35 Post-Hurricane Vegetation Response in South Florida Hammocks With and Without *Dioscorea bulbifera* L. Control

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Abstract

Air potato (*Dioscorea bulbifera* L.) has the potential of rapidly invading and displacing native forest communities of Florida. Management of this exotic, as with most, has been conducted using a varity of mechanical and/or chemical control techniques. The purpose of this study was to contrast and compare the effectiveness of two control methods, hand pulling and herbicide application, in six hardwood hammocks in southern Florida,. Effective management will maximize control, while minimizing impacts to native plant communities.

Introduction

The invasion of non-indigenous plant species into natural areas in southern Florida threatens natural community structure and composition characteristics. When these invasive species are twining vines, they often have dramatic influences on the natural community because of their ability to rapidly reach the canopy, suppress sapling growth, and link the canopies of several trees (Schmitz et al. 1997; Gordon

Presented at the Eleventh Annual Meeting of the Florida Exotic Pest Plant Council, held in Tallahassee, Florida, 7-9 May 1996.

1998). As a result, research on control methods for vines that invade the fragmented natural communities that remain in southern Florida is critically needed.

Air potato (*Dioscorea bulbifera* L.), a perennial, herbaceous vine with annual stems, is native to both Africa and Asia (Schmitz et al. 1997). This vine twines around supporting species and can out-compete canopy and understory species for light. Flowering, but not sexual reproduction, in this species has been documented in Florida. However, air potato reproduces rapidly through vegetative growth of aerial tubers or bulbils (The Nature Conservancy 1993). Numerous bulbils, usually in leaf axils, are produced by single plants. Bulbils of all sizes (1-20 cm in diameter) can produce new plants. New plants quickly form underground perennial tubers that can exceed 25 cm in diameter. These tubers support vigorous resprouting of stems (The Nature Conservancy 1993).

No work has examined whether repeated removal of air potato stems can reduce plant vigor, bulbil production, and ability to regenerate. Control methods have traditionally included hand-pulling and herbicide (Roundup) application, although the relative effectiveness of these two methods of control has not been compared.

This research was designed to examine the effectiveness of repeated pulling of above-ground air potato stems, versus pulling and treating resprouting leaves with Roundup herbicide. We hypothesized that (1) both hand-pulling and herbicide control treatments would significantly reduce density and cover of air potato, (2) herbicide application would be significantly more effective at reducing air potato abundance than hand-pulling, and (3) native and non-native species richness would not be affected by either air potato removal method. Treatments were compared in small plots within a matrix from which non-native plants under 3 m tall were removed and species were mechanically pruned to reduce vine access to the canopy. We replicated the treatments three times in two Miami-Dade County parks.

Our original intent was to treat the plots monthly for six months, comparing repeated pulling with repeated Roundup application. After the second month and first herbicide treatment, Hurricane Andrew impacted all blocks. As a result, no further plot treatments were imposed, although we were able to relocate the plots and assess the effects of the limited treatment at three year post-treatment, as planned. However, the conclusions drawn from this experiment are limited because all treatments were not completed and the hurricane may have confounded treatment results. The hurricane did suggest an additional hypothesis: control of air potato reduces its rate of density and cover increase post-hurricane.

Methods

Research blocks were located in hammocks at the Charles Deering Estate (2 blocks) and Kendall Indian Hammocks Park (1 block) (these sites will be subsequently called Deering 1 and 2, and Indian Hammocks, respectively). At each site, two plots were permanently marked. Non-native species removal (treatment) plots were 36 x 36 m, while the undisturbed control plots were 18 x 36 m to ensure constant density of sample subplots. Paired plots were not closer than 10 m to each other. Blocks were selected to be as similar in soil type, vegetative community, and density of air potato as possible.

Prior to treatment establishment in June 1992, 10 and 20 randomly distributed 1 m^2 subplots were located in each control and treatment plot, respectively (Fig. 1).

