Invasion of Carrotwood (*Cupaniopsis anacardioides*) in Florida Natural Areas (USA)

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Natural Areas Journal 19:254–262

ABSTRACT: Carrotwood (*Cupaniopsis anacardioides* [A.Rich.] Radlkf.) was first identified as a potentially invasive tree in 1989, about 10 years after it became popular as a landscape tree. Since then, seedlings to medium-sized trees have become established in disturbed sites as well as undisturbed natural areas. Birds disperse the seeds and contribute to a rapidly expanding wild population that includes isolated islands. As of 1996, *C. anacardioides* had invaded a wide variety of habitats in 14 southern and central Florida counties. It also occurs with other invasive nonindigenous trees. Naturalized *C. anacardioides* is known to be fruiting in three Florida counties. Six study sites in five counties were sampled. Mean maximum densities were 14.6 plants m^{-2} in mangroves, 21.5 plants m^{-2} in tropical hammocks, and 0.2 plants m^{-2} in coastal strand. The distribution of naturalized *Cupaniopsis anacardioides* coincides with that of all three mangrove tree species native to Florida. The presence of *C. anacardioides* tends to be associated with an increase of species richness in mangroves and may cause a reduction of species richness in tropical hammock communities. Education and responsible action can minimize a costly management problem in the near future.

Index terms: carrotwood, *Cupaniopsis*, exotic species, invasive species, nonindigenous species

INTRODUCTION

Few of the introduced nonindigenous plants that are established in the United States have succeeded in dominating our native plant communities, but those that have are disrupting native ecosystems and costing taxpayers billions of dollars. Outside of Hawaii, there is no equal to the ecosystem devastation occurring in Florida (McKnight 1993, Office of Technology Assessment 1993, and Simberloff 1994).

Schmitz and Brown (1994), Simberloff et al. (1997), Gordon (1998), and Austin (1998) described a wide array of impacts from nonindigenous plants, including alteration of species composition, competition with native plants for nutrient and water resources, creation of novel habitats, and alteration of fire regimes and soil chemistry. Because of these costly and potentially devastating effects, it is important to heighten awareness regarding introduced species that become invasive.

In the following discussion we provide some baseline data on a nonindigenous species that was first noted in native ecosystems in 1989. That tree is *Cupaniopsis anacardioides* (A.Rich.) Radlkf., commonly known as carrotwood or tuckeroo.

Description and History

Cupaniopsis anacardioides (Sapindaceae) is a native of the northern and eastern coastal districts of Australia, where it occurs on stabilized sand dunes, rock outcrops, and rocky beaches and in hilly scrub, monsoon forests, vine thickets, and riverine forests (Reynolds 1985, Brock 1988). This tree thrives in nutrient-poor soils (Oakman in Hawkeswood 1983a). Older trees are able to withstand temperatures to ca. 22° F (-6° C), which cause frost damage on the outer canopy (Stresau 1986). These trees are also tolerant of smog-polluted urban areas in California (E. Golby, retired horticulturist, Sarasota County, Florida, pers. com.).

Cupaniopsis anacardioides is a monoecious tree that grows to 10 m tall in Australia. Leaves are variable, even- or odd-pinnately compound, with 4 to 12 oblong leaflets, a rounded or slightly indented apex, and a swollen petiolule base. Small, numerous white or greenish-yellow flowers erupt on axillary panicles. Fruits are woody capsules with three distinctly ridged segments on short stalks, appear yellow-orange when ripe, and expose three shiny elliptical black seeds covered by a yellow to red aril when open (Reynolds 1985, Brock 1988).

Flowering occurs in late winter, usually January to February, and fruits typically mature in April to June. This period corresponds to the "opposite" seasons of Australia, in the southern hemisphere. Australian references cite flowering and fruiting in late summer and fall, respectively (Reynolds 1985, Brock 1988).

Carrotwood was introduced as an ornamental in subtropical parts of the world, including California and Florida (Oliver 1992). Naturalized populations in peninsular Florida are mostly coastal so far, with occasional inland localities. Bird dispersal explains *C. anacardioides* populations on isolated islands in the Gulf and Atlantic Intracoastal Waterways. Numerous seedlings are often found among bird droppings under trees and telephone poles. Fish-eating crows (*Corvus ossifragus*), which roost on those islands, mockingbirds (*Mimus polyglottos*), and starlings (*Sturnus vulgaris*) have been observed feeding and fighting over the seed (D. Austin, unpubl. data, 1990–1996). Other birds observed feeding on the fruit include cardinals (*Cardinalis cardinalis*) and blue jays (*Cyanocitta cristata*) (K. Glazier, biologist, Port St. Lucie, Florida, pers. com.). Seedling clusters characteristic of small mammal dispersal have also been observed (C. Lockhart, unpubl. data, 1997).

