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Ecology and Management of Sheoak (*Casuarina* spp.), an Invader of Coastal Florida, U.S.A.

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ABSTRACT

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The *Casuarina* spp. are invasive plants in Florida that threaten biological diversity and beach integrity of coastal habitats. The trees include three species and their hybrids that aggressively invade riverine and coastal areas. Of the three species, *C. equisetifolia* and *C. glauca* are highly salt tolerant and widespread in coastal areas. The third species, *C. cunninghamiana*, invades riverine habitats. These species pose dangers to both the environment and public safety. The environmental damage includes interfering with nesting by endangered sea turtles, American crocodiles, and the rare swallow-tailed kite. Additionally, allelochemical leachates reduce germination and establishment of native vegetation. Casuarina-infested beaches are more prone to sand loss and erosion. Moreover, with shallow roots and tall canopies, they are among the first trees to fall in high winds and as such restrict evacuation efforts during hurricanes. Control of these species is mostly with herbicides, requiring repeated applications and monitoring. One of the most cost-effective means of controlling these invasive species would be with classical biological control. Australian surveys for potential biological control agents began in 2004, resulting in the discovery of several promising candidates. These include seed-feeding torymid wasps, defoliating caterpillars and weevils, leaf tip gall-formers from cecidomyiid midges, and sap-feeding psyllids. Continued work is needed to determine the suitability of these species for biological control. Despite conflicts of interest expressed by some homeowners and the agricultural industry who value the trees for shade and windbreaks, there are good prospects for safe and effective biological control of these invasive species.

ADDITIONAL INDEX WORDS: *Australian pine, invasive species, biological control, weeds.*

INTRODUCTION

Invasions by naturalized nonindigenous species threaten the biodiversity of coastal flora and fauna worldwide. These invasive species are often spread intentionally beyond their native range, resulting in biotic homogenization of species that diminishes the regional distinctions of flora and fauna (Olden *et al.*, 2004). A loss of diversity carries ecological, evolutionary, and economic costs that result in communities more vulnerable to perturbation and environmental change (Sankaran and McNaughton, 1999; Tilman *et al.*, 1997). Invasive plant species displace native plants, resulting in a decrease in plant species richness and ecosystem function in the invaded areas (D'Antonio and Vitousek, 1992). Invasive species generally have superior competitive abilities that can irreversibly modify natural systems (Gordon, 1998). In the United States, invasive trees are well known invaders that cause environmental harm in diverse habitats including wetland and coastal areas (Bruce, Cameron, and Harcombe, 1995; Whitcraft *et al.*, 2007).

The composition of coastal vegetation can be dramatically changed by natural and anthropogenic factors. Natural disturbances caused by intense storms (Armentano *et al.*, 1995; Horvitz and Koop, 2001; Loope *et al.*, 1994; Smith, Nicholas, and Zedaker, 1997) can have long-lasting impacts on the succession of coastal communities. Similarly, the introduction of invasive species can have negative consequences that are nearly as severe as habitat destruction and exploitation (Dirzo and Raven, 2003). These two forces may act together as natural disturbances and can result in a habitat being more vulnerable to invasion (Loope *et al.*, 1994; Smith, Nicholas, and Zedaker, 1997). Because coastal areas may be the most heavily populated and have the longest history of human presence, they can have the greatest diversity of exotic flora (Mack, 2003; Seabloom, Dobson, and Stoms, 2002). These same habitats may also have the greatest number of threatened species, and the decline of many can be traced to invasive species (Seabloom *et al.*, 2006).

The *Casuarina* spp. are fast growing evergreen trees that have become serious invasive plants in the coastal United

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States including southern Florida, Hawaii, and throughout the Caribbean. In Florida these include three species and their interspecific hybrids (Gaskin *et al.*, 2009) that are now considered among the most severe coastal problems. These species rapidly colonize open, sandy habitats, especially along shores and on barrier islands where they threaten and replace native vegetation (Small, 1933, Woodall and Geary, 1986).