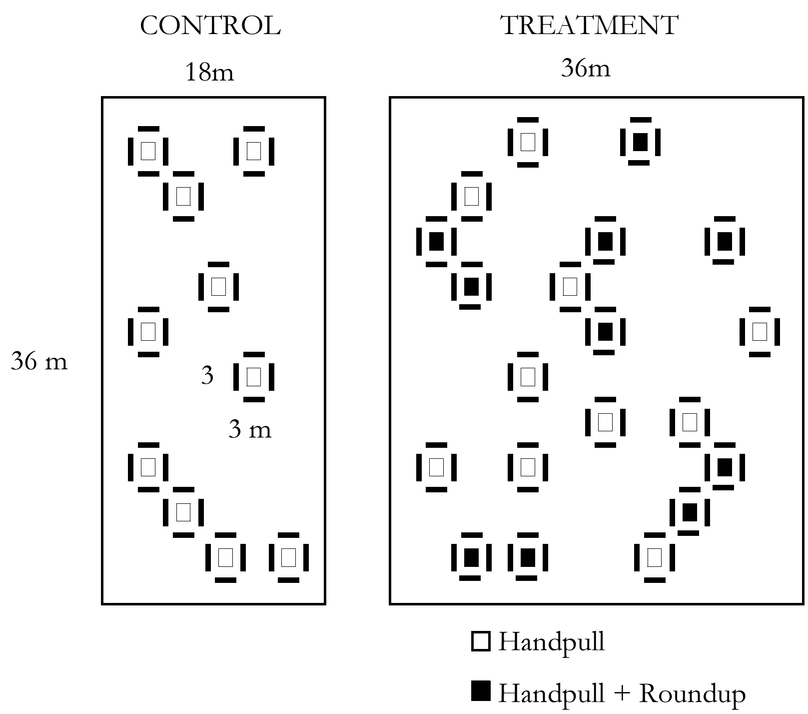

Figure 1. Sampling design for the control and *Dioscorea bulbifera* removal treatment blocks. Treatments were imposed in the 3 x 3 m subplots; measurements were taken in the central 1 x 1 m quadrats. Subplot density was held constant across the blocks.

Subplots were selected from a grid with intersections every 3 m in each plot. In the treatment plots, the subplots were surrounded on all sides by a 1 m buffer area, making effective plot size 9 m^2. Measurements in treatment and control blocks were conducted each May from 1992 (pre-treatment) through 1995.

Within the 1 m^2 subplots, we counted the total number of unrooted bulbils, and rooted first year (aerial tuber visible) and older air potato stems in 0-1 m, 1-3 m, and >3 m height classes. We also ocularly estimated the percent cover of air potato in the three height strata. The number of all individuals rooted in plots was counted by species and by species group (native or non-native).

Within the larger experimental and control plots in each block, five 36 m long, randomly located permanent transects were established. Point intercepts every 6 m (3 m in control blocks) along the transects were used to examine canopy cover of native and non-native tree species at 1-3 and >3 m heights. Percent canopy cover was also measured with a spherical densiometer every 6 m. Following the hurricane, the point intercept data were collected from the diagonal corners of the 9 m^2 sampling subplots because access throughout the plots was difficult.

Treatments were established in June 1992, following completion of the initial data collection. Throughout the 36 x 36 m treatment plot in each block, non-native species removal efforts were imposed. All climbing non-native vines, except air potato, were cut at <10 cm and again at a height of 2 m. Stumps of woody vines were treated with Garlon 4 (5% in oil) to prevent resprouting. Seedlings of vines were hand-pulled. Readily resprouting vines like *Epipremnum pinnatum* (L.) Engl. were cut at 2 m above ground and physically removed below that height. All stems of air potato were pulled to uproot or break at ground level. Aerial tubers that had not yet established, and rooted tubers from 1991, were manually removed. All other non-native species under 3 m in height were hand-pulled, grubbed-out, cut and/or treated with Garlon or Roundup. Lateral branches of remaining trees and vertical shrubs that provided support for climbing plants were also trimmed. No entire plants of native species were removed.