Fast-growing, evergreen, symmetrical canopy growth, salt-tolerant, xeric, and tolerant of sunlight, shade, poor soils and poor drainage—these are qualities that made *C. anacardioides* popular in southern California and are increasing its popularity in Florida. The oldest record of *C. anacardioides* in Florida (May 2, 1955) is a cultivated specimen from St. Lucie County in the University of Florida Herbarium (FLAS). Large-scale propagation of this tree began in the early 1960s when seeds and a live specimen were shipped from southern California to a southwest Florida nursery (E. Golby, pers. com.). The live specimen was planted on Siesta Key (Sarasota County) and is said to still be there. By the late 1970s and early 1980s, nurseries throughout the state were growing and selling *C. anacardioides* to landscapers and developers throughout the southern half of the state. *Cupaniopsis anacardioides* was also planted as a quick-growing barrier or privacy screen. Ease of propagation and rapid growth made this an easy money maker for nurseries.

In 1989 *C. anacardioides* began to appear outside of cultivation in a variety of habitats in disturbed and natural areas (Oliver 1992). The expansion of *C. anacardioides* has been compared with that of *Schinus terebinthifolius* Raddi (Brazilian pepper), one of Florida's worst invasive nonindigenous species (Hamner 1992). *Cupaniopsis anacardioides* also grows beside other aggressive nonindigenous trees, including *Melaleuca quinquenervia* (Cav.) Blake (broad leaf paper bark tree) and *Casuarina equisetifolia* L. ex J.R. Forst. and G. Forst. (Australian pine) (A. Cox, biological scientist, University of Florida, The Nature Conservancy NW Program, Liberty Council, and R. Clark, biologist, Lee County Department of Parks and Recreation, Fort Myers, Florida, pers. com.). The invasive nature of *C. anacardioides* is recognized by many park managers, naturalists, and field biologists, yet the lack of published scientific documentation of the problem has left many skeptics.

Mangroves and coastal hammocks were the primary foci for our study. The objectives of this study were to (1) determine the geographic distribution of wild *C. anacardioides* within the state of Florida, (2) determine *C. anacardioides* size classes and density in natural areas, (3) calculate species richness in natural areas where naturalized *C. anacardioides* is found, and (4) record plant species growing with naturalized *C. anacardioides*.

Cupaniopsis anacardioides

METHODS

Distribution Map

Specimens of *C. anacardioides* in Florida herbaria were mostly from cultivated plants. Because herbarium collections often lag behind actual conditions, especially of invasive nonindigenous species, the locations of naturalized populations of *C. anacardioides* were identified primarily from a 1995–1996 survey conducted by the Florida Exotic Pest Plant Council (EPPC) and provided by the Florida Department of Environmental Protection, and from field biologists' reports from various parts of Florida. An update of this information is available on the World Wide Web [http://www.fleppc.org]. At least two reports were required for each county to be included in a distribution map, which was generated with the use of MapArt by Micromaps Software (1992).

Density, Species Diversity, and Associated Plants

Six study sites were chosen on the basis of wild *C. anacardioides* presence in natural areas, accessibility, and the recommendations of field biologists. It was necessary to study sites where this species was present, in order to determine current densities; thus, sites were not randomly selected. We used belt transects to sample *C. anacardioides* density. Transects were 25 m long, consisting of five adjacent plots, 2 m wide by 5 m long, in the same compass heading. A minimum of three transects per site were studied. When a site had multiple habitats, a maximum of six transects were sampled. Some transects passed through more than one habitat type. A minimum of 3 m was maintained between transects. Longitudes and latitudes for study sites were determined with a Global Positioning System (GPS) when available, or by using maps.

Within each 2-m x 5-m plot, plants were identified and the following data were recorded: (1) number of individuals of each species, (2) size class of each individual (categories were < 0.5 m tall = seedling layer, 0.5–2 m tall = shrub layer, > 2 m tall = tree layer), and (3) dominant canopy species. *Cupaniopsis anacardioides* seedlings and saplings were removed from within each transect.

Each plot was identified by habitat type (mangrove, hammock, coastal strand) and disturbance status. Plots were identified as disturbed if there was history or evidence of disturbance such as, spoil mounds, branch piles, or storm damage. Plots without such evidence were labeled "undisturbed."

Average *C. anacardioides* density (plants per square meter) was determined for each habitat and site by disturbance. The data were not normally distributed due to wide variation within habitats at different sites. A Bartlett test showed that the variances were heterogeneous; therefore, the Kruskal Wallis test (Zar 1996) was used to examine density differences between disturbed and undisturbed plots using shrub and tree layer data in the mangrove, hammock, and coastal strand habitats. The *C. anacardioides* seedling layer (< 0.5 m tall) was not included in these comparisons because it is a less reliable indicator of plant establishment. The effects of disturbance on density were also tested at individual sites where both disturbed and undisturbed data were available.