We propose that the most sustainable cost-effective management of *Casuarina* spp. is with safe biological control as a component of a more comprehensive integrated control strategy. This management technique, in which specialized natural enemies from the native range of the weed are developed as control agents, not only reduces pesticide exposure to humans but can be highly effective. A preliminary step in this process is a feasibility study that defines the problem, proposed solution, and conflicts of interest. Conflicts of interest are not uncommon in invasive species control, and they are frequently considered when initiating biological control programs (Pemberton, 1996; Sheppard, Haines, and Thomann, 2006). Most invasive species were intentionally introduced for food, fiber, and/or ornamental purposes, and many retain inherent value to segments of society (Pimentel, Zuniga, and Morrison, 2005). In these situations, the value of the invasive species to these stakeholders may be difficult to calculate (Binimelis, Monterroso, and Rodríguez-Labajos, 2007). This paper reviews the biology of these *Casuarina* species as important components of the Australian flora and as invasive threats to the United States and Caribbean islands, and examines the prospects for management in their invasive range.

TAXONOMY

The Casuarinaceae is a Gondwanic family with no clear close evolutionary affinities (Steane, Wilson, and Hill, 2003). The Casuarinaceae is assigned to the Order Juglandales along with the major families Betulaceae, Fagaceae, Juglandaceae, and Myricaceae (Judd *et al.*, 2002). Casuarinaceae is a flowering plant family, quite unrelated to the Pinaceae despite their superficial resemblance. The family comprises four genera and 95 species from tropical, subtropical dry, and warm temperate areas (Steane, Wilson, and Hill, 2003; Wilson, 1997). The family is native to Southeast Asia, southern Pacific islands to Tahiti and Samoa, and Australia. The three invasive sheoak species that occur in North America are assigned to the genus *Casuarina*.

The genus *Casuarina* contains 17 species, of which three are considered invasive (Wilson and Johnson, 1989; Steane, Wilson, and Hill, 2003). The most troublesome species, *C. equisetifolia* L. (= *C. litorea* L. ex Fosberg & Sachet) (common names: Beach she-oak, Coast she-oak, casuarina, Australian pine, horsetail casuarina) has two subspecies in its native Australia; however, only *C. equisetifolia* ssp. *equisetifolia* is known from Florida (Wilson, 1997). The other two invasive members of this genus include *C. glauca* (common names: swamp she-oak, gray she-oak, suckering Australian pine, scaly-bark beefwood, Brazilian beefwood) and *C. cunninghamiana* (common names: river she-oak, Cunningham's beefwood). These latter two species are dioecious where separate male and female trees occur. However, in Florida and much of its adventive range, the males of *C. glauca* are rare, if they occur at all. In Florida, *C. glauca* spreads through sprouting from root suckering. Less salt tolerant than the other species, *C. cunninghamiana* occurs mostly inland along streams and rivers. Two subspecies of *C. cunninghamiana* are known in Australia; however, only *C. cunninghamiana* ssp. *cunninghamiana* occurs in Florida (Wilson, 1997).

HYBRIDIZATION

Interspecific hybridization has emerged as a major factor contributing to the success of invasive species (Ayres *et al.*, 2004; Ellstrand and Schierenbeck, 2000; Gaskin and Schaal, 2002). Interspecific hybrids between the three species of *Casuarina* appear to be common in Florida, which makes morphological distinctions problematic (Gaskin *et al.*, 2009; Geary, 1983; Woodall and Geary, 1985). These hybrid individuals may be difficult to identify because they have combinations of characteristics consistent with each parental species. Recent molecular analysis has detected hybrids in Florida between *C. equisetifolia* and *C. glauca* and possibly between *C. glauca* and *C. cunninghamiana* (Gaskin *et al.*, 2009). Similar hybridization has been reported from Taiwan between these species (Ho, Yang, and Hsiao, 2002). Even though the native ranges of these species overlap, no hybridization was detected in Australia (Gaskin *et al.*, 2009). The role of these novel hybrids in the success of this invasive species has not been investigated.

CASUARINA SPP. IN THEIR NATIVE RANGE

Members of the Casuarinaceae are valued and protected trees in their native range as they have Australian national biodiversity, cultural, and evolutionary significance (Boland *et al.*, 1984). For example, traditional canoes were constructed from the bark of the trees by the Australian aborigines (Flannery, 1999). Also, there are notable examples of a close evolutionary association between the casuarinas and the black cockatoos (*e.g.*, *Calyptorhynchus lathami halmaturinus*; Joseph, 1982; Chapman, 2007). Habitat loss has threatened these endangered cockatoos and conservation efforts focus on preserving these trees as critical food sources. Additionally, in their native range, these large trees may be hosts for numerous epiphytic orchids (Blombery, 1977), and one species is host to the critically endangered Bulloak Jewel Butterfly, *Hypochrysops piceatus* Kerr, Macqueen & Sands (Lepidoptera: Lycaenidae; Sands and New, 2002).