Within the 9 m^2 subplots intended for the hand-pulling treatment only, neither herbicide nor grubbing occurred. Within the central 1 m^2 of those subplots , the numbers of air potato stems sprouting from aerial tubers (seedlings) and resprouting from underground tubers were recorded each time they were pulled (in June and July 1992 only). Within the 9 m^2 clipped Roundup treatment with buffer plots (n=10/block), all stems of air potato were pulled to uproot or break at ground level, in June 1992. Resprouting leaves were sprayed once with Roundup in July; under the original plan, spraying was to be monthly until January. Similar to the hand-pulling treatment, no grubbing or Garlon herbicide was used. The plant material removed was piled outside the plots in the treatment blocks. Non-native species that readily resprout from shoot tissue, and aerial and below-ground tubers of air potato, were placed in non-biodegradable plastic bags adjacent to debris piles.

Treatment and control blocks were remeasured each May, from 1993 through 1995. Conditions in all the blocks had substantially changed because most of the original canopy was removed by Hurricane Andrew. All blocks were exposed to Hurricane impacts, with each paired control and treatment block similarly affected; as a result, comparisons were conducted as planned.

The effects of the hand-pulling versus pulling plus herbicide treatments on the numbers and cover of air potato plants were assessed between 1992 and 1993 using Kruskal-Wallis non-parametric tests; between 1992 and 1995, repeated measure analysis of variance on transformed data was used. Canopy cover data and changes in composition of other native and non-native species within the plots were similarly analyzed. All data were square root transformed except the cover data which were arcsine transformed. Residuals from these analyses were examined and consistent with the assumptions of the tests. Changes in the relative representation of native and non-native species in the canopy were assessed with chi-square tests.

Results

Air potato

Non-parametric analysis of variance on the main and interactive effects of site and treatment on change in air potato number and cover for the period 1992-1993 showed that only a few of these effects were significant (Table 1). Overall, differences were only between the control plots and the treatment plots, with no differences in effect between the two types of treatment. By 1993, treatments had reduced the number of rooted air potato seedlings less than 1 year old roughly four-fold compared to the controls (Table 2). Although the number of stems less than 1 m tall decreased in all blocks, perhaps due to hurricane effects, the decrease

Table 1. Summary of p-values from Kruskal-Wallis tests of treatment and site effects on air potato numbers and cover, 1992-1993.

Factor	df	No. bulbils	Number of plants		Number of stems			Percent cover		
			<1yr	>1yr	<1m	1-3m	>3m	<1m	1-3m	>3m
Treatment	2	0.12	**0.0001**	0.81	**0.0002**	0.29	0.68	0.06	0.06	0.22
Site	2	0.31	0.57	0.81	0.65	0.36	0.39	0.52	0.59	0.42
Plot (site)	3	0.26	0.98	0.76	0.53	0.34	0.17	0.95	0.60	0.55
Site x treatment	4	**0.02**	0.49	0.15	0.37	**0.02**[1]	0.19	0.40	0.48	0.32
Error	86							87		

[1] Overall model not significant.

Table 2. Summary of mean air potato numbers and cover (with standard deviation) by treatment, 1992-1995.