Using all three strata, mean species richness was determined for each habitat, comparing 10-m^2 plots containing *C. anacardioides* and other nonindigenous species with plots from intact communities without nonindigenous infestations.

Because this study provides baseline data for *C. anacardioides*, a list of all plant species that were growing within the plots was compiled from the data for each study site.

Habitat Types

Habitat types within each study site are modified from descriptions in Myers and Ewel (1990). The following are habitat types as defined for this study.

The mangrove habitat is a tidal forest whose species, while able to utilize both fresh and salt water, have an adaptive mechanism for salt exclusion or excretion. Anaerobic saltwater, sediments, and fluctuating water levels limit competitors in the mangrove community (Kuenzler 1974 in Myers and Ewel 1990). The key tree species of this forest are *Rhizophora mangle* L., *Avicennia germinans* (L.) L., and *Laguncularia racemosa* Gaertn. f. An understory is usually lacking except near ecotonal regions (Corlett 1986). While plant species richness is low in mangrove forests, primary productivity and nutrient levels are high, and mangroves provide habitat for a wide range of animals, particularly birds, fish, and invertebrates.

Tropical hammocks are hardwood forests occupying stable dunes inland from beach plant communities. Species in tropical hammocks compete well on drained calcareous soils. In comparison with other beach ecosystems and mangroves, tropical hammocks have a higher species richness. Typical species of tropical hammocks include *Bursera simarouba* (L.) Sarg., *Masticodendron foetidissimum* (Jacq.) H.J. Lam, *Sabal palmetto* (Walt.) Lodd. ex Schultes, *Coccoloba diversifolia* Jacq., and *Eugenia* spp. in the canopy. *Psychotria nervosa* Sw., *Forestiera segregata* (Jacq.) Krug and Urban, and *Chiococca alba* (L.) Hitchc. are common in the understory.

The coastal strand habitat typically occupies the transitional dune or "prickly zone" of beach communities (Myers and Ewel 1990). More variable and species-rich than the foredune, vegetation in this ecosystem tends to be spiny and consists primarily of herbs and shrubs. Species composition differs between east and west coasts, but foredunes on both are dominated by *Serenoa repens* (Bartr.) Small (Austin and Coleman-Marois 1977). Other species found in the coastal strand include *Yucca aloifolia* L., *Coccoloba uvifera* (L.) L., *Caesalpinia bonduc* (L.) Roxb., *and Randia aculeata* L.. On the southwestern coast, *Bumelia* sp. may also be present.

Study Sites

East Coast

Lake Wyman Park, Boca Raton, N 26° 21' 49.62", W 80° 04' 38.71", is located on the western bank of the Atlantic Intracoastal Waterway in southern Palm Beach County. The park consists of disturbed tropical hammock and mangrove swamp. Mosquito ditches run through the mangrove swamp. Transects were run through both the tropical hammock and mangrove habitats.

John D. MacArthur Beach State Park, North Palm Beach, N 26° 50.138', W 80° 02.75', extends from the Atlantic Ocean to Lake Worth Lagoon in northern Palm Beach County. Transects were run through a disturbed tropical hammock that continued into a mangrove swamp and across a small mosquito ditch.

Blowing Rocks Preserve, Jupiter Island, Martin County, N 26° 58' 48.8", W 80° 04' 94.8", is managed by The Nature Conservancy (TNC) and borders the Atlantic

Ocean and the eastern shore of the Indian River Lagoon. The preserve consists of several coastal habitats, and transects were run through the mostly undisturbed tropical hammock, coastal strand, and a disturbed mangrove remnant. Nonindigenous plant removal records provided by TNC were useful in dating the initial appearance of *C. anacardioides* and in documenting reinfestation in a natural area.

West Coast

John MacDonald Island, in Robert's Bay, Sarasota County, N 27° 17' 15", W 82° 32' 95", was formed circa 1960 from sand dredged to form the Gulf Intracoastal Waterway. Mangroves dominate the coast and nonindigenous species like *Casuarina equisetifolia, Schinus terebinthifolius*, and *C. anacardioides* dominate the interior. Transects were run through a *Casuarina* forest, a mangrove swamp, and an ecotonal area (mangrove swamp–*Casuarina* forest).

Delnor Wiggins Pass State Recreation Area, N 26° 16' 23", W 81° 49' 08" borders the Gulf of Mexico in northern Collier County. The habitat is primarily mangrove forest, with tropical hammock and a dense population of *Casuarina equisetifolia* at the northern end. Transects were run through the hammock and bordered a mangrove forest.