In their native Australia, *C. cunninghamiana* and *C. equisetifolia* have an extensive range from temperate to subtropical areas along the east and north coast of Australia. This range extends from 12° S to 37° S latitude where these trees are often the dominant species in these beach habitats (Boland *et al.*, 1984; Midgley, Turnbull, and Johnson, 1983; Wilson and Johnson, 1989). Of the three species discussed here, *C. equisetifolia* has the greatest native range. This dominant beach species ranges into more tropical areas from Burma to Vietnam, Malaysia, Melanesia, and Polynesia (Wilson, 1997; Wilson and Johnson, 1989). The native range of *C. glauca* is

narrower along the eastern coast of Australia from mostly 26° S to 25° S in New South Wales and Queensland (Blombery, 1977; Boland *et al.*, 1984).

CASUARINA SPP. IN THEIR ADVENTIVE RANGE

The species *C. equisetifolia* was introduced in Hawaii before 1895 and Florida during the 1890s as windbreaks and shade trees. Both *C. glauca* and *C. cunninghamiana* were introduced in Florida before 1924 (Morton, 1980). The species *C. equisetifolia* and *C. glauca* pose the greatest threats to maritime coastal regions because they are adapted to sites with relatively high salinity, arid conditions, and low soil fertility. In Florida *C. equisetifolia* is the most widespread, reported from 17 habitats and 143 conservation areas (Gann, Bradley, and Woodmansee, 2008). This species generally colonizes beaches, hammocks, flatwoods, marshes, swamps, and tidal marshes. Colonization may begin in ruderal habitats, sites disturbed either by human activity or by storm damage (Craighead, 1971; Morton, 1980). The other two species *C. glauca* and *C. cunninghamiana* are generally found in disturbed upland sites especially near coastal and riparian areas, respectively (Gann, Bradley, and Woodmansee, 2008). In Florida, the possession, propagation, or transportation of the most invasive species, *C. equisetifolia* and *C. glauca*, is prohibited by the Florida Department of Agriculture and Consumer Services. Furthermore, these two species are considered the most serious type of environmental threat. They are considered Category I weeds (*C. cunninghamiana* is a category II) by the Florida Exotic Pest Plant Council (FLEPPC Plant List Committee, 2003), defined as "invasive exotics that are altering native plant communities by displacing native species, changing community structures or ecological functions, or hybridizing with natives." *C. equisetifolia* and *C. glauca* are also invasive in Hawaii (USDA, 2010).

Of all the *Casuarina* species, *C. equisetifolia* has the largest range in Florida and extends farther north than the other two congeners. However, because all these *Casuarina* species are sensitive to cold, their northern limits are defined by prolonged seasonal freezes (Morton, 1980). Areas infested with *C. equisetifolia* extend north from the Florida Keys, mostly along the coasts to central and north Florida (Wunderlin and Hansen, 2008). Along the east coast of the state, *C. equisetifolia* has been reported as far north as Daytona Beach Shores (29°10′ N), Volusia County, and on the west coast from Apalachicola (29°45′ N), Franklin County (Wunderlin and Hansen, 2008). However, it's doubtful this population still exists (Don Schmitz, FWC, personal communication), and a more conservative estimate is further south from Dixie County (29°35′ N; Langeland and Craddock-Burks, 1998).

Throughout Florida, sheoaks have been reported from 30 state parks, and they are estimated to invade nearly 161,880 ha (Cox, 1999). Aerial surveys conducted recently (Systematic Reconnaissance Flight 2003; Figure 1) indicate that these species have 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 is heavily invaded by sheoaks