Year	No. bulbils	Number of plants		Number of stems			Percent cover		
		<1year	>1year	<1 m	1-3 m	>3 m	<1 m	1-3 m	>3 m
					A. Control				
1992	0.30 (0.65)	2.70 (4.49)	34.67 (22.64)	37.37 (22.64)	3.37 (3.57)	0.77 (1.57)	40.50 (35.47)	15.50 (25.23)	5.77 (17.08)
1993	3.04 (5.76)	20.28 (13.68)	8.57 (8.46)	28.71 (20.34)	2.86 (3.58)	0.68 (2.00)	31.50 (28.51)	11.17 (16.70)	0.57 (2.01)
1994	0.26 (0.45)	20.48 (16.07)	34.74 (28.44)	55.22 (36.01)	7.33 (7.25)	1.41 (1.97)	40.65 (39.27)	41.02 (35.92)	13.80 (16.76)
1995	0.29 (o.60)	13.82 (11.67)	86.32 (57.16)	100.14 (62.97)	18.57 (17.30)	0.86 (1.27)	62.14 (31.77)	45.98 (33.47)	17.41 (27.70)
					B. Hand Pulled				
1992	0.47 (0.94)	2.03 (3.49)	29.70 (16.34)	31.73 (17.43)	2.37 (2.68)	0.50 (1.01)	24.83 (17.98)	18.87 (24.49)	4.17 (7.44)
1993	0.86 (2.92)	5.38 (5.17)	1.86 (2.32)	7.21 (5.89)	0.28 (0.59)	0	5.00 (7.68)	1.10 (1.79)	0.10 (0.55)
1994	0.43 (1.00)	11.39 (11.49)	5.11 (6.04)	16.50 (16.77)	3.28 (4.04)	0.32 (0.94)	16.07 (20.39)	25.18 (25.83)	3.93 (7.89)
1995	0.24 (0.44)	18.69 (20.97)	27.00 (27.74)	45.69 (37.97)	10.03 (8.63)	0.41 (0.87)	28.28 (23.72)	42.07 (35.06)	8.88 (12.62)
					C. Herbicide				
1992	0.50 (1.01)	2.23 (3.53)	28.33 (16.60)	30.57 (18.72)	1.37 (1.71)	0.30 (0.60)	27.00 (27.02)	11.20 (21.18)	4.17 (10.09)
1993	0.33 (0.88)	5.80 (5.22)	1.63 (1.96)	7.43 (6.16)	0.20 (0.41)	0	4.50 (3.61)	1.77 (5.52)	0
1994	0.27 (0.69)	11.07 (10.82)	6.87 (6.42)	17.93 (15.68)	4.03 (4.11)	0.33 (0.71)	20.08 (19.90)	21.83 (24.33)	3.75 (12.89)
1995	0.23 (0.63)	19.47 (19.31)	29.10 (26.40)	48.57 (34.33)	12.97 (9.86)	0.43 (0.87)	37.50 (31.03)	44.08 (34.33)	6.67 (12.60)

was more than three times higher in the treatment plots than in the controls. The other variables showed similar but non-significant trends. Additionally, the effect of the treatments on the number of unrooted bulbils and stem density in the 1-3 m height stratum were dependent on the site.

When we returned to clipped plots for the second shoot removal treatment in 1992, we found marked differences in the number of shoots derived from newly sprouting bulbils versus those resprouting from old tubers. The sprouts from new bulbils represented between 77 and 92% of all sprouts present. On average, sprouts from new bulbils averaged 5.80, 6.10, and 5.60/m^2; those from resprouts averaged 0.75, 0.68, and 1.71/m^2 from Deering 1, Deering 2, and Indian Hammocks, respectively. Thus, resprouting may be less important than originally suspected. The number of unrooted bulbils was significantly higher in 1993 than in 1994 and 1995 across all sites (Tables 2-3).

If all four years of data are examined, the patterns become clearer (Table 3). Initial air potato densities at all heights examined were similar across the three sites (Figs. 2-4). In 1993, both the treatment and control plots contained comparably depressed densities of air potato under 3 m tall (Figs. 2-3). As a result, by 1995, while air potato densities in the treatment plots were twice those of the 1992 starting conditions, densities in the control plots were significantly higher (Table 3). Again, no differences in air potato responses were attributable to the method of removal employed; all significant treatment effects were between the treatment and control blocks.

Table 3. Summary of p-values from Kruskal-Wallis tests of treatment and site effects on air potato numbers and cover, 1992-1995.

Factor	df	No. bulbils	Number of stems			Percent cover		
			<1m	1-3m	>3m	<1m	1-3m	>3m
Treatment	2	.07	**.0001**	**.0001**	**.0001**	**.0001**	.05	**.04**
Site	2	**.0001**	**.0001**	**.0003**	**.02**	**.0001**	**.0001**	.14
Plot (site x tmt)	85	.74	**.0001**	**.0001**	**.0001**	**.0001**	**.0001**	**.0002**
Year	3	**.01**	**.0001**	**.0001**	**.0001**	**.0001**	**.0001**	**.0001**
Year x tmt	6	**.006**	**.0001**	.06	.07	.19	**.01**	.05
Error	250					251		