Carl Johnson County Park, Lee County, N 26° 50', W 81° 90', abuts the southwestern coast of Florida near Fort Myers Beach. A monospecific canopy layer of *Casuarina equisetifolia* forms a narrow beachfront strand. There are also mangrove bays and *Casuarina–Rhizophora mangle* transition areas. Transects were run through a disturbed coastal strand that bordered a mangrove bay.

RESULTS

Distribution Map

Naturalized *Cupaniopsis anacardioides* currently grows in 14 counties from

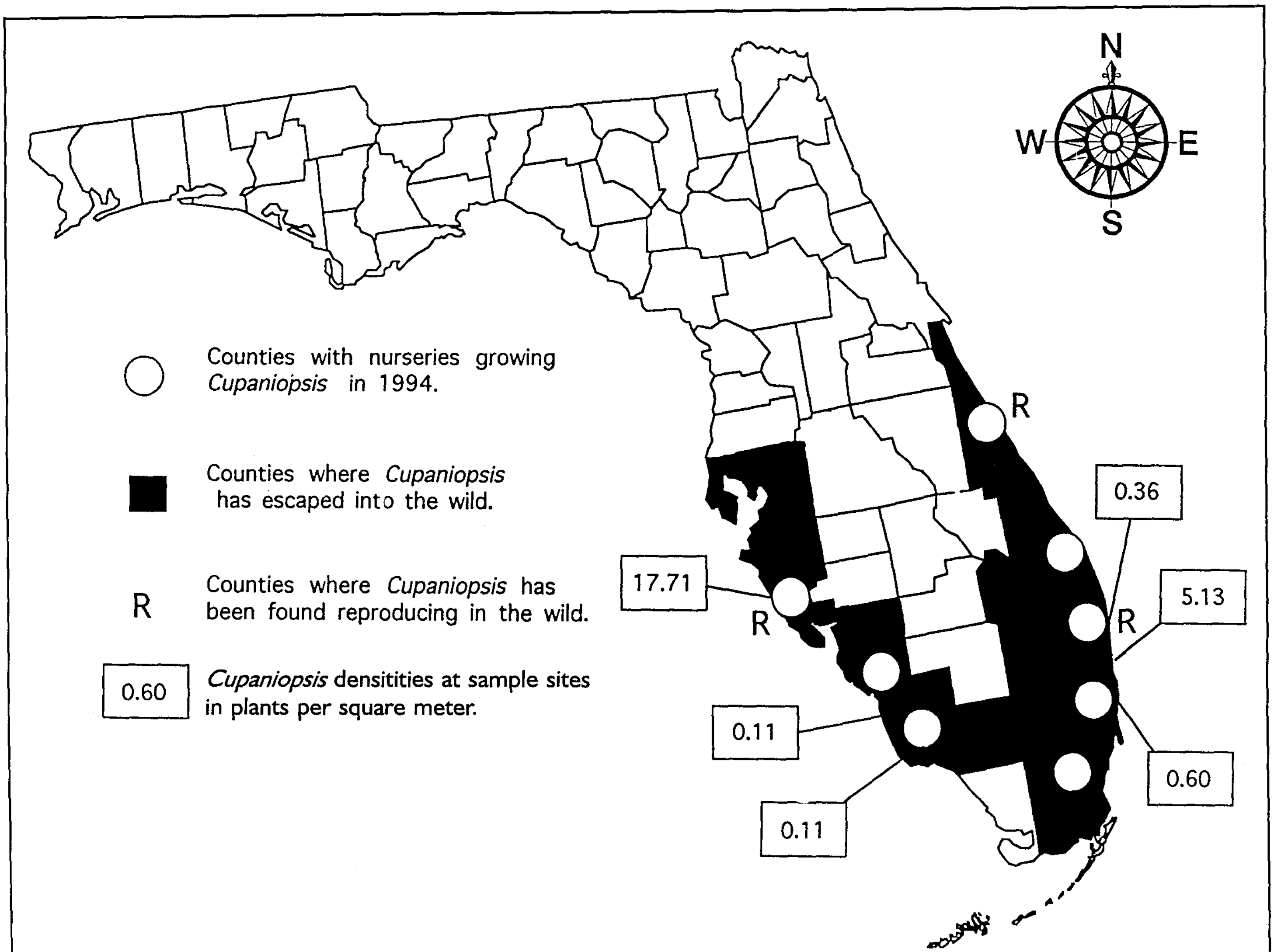

Figure 1. Distribution of *Cupaniopsis anacardioides* in Florida, showing counties where it has escaped cultivation and average densities from all strata and habitats at each study site.