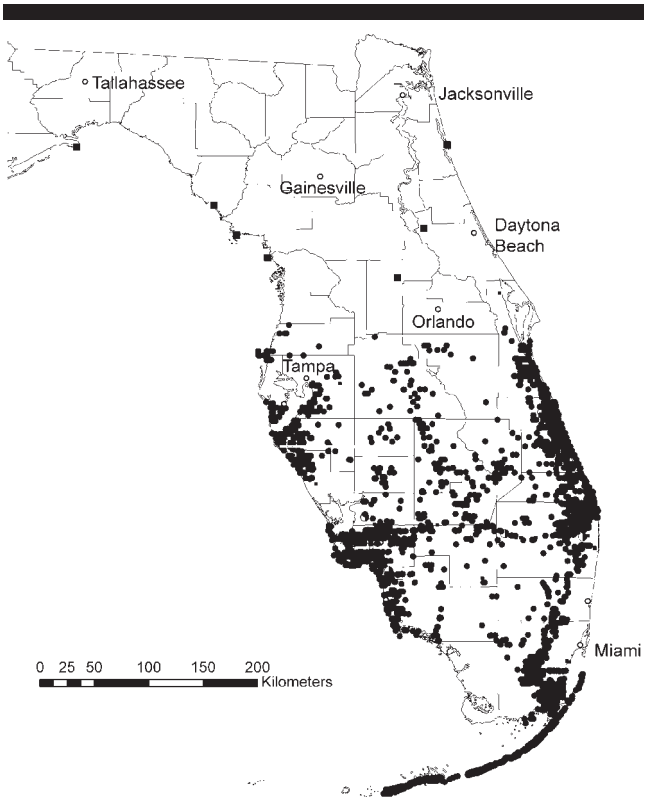

Figure 1. Distribution of the three species and hybrids of *Casuarina* in Florida during 1999–2003 surveys. Data provided by the South Florida Water Management District (SFWMD), National Park Service (NPS), and U.S. Fish and Wildlife Services (USFWS) Systematic Reconnaissance Flight (SRF) for invasive exotic plants. Additional herbarium data provided by Wunderlin and Hansen (2008).

(Glisson, 1997). On the Atlantic coast from Indian River to Dade counties, 46% of the undeveloped barrier island coastline is heavily invaded (Johnson and Barbour, 1990). In surveys of the Everglades National Park, dense stands of sheoaks were reported from 7200 ha in the southeastern corner of the park and from the 42,400 ha East Everglades Acquisition Area (East Everglades) (Doren and Jones, 1997).

RISKS TO HUMAN HEALTH

The respiratory ailments associated with *Casuarina* species have been well documented because the seasonal release of pollen causes allergic symptoms in sensitive individuals (Morton, 1980). Surveys of the pollen of metropolitan areas indicate that *Casuarina* is one of the most common sources of airborne pollen grains (Mandal *et al.*, 2008). Positive skin prick, nasal, and bronchial tests indicate asthmatic and hay fever reactions to the pollen (Bucholtz, Hensel, and Lockey, 1987; Zivitz, 1949).

ENVIRONMENTAL DAMAGE

Since the introduction of *Casuarina* species beginning in the 1890s, they have become one of the greatest threats to native beach vegetation (Craighead, 1971; Johnson and Barbour,

1990). Without control, some predict they will completely replace the native coastal vegetation of southern Florida (Cox, 1999). These species dramatically alter the habitat of infested areas, inhibiting native plants with rapid growth, dense coverage, and thick litter accumulation (Hammerton, 2001). The leaching of allelopathic compounds (Batish, Singh, and Kohli, 2001) may explain the reduction in the germination and establishment of Florida native vegetation including sea oats (*Uniola paniculata* L.), inkberry (*Scaevola plumieri* (L.) Vahl), and sea grape (*Coccoloba uvifera* (L.) L.). Casuarinas are reported to promote beach erosion (Austin, 1978; Deaton, 1994; Hammerton, 2001; Sealey, 2006), reduce populations of small mammals (Mazzotti, Ostrenko, and Smith, 1981), and interfere with the nesting of endangered sea turtles and American crocodiles (Doren and Jones, 1997; Klukas, 1969). Planted along beaches and near homes for protection against wind; the trees are among the first to fall during high winds because of their great height and shallow roots (Craighead, 1971; Nelson, 1994). During the hurricane season of 2005, these trees were among the most damaged by high winds of storms that crossed Florida (L. Rodgers, South Florida Water Management District, personal communication). Biologists have noted the connection between the decline of plants and animals with the expansion of *Casuarina* populations. For example, these trees are often the tallest in the forest canopy and thus are a preferred nesting site for the rare swallow-tailed kite (*Elanoides forficatus* L.; Loope *et al.*, 1994). Unfortunately, nests constructed in these trees have a significantly greater failure rate than in native trees (Palis, 2000). The shade produced by large trees on sandy beaches may decrease the incubation temperature of buried sea turtle eggs. As with other species of reptiles, the sex of loggerhead sea turtle hatchlings is temperature dependent (Yntema and Mrosovky, 1980). Consequently, sea turtle hatchlings emerging from such shaded conditions may have skewed sex ratios thwarting restoration efforts (*c.f.* Schmid *et al.*, 2008).

