark and cut-stump treatments, and prescribed fire. Monitoring of the project included visual observations as well as the establishment of permanent vegetation transects. The project was completed in 1999 and by 2001 the restoration project had seen marked improvements in beach morphology. Steep embankments were replaced by gradually sloping beaches free of Australian pine roots (Pernas et al. 2001).

There are many other examples of successful restorations in Florida. Following are two in-depth case studies of large scale Australian pine restorations.

XV. Case Study: Bill Baggs Cape Florida State Park

Bill Baggs Cape Florida State Park (CFSP) is located on the southern quarter of the barrier island of Key Biscayne, just minutes from downtown Miami in Miami-Dade County. Situated between Biscayne Bay and the Atlantic Ocean, the park is currently comprised of 132 hectares of uplands and 43 hectares of submerged habitats.

Over the last sixty years, the property has been through several major transformations, the most recent being the restoration of its historic native plant communities.

In the late 1940s, the property that is now CFSP was in private ownership and was slated for development. More than 80% of the site’s biologically diverse landscape—including extensive areas of coastal strand, mangroves, and seasonal freshwater wetlands—was destroyed,
and the property was filled and leveled with material dredged from Biscayne Bay. The site ultimately comprised over 162 hectares of upland area. An aerial photograph from 1950 shows the majority of the area as flat, barren and white due to the marl fill.

The same photograph also shows a thin fringe of Australian pine trees along the site’s eastern beach shoreline. The anticipated development of the site ultimately did not occur, and the property lay fallow for years. Australian pine, already onsite, subsequently invaded the hectares of bare fill and took over the few remaining natural areas. By the late 1960s, when the state of Florida acquired the property for recreational purposes, Australian pine trees dominated the site. By 1991, this exotic species formed a near-monoculture in the majority of the park.

Prior to Hurricane Andrew in 1992, CFSP had modest plans for the control of Australian pine. The park was a popular urban park with annual entrance numbers averaging 800,000 visitors. Park users enjoyed the widespread shade that the exotic trees provided and the accessibility given by the open understory. While the removal of the Australian pine forest was the desired goal in the park’s 1991 unit management plan, it was considered best to move forward gradually. There was concern about denuding whole sections of the park and a wish to take into consideration the public’s needs. The high cost of large-scale tree removal and replanting with native species may have been a factor as well.

Deliberate Australian pine removal at CFSP occurred as early as 1982, as documented by internal Florida Park Service memoranda. Until 1993, trees were removed annually from remnant natural areas and from locations where better visibility, safety and access was desired, such as near the park’s lighthouse, around parking lots and along the seawall. Trees, saplings and seedlings were cut and physically removed, chemically treated with triclopyr, or hand-pulled. Work was done primarily by park staff, but volunteers and (in 1990) contractors were used as well.

In 1985 there were two unplanned reductions in the Australian pine cover. A park memorandum briefly mentions approximately 4,200 trees killed by a wildfire in August. Another estimated 300 were thought to have blown over as a result of Hurricane Kate in November 1985. The eye of Hurricane Kate passed south of Florida hitting the northern coast of Cuba, and Key

Figure 10 Location of Bill Baggs Cape Florida State Park.
Biscayne received sustained winds of only 37 mph and gusts of 78 mph (Clark, 1986). The weakness of Australian pine to windstorms at CFSP was thus demonstrated.

![Image](image.png)

**Figure 11** Bill Baggs Cape Florida State Park (prior to 1992) showing a near-monoculture of Australian pines.

A much more powerful storm, Hurricane Andrew, made landfall in south Florida on August 24, 1992, causing the second radical change to the landscape at CFSP. Key Biscayne was hit by the northern eye wall of the storm in which sustained winds were as high as 145 mph and gusts 175 mph (Rappaport 1992, 2005). The force of the storm destroyed the park’s Australian pine forest. Tens of thousands of trees once standing up to 100 feet tall and three feet thick were left in a flattened pile on the landscape, giving the appearance of a gigantic dropped box of toothpicks. The hectares of toppled trees crushed structures and buildings, damaged utilities, and blocked roads.