Brevard to Hillsborough Counties and southward (Figure 1). A compilation of 80 field reports indicates the occurrence of naturalized *C. anacardioides* in disturbed and undisturbed areas, including spoil islands and intact native habitats. Plant communities in which naturalized *C. anacardioides* have been found are mangrove swamps, cypress swamps, beach dunes, coastal strand, coastal hardwood hammocks, inland hammocks, pine flatwoods, sand pine scrub, and freshwater marshes. By location, average *C. anacardioides* densities ranged from 0.1 to 17.7 plants m^{-2} (Figure 1).

Table 1 lists the counties and habitats known to be impacted. Plant sizes described for Table 1 ranged from seedlings to trees up to 5 m tall. Incidences per site ranged from a single or a few plants to dense, nearly monoculture populations. While records exist for fruiting *C. anacardioides* in Sarasota, Martin, and Brevard Counties, there were no reproductive trees within the study plots used for density sampling.

Table 1. Habitat types invaded by *Cupaniopsis anacardioides*, by county.

County	Habitat Types[a]
Broward	3,4,7,10
Brevard	7,9
Charlotte	0,1
Collier	2,7,9,10
Dade	9,10
Hillsborough	2,9
Indian River	7,9,10
Lee	6,7,9
Manatee	1,2,7
Martin	0,6,7,8,9,10
Palm Beach	1,2,4,7,9,10
Pinellas	0,9,10
St. Lucie	0,7,9,10
Sarasota	0,1,2,4,5,7,9,10

[a] Habitat types are modified from Myers and Ewel (1990): 0 = unknown, 1 = pine flatwoods / dry prairie, 2 = sand pine scrub / high pine, 3 = temperate hardwood / inland hammock, 4 = freshwater swamps, 5 = freshwater marshes, 6 = dunes / coastal strand, 7 = mangroves, 8 = rivers, springs, 9 = disturbed / developed, 10 = tropical hammock / coastal hardwood hammock.

Density and Class Size

A total of 1,240 m^2 were sampled. There was a broad range of *C. anacardioides* density among sites, among habitats, and between disturbed and undisturbed plots. By location and disturbance, hammocks showed the highest average densities, ranging from 0.1 to 21.5 plants m^{-2}. Hammocks had even greater densities in individual 10-m^2 plots, reaching as high as 37.8 plants m^{-2}. Mean densities in mangroves ranged from 0.05 to 14.6 plants m^{-2}. Individual 10-m^2 plot densities totaled as high as 44.9 plants m^{-2}. The lowest densities occurred in the coastal strand, where mean densities ranged from 0.1 to 0.2 plants m^{-2}, and per plot densities were as high as 0.6 plants m^{-2}.

When all sites are grouped for a single plant community, results from the Kruskal-Wallis test indicate a statistically significant increase in density for disturbed plots in mangroves ($p < 0.001$) and hammocks ($p < 0.01$), but not in coastal strand ($p > 0.6$) (Table 2A). When disturbed and undisturbed plots for a given site and habitat are analyzed (Table 2B), a statistically significant increase in density is found at the mangrove site ($p < 0.01$), but not at either of the hammock sites ($p > 0.7$), nor at the coastal strand site ($p > 0.2$). Thus, the plant community results are consistent with the individual site results in mangrove and strand habitats. Results from grouped hammocks differed from those of individual site samples. While the effect of disturbance on *C. anacardioides* density appears to vary with community type, the direction of effect in the hammock community is currently inconclusive.

Size class information is presented in Table 3. Of *C. anacardioides* plants in mangroves, 83.4% are in the seedling layer, 15.6% in the shrub layer, and 1.0% in the tree layer. In hammocks the corresponding relations are 91.1%, 8.3%, and 0.7%. For coastal strand they are 85.2%, 14.8%, and 0%.

Species Richness

Mean species richness values are listed in Table 4 and are based on species number per 10 m^2. Mean richness for this study was 4.5 in mangroves, 9.8 in tropical hammock, and 3.6 in coastal strand. A comparison of mangrove species richness between plots with only native plants and plots with nonindigenous species, including *C. anacardioides,* yielded means of 2.3 and 5.3, respectively. Results from a Student's *t*-test on square root transformed data indicate a statistically significant difference ($p < 0.001$). The presence of nonindigenous species appears to artificially increase species richness in the mangrove habitat.

Table 2. Kruskal-Wallis statistics (H) for effects of disturbance on *C. anacardioides* densities of shrub and tree strata, in habitats (A) as a whole and (B) in specific sites. Degrees of freedom (df), number of 10-m^2 plots sampled (N), and *p* refer to H statistic; ns = not significant.