POTENTIAL CONFLICTS OF INTEREST

Promoters of these trees in Florida predicted a great future as sources of wood and tannin. Many species from the *Casuarina* genus have been distributed throughout the world for a variety of purposes such as firewood, windbreaks, lumber, and as ornamental trees (Morton, 1980). However, none of these economic uses has been successful (Morton, 1980). Picnickers and homeowners like the shade provided and the whistling sound of the wind blowing through the "needles." In Florida the citrus industry plans to use *C. cunninghamiana* trees as windbreaks surrounding their groves. Their goal is to reduce the spread of the disease citrus canker (*Xanthomonas campestris* (Hasse) Dye). However, previous attempts to grow windbreaks around citrus failed when the *Casuarina* fell on the fruit trees during storms (Geary, 1983; Morton, 1980). It is widely recognized that the best use of *Casuarina* is for fuel (Morton, 1980). However, the practice of producing charcoal from *Casuarina* in Caribbean countries has become unpopular following beach erosion and damage caused by these trees during hurricanes (Geary, 1983).

DESCRIPTION OF GROWTH

The *Casuarina* spp. are evergreen trees that produce distinctive segmented needlelike foliage and woody conelike structures. The taxonomy and morphology of these species is described in detail elsewhere (Wilson, 1997; Wilson and Johnson, 1989; Woodall and Geary, 1986); however, details are briefly covered here. Of the three species, *C. equisetifolia* is the tallest in Florida and may reach 30 to 45 m in height (Morton, 1980). In Florida, *C. equisetifolia* trees generally appear flat topped, whereas *C. glauca* may be dense and erect and *C. cunninghamiana* trees are pyramid shaped (Woodall and Geary, 1986). Growth rates up to 3 m per year have been reported (Rogers, 1982).

FOLIAGE

The foliage occurs as olive to green 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 (*C. equisetifolia*) or may be glabrous (*C. glauca*) or sparsely to minutely pubescent (*C. cunninghamiana*). The leaves are reduced to erect scalelike teeth (0.3–0.8 mm long) arranged in whorls at the apex of each segment.

FLOWERING AND FRUITING

Seasonal flowering for *C. equisetifolia* occurs twice each year during the spring and summer (Rogers, 1982; Wilson, 1997). Species may be either monoecious (*e.g.*, *C. equisetifolia*) producing both staminate (male) and pistillate (female) flowers. Alternatively, dioecious species exist that have both male and female plants (*e.g.*, *C. cunninghamiana*, *C. glauca*). The fruit is woody and cylindrical (an infructescence) and referred to as a cone. These cones are slightly longer than wide and sparsely pubescent (Wilson, 1997). The seeds are pale brown, solitary, and occur as samaras, which are shed when mature and are dispersed by wind and water. Trees of *C. equisetifolia* are capable of producing viable seeds at 2 years (Rai, 1990). In Florida a seedling 4–5 years of age may begin flowering and producing abundant fruit (Morton, 1980).

REPRODUCTION

Despite mechanical and herbicidal removal of many older trees, *Casuarina* spp. continue to be a severe problem in coastal areas. The enormous reproductive capacity of these trees is due to wind-blown seeds that germinate to form dense populations of seedlings and eventually mature trees in remote and often inaccessible areas. The *Casuarina* spp. are generally wind pollinated, and *C. equisetifolia* mostly reproduces by seed production. The species of this genus are primarily outbreeders (Barlow, 1981). *C. equisetifolia* generally does not form root suckers, coppices weakly from low stumps, but may coppice well from stumps taller than 1 m. The dioecious species, *C. glauca* is known to reproduce in its adventive range only from aggressive suckers that arise from wide-spreading roots, especially when pruned (Morton, 1980).