The cleanup, repairs, and rebuilding activity that followed Hurricane Andrew left CFSP closed for one year. The cost of clearing the Australian pine wreckage alone was approximately $1 million. This money, provided by FEMA, was spent primarily on cutting, bulldozing, hauling and chipping the tremendous mass of woody debris. To control soil erosion and exotic plant regrowth, the resulting mulch was spread over large areas of the park, in some areas almost two feet deep. The resulting flat landscape, largely empty of vegetation, was reminiscent of the site’s 1950 appearance. Some observers at the time said the park resembled a “desert” or a “moonscape.”
During the clean-up, there were two areas in which the Australian pine debris was not cleared. The first was an archeologically sensitive area at the southern tip of the park. Past fill operations had not occurred at this location, and there was the possibility that cultural artifacts were at or near the surface of the ground. It was decided that the use of heavy equipment was not appropriate and that the removal of stumps and roots would cause too much ground disturbance.

The other site was a biologically sensitive area located along a high dune ridge parallel to the Atlantic shoreline. This location also had not been impacted by past fill operations, and native plants had survived or recolonized in the decades following the 1950 land clearing. In both areas, surviving Australian pine trees were killed with herbicides. All debris, both standing and fallen, was left in place to decay.

In mid-1993, CFSP started new exotic plant control efforts. Heavy equipment and the clearing operations had caused severe ground disturbance to much of the park, and multiple invasive plant species, including Australian pine, had started to re-invade. New seedlings and small saplings were found primarily along the beach or at the edge of the tidal wetlands, where seeds wash up from off-site areas and germinate. Florida Park Service staff volunteers and contractors worked on removing these invasive plants and the number of Australian pines treated or removed at CFSP continued to decline. Australian pine is no longer considered a major component of the park vegetation.

Several other invasive species such as Burma reed (Neyraudia reynaudiana), beach naupaka (Scaevola sericea) and Senegal date palm (Phoenix reclinata) are now largely under control as well. However, a few exotic species are an on-going problem. In particular, day
flowering jasmine (*Cestrum diurnum*) and Brazilian pepper (*Schinus terebinthifolius*) continue to pose a challenge, due in part to their fruits which are attractive to wildlife and widely dispersed. Latherleaf (*Colubrina asiatica*) also continues to persist in some sections of the park.

Cape Florida State Park today continues to be restored to its past native plant communities. More than 300 native plant species and multiple habitats exist where a near monoculture of Australian pine stood for decades. Native wildlife has also benefited from the change, increasing both in numbers of species and populations.

![Figure 13](image.png)

*Figure 13* Bill Baggs Cape Florida in 2012 showing restored native vegetation following Australian pine management.
XVI. Case Study: Thousands Islands, Cocoa Beach, FL

Australian pine (*Casuarina equisetifolia* and *Casuarina glauca*) recruited heavily along the barrier islands of east central Florida in the 1950s and 1960s, including spoil islands in the Indian River Lagoon (IRL). The only islands in the IRL immune to the invasion by these species and Brazilian pepper (*Schinus terebinthifolius*) were natural islands at wetland elevation (mangrove/saltmarsh) that were too low to allow invasion by these exotics.

However, many Florida east-coast mosquito control districts engaged in source-reduction of salt marsh mosquitoes and these islands were dredged and filled to prevent mosquito breeding. Typically islands were dredged and filled outright, or deeper channels were dredged throughout the target area, leaving open, deeper channels and filled wetlands. In either case, it was an effective technique for reducing mosquito numbers, though with dire environmental consequences. The piles of resulting dredge spoil, lacking any competition from native vegetation, were easy targets for exotic plant invasion.

A typical site for this type of mosquito source-reduction activity was the island group known as the Thousand Islands (TI) in the Banana River immediately west of Cocoa Beach, Florida. Developers engaged in considerable dredge and fill activity to create water/canal-front homesites. These islands were originally a single large group of dozens of islands (see Fig. 14). The TI are known for their unique geology, having long ago originated from the breaching of the barrier island by an historic storm event, with the islands appearing in the resulting tidal overwash fan (R. Parkinson, pers. comm.). Following the dredge and fill activity, the North TI and the South TI were bisected by the Minuteman Causeway, itself a dredge and fill creation at Lat N28° 19.037’ Long W80° 38.115’.