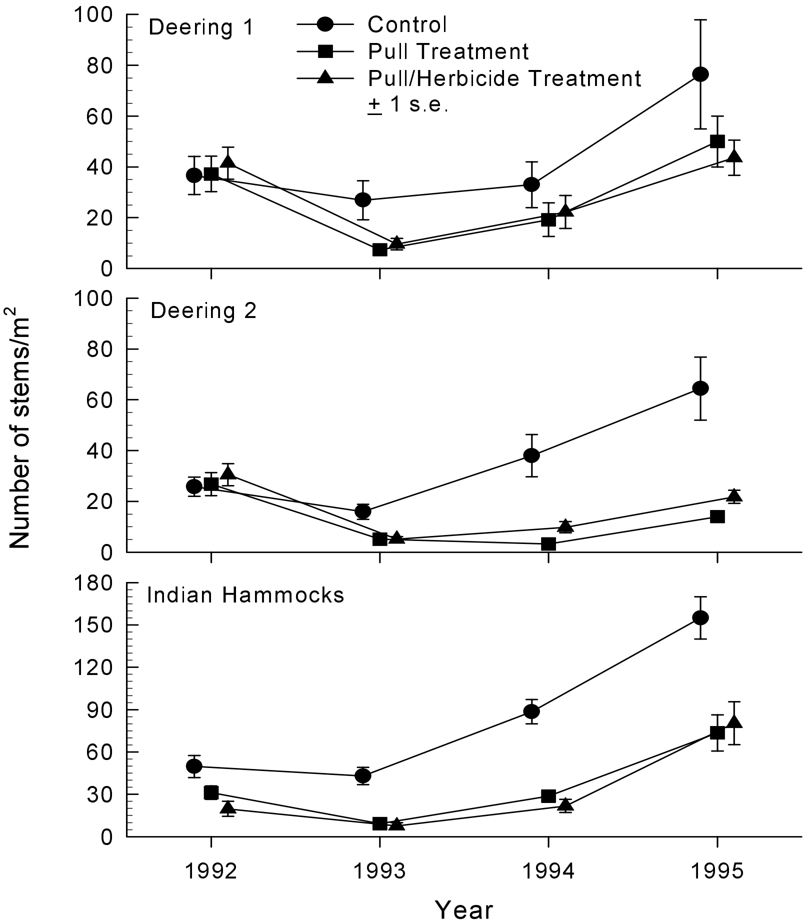

Figure 2. Density of *Dioscorea bulbifera* stems under 1 m in height, by site.

Significant differences among the sites were evident in all measures except percent cover in the uppermost stratum (Table 3). These differences reflect higher average stem densities at Indian Hammocks than at either of the Deering sites (Figs. 2-4); however, percent cover was higher at Deering 1 than at the other two sites (Fig. 5).

The small sample size of vines taller than 3 m complicates the interpretation of the dynamics within this size class (Fig. 4). However, density of this group was lowest in 1993; the substantial reduction in canopy height caused by the hurricane may explain this result. Even though few vines reached the upper stratum, their percent cover tended to increase over time in two of the three sites (Fig. 5). As in