HERBICIDAL AND MECHANICAL CONTROL

Numerous public and private conservation organizations conduct operations to remove *Casuarina* spp. from their property. These efforts are expensive ($370/ha; G. Jubinsky, Florida Fish Wildlife Commission; personal communication) and offer only temporary control, requiring follow-up monitoring and repeated applications. In Florida, the casuarinas are among the top five upland invasive species targeted for herbicidal treatments by public land managers (G. Jubinsky, Florida Fish Wildlife Commission personal communication). Current control recommendations include hand removal of seedlings, basal bark treatment with herbicides for trees less than 20 cm in diameter, and cut stump treatments for large trees (FLEPPC, 2010). Posttreatment monitoring of the applications will be needed for at least 3 years as seeds remain viable on the ground for 2–2.5 years (Klukas, 1969).

Prescribed fire was attempted as a control measure in fire-tolerant communities but with limited success (Doren and Jones, 1997). Mechanical removal resulted in unsatisfactory control because the trees resprouted from coppiced stumps (Klukas, 1969). Uprooting of seedlings and saplings (up to 1.2 m in height) was more effective, especially in loose sandy soils. Raking and removal of leaf litter, cones, and seeds is recommended to minimize impact on native communities. Efforts should be made to minimize encroachment into recently disturbed beach habitat by the planting of native species (Klukas, 1969).

NEED FOR BIOLOGICAL CONTROL

Reports of insects or diseases of *Casuarina* spp. in Florida and other areas where these trees are invasive are uncommon, consisting of a few species that have expanded their host range to include these exotic trees. None causes major damage to the populations of these trees in Florida. The exotic mangrove borer, *Chrysobothris tranquebarica* Gmelin (Coleoptera: Buprestidae), was found feeding on the bark and wood of *C. equisetifolia* in Florida and throughout its native range in the Caribbean islands (Ivie and Miller, 1984; Snyder, 1919), although it was also suggested that this species feeds on dead and decaying tissues (Craighead, 1971). The *Casuarina* spittlebug, *Clastoptera undulata* Uhlar (Homoptera: Cercopidae), native to the Caribbean, feeds on leaves, but their impact on the populations of trees in Florida has been negligible (Mead and Bennett, 1987). Disease organisms that have been reported in Florida and elsewhere include a native mushroom root rot caused by *Clitocybe tabescens* (Scop.) Res. (Morton, 1980). The insects listed here were all exotic and ineffective at managing *Casuarina* spp.; however, well-researched classical biological control introductions show great promise as a component of integrated, effective, and low-risk control.

RECORDED AUSTRALIAN HERBIVORES OF *CASUARINA* SPP.

Historically, Coccidae were found associated with the Casuarinaceae represented by more than 25 species from 15 genera (Froggatt, 1933). Beginning in 2004, surveys were conducted in Australia for *Casuarina* spp. herbivores searching for potential biological control agents. This work is still in progress and continues to discover new associations and undescribed species. These include specialist seed feeders such as *Bootanelleus orientalis* (Mathur & Hussey) (Hymenoptera: Torymidae); a suite of lepidopteran defoliators, foliage binders, and stem borers particularly in the xyloryctine Oecophoridae; sap feeders such as various scale insects (Hemiptera: Coccoidea) and jumping plant lice (Hemiptera: Triozidae) (G.S. Taylor, personal communication); and granivorous and gall-forming flies (Diptera: Cecidomyiidae). A list of selected insect herbivores associated with *Casuarina* spp., with notes on feeding behavior (as functional groups), is presented in Table 1. In addition, many new host associations of this previously little-known fauna are being elucidated, including the discovery of new species and the generation of new species descriptions. Modern DNA techniques are being used to provide the necessary data for classifying the unnamed insects, providing an evolutionary history between herbivore and hosts, and determining which might be best suited as biological control agents.