A. All Sites

Habitat	(df, N)	H	*p*
Mangroves	(1, 44)	13.346	<0.001
Hammocks	(1, 62)	7.458	<0.01
Strand	(1, 18)	0.252	ns

B. Sites containing disturbed and undisturbed plots

Habitat	Site	(df, N)	H	*p*
Mangrove	Lake Wyman Park	(1, 14)	8.516	<0.01
Hammock	Blowing Rocks Preserve	(1, 17)	0.000	ns
Hammock	MacArthur Beach State Park	(1, 9)	0.092	ns
Strand	Blowing Rocks Preserve	(1, 10)	1.143	ns

The presence of nonindigenous species may potentially degrade or enhance species richness in hammocks. The least disturbed tropical hammocks were in Martin County on the east coast and Collier County on the west coast.

The physiognomy of the hammock on the spoil island in Sarasota County is different from that of other hammocks. The infestation by nonindigenous species appears to preclude the establishment of most native species. At this site, species richness was 4.8, where nonindigenous species made up 17% of the total number of species but comprised 97% of the individuals and 97% of plants over 2 m tall.

There are insufficient data to comment on species richness trends in coastal strand communities.

Associated Plants

A list of all the species found within all test plots by location can be found on the EPPC Web site [http://www.fau.edu/envsci/adaptations.htm] and [http://members.aol.com/habitatsp/]. Habitat types are indicated for each species, and non-native plants are identified.

DISCUSSION AND CONCLUSIONS

This study confirms that *Cupaniopsis anacardioides* is yet another nonindigenous tree that has not only escaped into the wild, but is also invasive and reproductive in Florida's natural areas. Our findings can be summarized as follows: (1) *C. anacardioides* has escaped cultivation in 14 southern and central Florida counties; (2) *C. anacardioides* has invaded most of the major habitat types in the state of Florida; (3) birds are the dispersal agents for this nonindigenous species; (4) naturalized carrotwood trees are reproductive in three counties; (5) *C. anacardioides* densities are high in hammocks and in mangroves, but low in coastal strand communities; and (6) *C. anacardioides* may contribute to the alteration of species richness, particularly in mangrove communities.

The extent to which *C. anacardioides* may expand its distribution is unknown at this time. Stresau (1986) described the species' cold tolerance level as about -6° C. Experimental trees planted in northern Florida (Leon County) continue to persist despite several days of subzero degrees (C) weather in 1989 and 1996 (G. Jubinsky, environmental administrator, Florida Department of Environmental Protection, Tallahassee, pers. com.). The distribution gap in the interior of the state (Figure 1) does not suggest that *C. anacardioides* will not grow there—it just has not yet been found there in the wild.

A major element in the geographic expansion of *C. anacardioides* is its dispersal mode. The fruit of *C. anacardioides* is brightly colored and attractive to birds. The feeding on *C. anacardioides* fruit by generalists such as mockingbirds, fish-eating crows, and starlings (D. Austin, unpubl. data, 1990–1996) probably explains why this tree has escaped to islands and can be found miles from the nearest parent plant.

In California *C. anacardioides* is not known to be invasive, perhaps due to the region's drier climate. Based on the range of habitat types where it grows (Reynolds 1985), *C. anacardioides* growth patterns in Florida appear to parallel those in Australia.

In the Florida habitats in which it has been found, *C. anacardioides* currently is most prevalent in hammocks and mangroves (Table 1). It is not known if this is a product of habitat affinity, habitat susceptibility, or merely the popularity of perching and roosting areas for birds. All habitats appear to be at risk, however, and few Florida habitats are not listed among those already invaded.

Cupaniopsis anacardioides may favor colonization in disturbed areas of mangrove and hammock communities in general. Examination of specific locations where disturbed and undisturbed data were both available, however, did not support this generality for hammocks (Table 2). For example, *C. anacardioides* plants over 2 m tall were found in both disturbed and undisturbed plots at Blowing Rocks Preserve, suggesting that elements other than

Table 3. ***Cupaniopsis anacardioides*** **size classes by habitat and location. Size classes represent three strata: <0.5 m (seedling), 0.5–2.0 m (shrub), > 2.0 m (tree). Numbers represent plant counts per area sampled. Area sampled is given in m^2. Not all habitats are represented at all locations, as indicated by NA. Palm Beach N = MacArthur Beach State Park; Palm Beach S = Lake Wyman Park.**

	Habitats											
	Mangrove				Hammock				Coastal Strand			
County	<0.5 m	0.5–2 m	>2.0 m	Area	<0.5 m	0.5–2 m	>2.0 m	Area	<0.5 m	0.5–2 m	>2.0m	Area
Sarasota	1370	230	10	110	1722	195	15	90				NA
Palm Beach N	68	40	7	140	750	16	1	90				NA
Palm Beach S	2	1	0	60	46	10	2	150				NA
Martin	8	1	0	30	73	8	1	170	14	4	0	100
Lee	7	0	0	70				NA	8	0	0	80
Collier	0	0	0	30	7	9	0	110				NA

disturbance influence its distribution. Because coastal development borders many remaining natural areas, the impact of invasive nonindigenous plants used in landscaping tends to complicate management of otherwise intact natural areas.