![Figure 14](image.png)

**Figure 14** The Thousand Islands, Cocoa Beach, Florida. The Minuteman Causeway bisects the Islands into the North and South Islands.
This case study describes only management efforts on the South TI. Here, aerial photography from the 1950s indicates that dredging activity was underway and continued through the 1960s. With the exception of a few islands on the west side owned by the State of Florida, the entire southern island group was privately owned. Various development schemes for the privately owned properties had been broached through the years, but none came to fruition. In areas that were not filled, some pockets of native upland vegetation remained (including fragments of tropical hammock) and were even interspersed among the *Casuarina* spp. However, it can be safely assumed that Australian pines immediately invaded the dredge spoil areas and have flourished since, in spite of periodic severe freezes (e.g. December 1989) which top-killed many if not all of the Australian pines (T. Kozusko, pers. comm.) Infrequent hurricanes (e.g. Donna 1960; Francis/Jeanne 2004) caused minor damage by toppling some trees, but overall Australian pine has expanded to 100% coverage on portions of some islands. Over time, many members of the public grew fond of the dense stands of Australian pine, relishing the shade and open character of the habitat.

The TI are a popular recreational area for local residents and tourists, and there is heavy recreational boat/canoe/kayak use of the site. A heavily-used public boat ramp is located directly east of the site in Cocoa Beach. Included is an expanding eco-tourism kayak industry, with knowledgeable guides leading tour groups.

However, the situation on the TI began to change in 2006, when the Brevard County Environmentally Endangered Lands Program (EEL) began purchasing the south TI. The EEL Program is an environmental land acquisition program funded by citizen-approved voter referendums taxing homeowners to fund environmental land purchases. The primary goal of EEL is preservation of biodiversity, and removal of exotic plants is at the forefront of restoration goals on all EEL properties. The south TI purchase from two separate owners was completed in 2008. EEL acquired 336 acres (136 ha) (66/26 ac/ha of upland and 270/109 ac/ha of emergent wetland/submerged lands). Partnering with EEL in the purchase were the City of Cocoa Beach and The Conservation Fund, along with major funding from the Florida Communities Trust. EEL was the designated management agency.

Prior to management activities/restoration of EEL sanctuaries, management plans must be drafted and approved by an EEL scientific committee as well as presented for public comment. As EEL developed a draft plan for exotic removal, their preferred approach was to barge heavy equipment to the four larger islands and the single mainland site (see Fig. 15) and mechanically remove all Australian pine throughout the property, root-raking and pile-burning the material.

No supplemental plantings of native vegetation were originally proposed. When the notion of Australian pine removal was first broached by EEL, there was considerable opposition from some citizens of Cocoa Beach, to the extent that the City requested a strategic plan for phased exotic plant removal, as well as extensive supplemental plantings of native vegetation. Some of the rationales presented by citizens included 1) Australian pine were natural to the area, if not native, having been there for so long they had become naturalized; 2) Australian pine were critical to shoreline protection and provided a windbreak for homes to high winds from the west (there are no homes on the TI and most Australian pine were far away from any homes); 3) Australian pine are critical to wildlife, and pelicans and ospreys will have no place to nest; 4) the attractive height structure of the Australian pine will be lost forever; 5) the Australian pine shield nearby
residents from the bright lights of a recreational complex where night-time activities occur; and 6) Australian pine were a desirable aesthetic amenity.

EEL worked with the City of Cocoa Beach Land Management Committee to devise a workable plan that would meet natural resource interests and assuage public concern. A series of public meetings were held, soliciting input from the public. Some of this discussion was quite heated, with equally fervent opinions expressed pro and con regarding Australian pine removal. The most vocal were the opponents of Australian pine removal but it is likely that a majority of the public were in favor of the concept. In fact, nearly all of the residents from the street most adjacent to the primary project area signed a petition, presented to the Land Management Committee, which called for immediate removal of all Australian pine in the project site. After various iterations of the plan were discussed, including phased removal over time and leaving fringes of Australian pine along the island shorelines to visually screen the barren areas of removal more inland, a phased removal plan was adopted.

![Image showing the phased removal plan for exotics in the Thousand Islands.](image)

**Figure 15** The south Thousand Islands showing the original phased removal plan for exotics. Only Phase 1 has been completed; Phase 2 is pending and has been scaled down.
The gist of this complex plan was as follows:

Phase 1: Heavy equipment (excavator/loader) was barged to two of the islands (Crawford “Craw” 1, 2) and to the mainland site (Reynolds “Rey” 2) (Figure 15). The designated footprint was cleared of all exotics (uprooted or cut with chainsaw and stumps treated with triclopyr) and pile-burned (except for Reynolds 2, where proximity to homes meant burning was not feasible so debris was chipped/trucked off-site). The other six un-numbered polygons of Australian pine were hand-treated (girdle/frill with triclopyr). There were extensive plantings of 8 species of native trees/shrubs on Crawford 1 and Reynolds 2. The City of Cocoa Beach offered reuse water for irrigation of plantings at Crawford 1 and Reynolds 2 using a water line run underwater from a mainland site to Crawford 1.