BIOLOGICAL CONTROL APPROACHES

The selection of weed targets for biological control is an important decision because up to 20 scientist years may be required to reach a successful conclusion (Harris, 1979. Each weed project is unique with both positive traits and limitations such that not all weeds are amenable to biological control. Avoiding risk is a high priority for practitioners by introducing biological control agents that pose little or no danger to economic and valued plants. One of the best predictors of risk to desired plants is their taxonomic position relative to the target weed; close relatives may be most at risk of nontarget damage because of their similar biochemistry and nutrition (Pemberton, 2000). Members of the Casuarinaceae do not occur in North America other than the weed species of *Casuarina* mentioned here. Moreover, there are no native Casuarinaceae in North America. However, the value associated with these species by some poses special challenges and limits the types of damage that will be acceptable. To minimize these conflicts of interest, biological control agents that attack the tree's reproductive tissues, *i.e.*, flowers, fruit, seeds, can be prioritized. This type of damage will decrease *C. equisetifolia and C. cunninghamiana* reproduction and the spread of these species to natural areas while leaving the mature trees that are valued by segments of society relatively unharmed.

CONCLUSIONS

The results of this review illustrate the significance of the *Casuarina* invasive species to coastal habitats in Florida and options for control. One species in particular, *C. equisetifolia*, has become one of the most common coastal species throughout the tropics. These species threaten the diversity of coastal vegetation, affect populations of rare or endangered animals, and may increase beach erosion by interfering with the normal processes of sand deposition. Continued cultivation of these species for ornamental purposes or as an agricultural windbreak is particularly shortsighted considering the risk posed to

Table 1. *Host, habit data and distribution data for selected insect taxa considered as potential biocontrol agents against* Casuarina *spp.*

Order	Family: subfamily taxon	species or taxon	Host	Habit	Distribution	Reference/authority
Hymenoptera						
	Torymidae	*Bootanelleus orientalis* (Mathur & Hussey)	*C. equisetifolia*	Granivore	Qld, NSW	Naumann, 1991, Bouček, 1988, recorded in this study
	Torymidae	*Bootanelleus* sp.	*C. cunninghamiana*	Granivore	Qld, NSW	Recorded in this study
	Eulophidae	(undet spp.)	*C. glauca*, *C. cunninghamiana*	Gall-former	Qld, NSW	Recorded in this study
Lepidoptera						
	Oecophoridae: Xyloctinae	*Zauclophora pelodes* (Turner)	*C. equisetifolia*	Defoliator	Qld	Recorded in this study, Determined by Ted Edwards, CSIRO
	Oecophoridae: Xyloctinae	*Cryptophasa irrorata* (Lewin)	*Casuarina* spp.	Branch and stem borer	Qld, NSW, Vic	Froggatt, 1923, Common, 1990, recorded in this study
	Oecophoridae: Xyloryctinae	*Araeostoma aenicta* Turner	*C. glauca*	Defoliator; foliage-binder	NSW	Recorded in this study, Determined by Ted Edwards, CSIRO
	Oecophoridae: Xyloryctinae	*Lichenaula* sp.	*C. glauca*	Defoliator, foliage-binder	NSW	Recorded in this study, Determined by Ted Edwards, CSIRO
	Carposinidae	undet. genus, new undescribed species	*C. equisetifolia*	Cone feeder	NT	Recorded in this study, Determined by Ted Edwards, CSIRO
Coleoptera						
	Curculionidae	*Misophrice* spp.	*C. equisetifolia*, *C. glauca*, *C. cunninghamiana*, *Allocasuarina*. spp.	Unknown	Qld, NSW	Recorded in this study
	Curculionidae	*Apion* sp.	*C. cunninghamiana*	Unknown	NT	Recorded in this study
	Curculionidae	*Haplonyx* sp.	*C. equisetifolia*	Cone feeder	Qld, NSW	Recorded in this study
Hemiptera						
	Triozidae	New genera and species	*C. equisetifolia*, *C.cunninghamiana*, *C. glauca*	Sap-sucker	Qld, NSW	Recorded in this study
	Coccoidea	scale insects	*C. cunninghamiana*, *C. glauca*	Sap-sucker	Qld, NSW	Recorded in this study
Diptera						
	Cecidomyiidae	undet. genus and species	*C. equisetifolia*	Granivore or cone galler	Qld, NSW	Recorded in this study
	Cecidomyiidae	undet. genus and species	*C. glauca*	Shoot-tip galler	Qld	Recorded in this study

public safety and damage to coastal communities. These species are amenable to biological control in North America because the continent lacks native species of the family. Numerous potential biological control candidates have been discovered from surveys conducted in Australia. With few other cost-effective and sustainable options, biological control will be an important component limiting the spread of these invasive species.

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