The coastal strand community, perhaps due to its regular exposure to dynamic disturbance, does not show a significant difference in *C. anacardioides* density between disturbed and undisturbed plots.

The broad variation in plant density appears to be a function of time and exposure. Highest densities of *C. anacardioides* occur in Sarasota County, where it was first propagated in significant numbers. Sarasota County has had at least 10 more years of exposure than other parts of Florida. Popularity and landscape planting since the early 1980s in Palm Beach County may have allowed it to achieve the second highest *C. anacardioides* density.

Species diversity and community plant composition tend to be altered by disturbance and the presence of naturalized, nonindigenous species (Molnar 1990, Vitousek 1990, Horvitz et al. 1995, Gordon 1998). The normally low number of species in the mangrove community is artificially raised by disturbance. The normally high number of species in tropical hammocks may be reduced. Continued monitoring is needed to determine the long-term impacts of *Cupaniopsis* on species richness and on succession in each habitat.

The distribution of *Cupaniopsis anacardioides* in Florida is nearly identical to that of all three mangrove tree species (Figure 2). Mangroves are highly adapted, but not very competitive (Kuenzler 1974, Tomlinson 1986). It is too early to say how the invasion of *C. anacardioides* affects the floristically simple, but highly productive mangroves, on whose food chain numerous Florida industries depend. Major concerns include increased susceptibility to infestation by nonindigenous species in mangrove communities where canopies have been opened or damaged by storm events or by aesthetic "trimming," allowed under current law (Section 403.9321–403.9332, Florida Statutes).

Kowarik (1995) described the average time elapsed between plant introduction and escape into the wild as being 147 years in Europe. *Schinus* was introduced ca. 1900 and appeared outside of cultivation by the 1950s (Alexander and Dickson 1970, Morton 1978). *Melaleuca* was introduced in 1906 and by the 1930s saplings were harvested from the wild for ornamental use (Meskimen 1962). *Cupaniopsis anacardioides* was introduced by the early 1960s and observed in spoil islands and natural areas by 1989 (Oliver 1992). The speed at which *C. anacardioides* has escaped in Florida rivals that of its damaging nonindigenous predecessors.

Cupaniopsis anacardioides has traits comparable to *Schinus* that promote colonization and persistence. These include a colorful seed that persists on the tree, large leaves, hard wood, prolific seed production, and a mobile seed disperser. Several of the species' traits fuel concerns regarding the expansion and long-term impacts of *C. anacardioides*. Hawkeswood (1983b) estimated seed production by a single, mature *C. anacardioides* tree at 9,200–10,800 seeds. The tolerance of *C. anacardioides* to a broad range of soils, soil moisture, elevations, and salt reduces the factors that could limit its growth or expansion. *Cupaniopsis anacardioides* is a popular ornamental tree that has been highly promoted, much as *Schinus* was promoted in the 1960s and 1970s. Recent awareness regarding *C. anacardioides* invasiveness, however, has caused the nursery industry to reconsider its position regarding its promotion.

Cupaniopsis anacardioides, along with other recently identified invaders, is under review for listing on the Florida Noxious Weeds List. Awareness of the impacts of nonindigenous species on natural communities and the development of a screening process for plant introductions will help to reduce the potential for continued infestations and costly control efforts.

ACKNOWLEDGMENTS

We would like to thank Greg Jubinsky, Bureau of Aquatic Plant Management, Florida Department of Environmental Protection (FDEP) for sponsoring this re-

Table 4. Mean plant species richness within sampled 10-m^2 plots by habitat. Disturbed and undisturbed data are combined. Sample species richness in mangroves is compared for plots containing only native plants and those with nonindigenous species (N.I.S.). Palm Beach N = MacArthur Beach State Park; Palm Beach S = Lake Wyman Park.

		Species Richness		
Habitat	**County**	**Mean**	**Natives Only**	**w/ N. I. S.**
Mangrove	ALL	4.5	2.3	5.3
	Sarasota	5.2		3.4
	Lee	2.1	1.7	2.5
	Collier	1.7		
	Martin	7.0		
	Palm Beach N	6.3		
	Palm Beach S	4.2		
Hammock	ALL	9.8		
	Sarasota	4.8		
	Collier	8.7		
	Martin	11.7		
	Palm Beach N	14.4		
	Palm Beach S	8.7		
Coastal Strand	ALL	3.6		
	Lee	1.9		
	Martin	5.6		

search. We also thank the following individuals and agencies for their assistance with information, permits, and support: Ed Freeman, Sarasota County; Drs. Sandra Gilchrist and John Morrill, New College; The Nature Conservancy and Michael Renda, Blowing Rocks Preserve; J.B. Miller, FDEP, Jonathan Dickinson State Park; John Fillyaw and personnel at MacArthur Beach State Park; personnel at Delnor-Wiggins Recreation Area; Kimberly Polen, Collier County; Roger Clark, Lee County. Thanks also to those who provided technical support—Anne Cox and Charles Hilsenbeck, and those who assisted with the field work and data collection—Jill Young, Anupam Gaonkar, Marsha Colbert, Faith Deering, and Michael Manna, Florida Atlantic University; Aaron Gubin and Trenton Eilers, New College; Doug Scofield, Amy Ferriter, Thomas Farrell, Allen Rainey, and Beth Burger.