Phase 2: Commences 3 years after the start of Phase 1, with the criteria that 50% of Phase 1 plantings have survived. Heavy equipment once again will be barged to TI, targeting Reynolds 1 and Crawford 3 for mechanical clearing. Planting will take place as per Phase 1 in the mechanical removal footprints. Some hand-treatment of standing Australian pine, as above.

Phase 3: Commences 2 years after the start of Phase 2 and requires 50% survival of Phase 2 plantings. All remaining Australian pines on the four designated polygons to be hand-treated and left standing.

EEL had sought and received funding from the FDEP, Bureau of Invasive Plant Management (BIPM) for this project and received an award of $180,000. EEL funds were to supplement this, and the original intent was to perform all of the mechanical clearing work as a single project, thus avoiding the high cost of staging heavy equipment to the TI multiple times. However, the nature of the phased approach constrained the budget such that only Phase 1 could be completed with heavy equipment. Phase 1 was completed in 2008–09, with a total cost of $480,000 ($180,000 from BIPM and $300,000 from EEL). From this point, budget limitations have forced postponement, if not abandonment, of the phased removal plan. Phase 2 has now been delayed and presently revised to use only very limited EEL funds to hand-treat (chain saw/cut stump/girdle) Crawford 3 only (Fig. 15), a considerable scaling down of original plans. Some limited plantings will be done here also, but it is unclear at this point if re-use water will be available for irrigation. Future financial uncertainties leave further efforts in limbo.

Native planting success has been mixed. On Reynolds 2, survival approaches 70-80% and this site is restoring nicely, aided by easy access (no boat required) so that EEL staff can regularly treat recruiting exotics (Fig. 16).
Figure 16 Reynolds 2 (Rey 2) parcel before (above) and after (below) exotics removal by heavy equipment. Note planted southern red cedars (*Juniperus silicicola*) in foreground following removal. Heavy mulch layer in background (below) is the remains of mulched *Casuarina* spp.
Figure 17 Crawford Island before (left) and after (right) mechanical removal of *Casuarina* spp. Trees were cut/uprooted and pile-burned. Shrubs shown recruiting (right) are groundsel tree (*Baccharis halimifolia*) and Florida privet (*Forestiera segregata*). Other species planted are not shown.

Figure 18 Yellowtop (*Flaveria linearis*) recruiting in profusion on Crawford 1 following removal of *Casuarina* spp. (Photo: Tim Kuzusko)
On Crawford 1, survival of plantings is comparable but recruitment by native shrubs and trees, no longer competing with Australian pine, has exploded (Figs. 17, 18), exceeding the number of original plantings (data from T. Kozusko, pers. comm.). This calls into question the need for supplemental plantings where an existing seed bank is present in the form of existing native species. Additionally, to replace the height structure of the missing Australian pines, there was some pressure to plant trees that would grow to larger sizes (e.g. live oak, red cedar, slash pine, and cabbage palm). Some of these specimens, particularly several very large cabbage palms that were planted, did not survive. Very likely, the salty groundwater was problematic for these specimens. The presence of irrigation water at planting time probably enhanced survival. Dry weather following planting required continued irrigation and a lot of EEL staff and volunteer effort. Coordinating planting with the onset of the rainy season might preclude the need for irrigation but these seasons are no longer as predictable as they used to be.

Clearly, an opportunity was lost by not being able to complete the mechanical work in a single phase, but the constraints of public concern must be accommodated in an area such as the TI where residents are clearly very much involved with environmental issues. Agencies must work with all stakeholders and make decisions that are perhaps contrary to best fiscal and resource management. This careful balance is hard to achieve, certainly harder than killing Australian pine trees!
XVII. References/Literature Cited


Loflin, R. K. 2004. The agony that has been the history of Australian pines on public lands on Sanibel Island is all but over. *Wildland Weeds* 8(1): 4-5.