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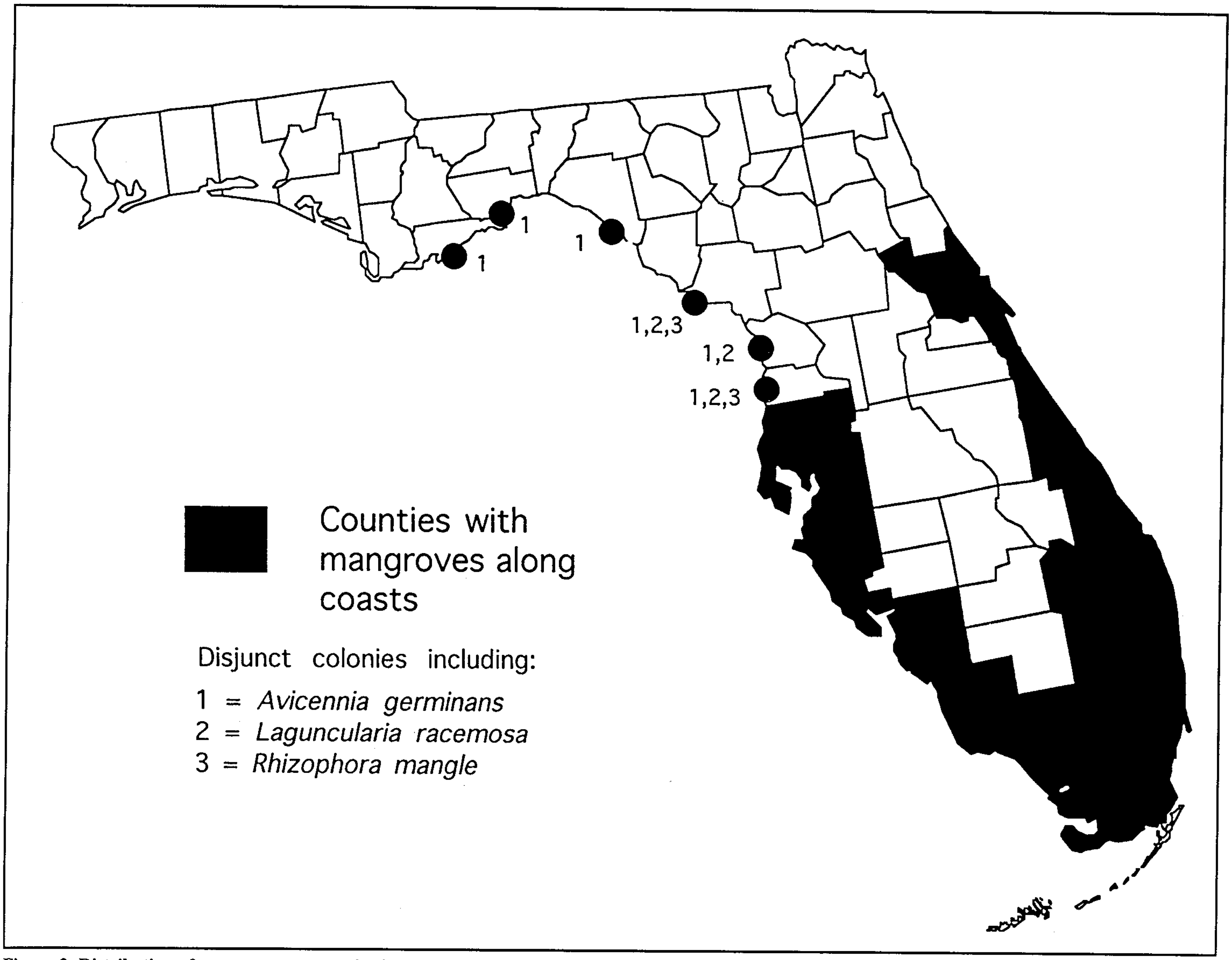

Figure 2. Distribution of mangrove tree species in Florida: *Rhizophora mangle, Avicennia germinans,* and *Laguncularia racemosa* (based on Little 1978).

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