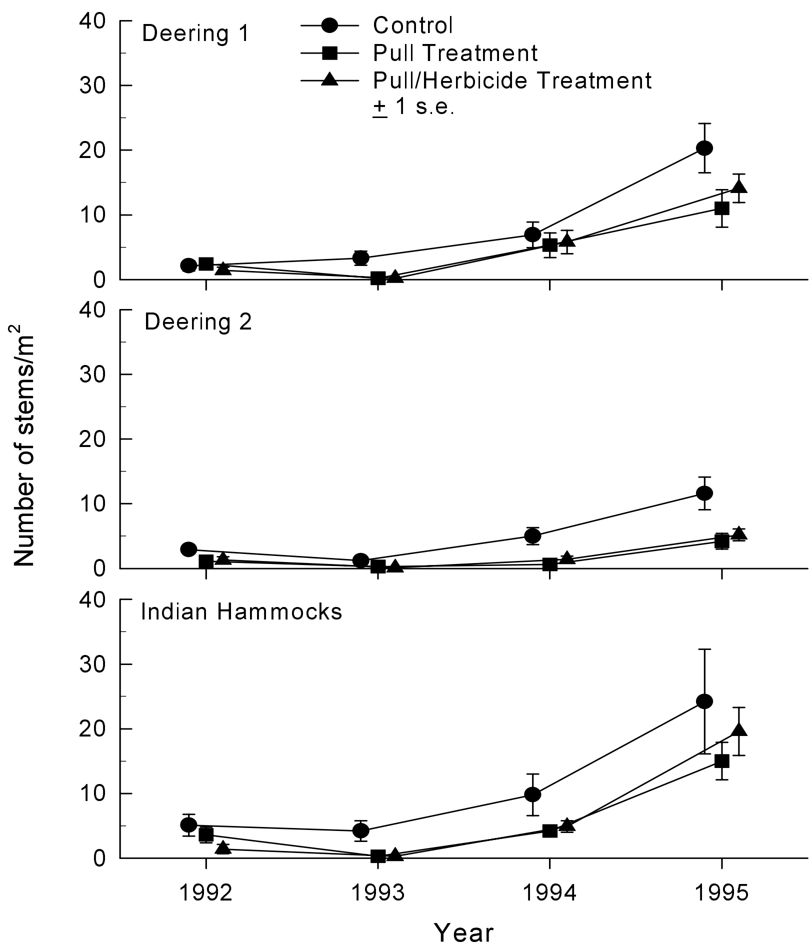

Figure 3. Density of *Dioscorea bulbifera* stems 1–3 m in height, by site.

stem densities, this increase was more rapid in the control plots than in the treatment plots, resulting in a significant treatment effect (Table 3). A significant year effect reflects the decrease in cover and density for the period 1992-1993, with 1994 and 1995 levels recovering to 1992 levels, as was seen in the lower strata. Because these patterns were similar for the other abundance measures recorded (see Table 2), and because of generally weak correlations among the variables, no other variables were graphed.

Other species

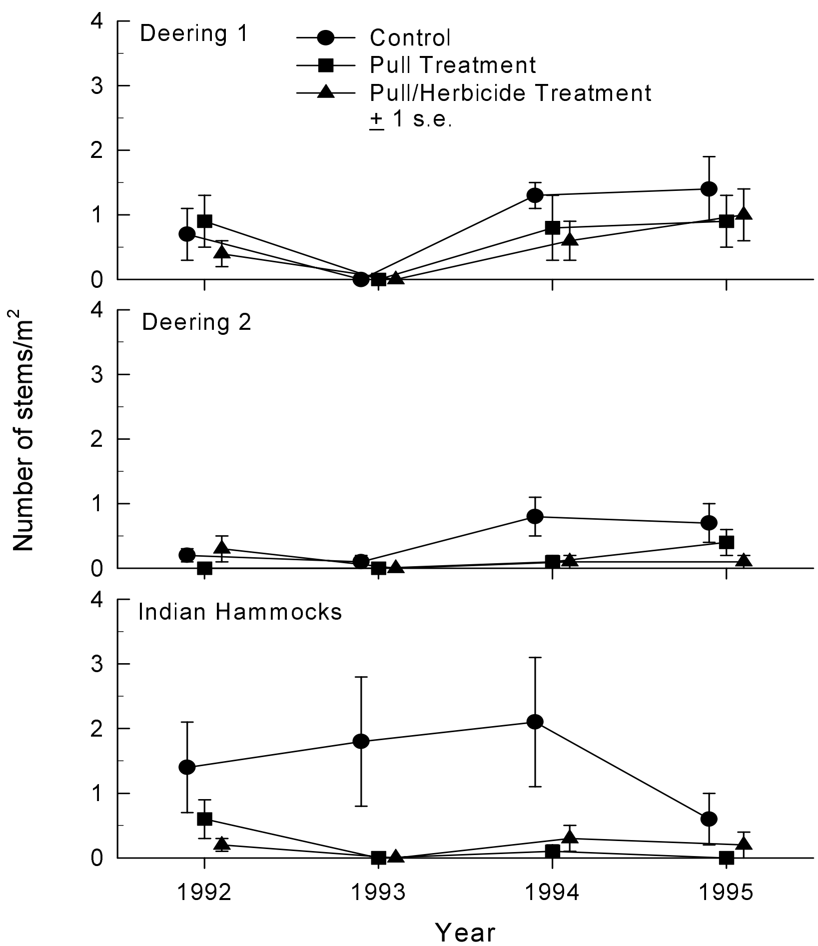

Figure 4. Density of *Dioscorea bulbifera* stems greater than 3 m in height, by site.

Richness

Responses of other species in the plots was examined by separating species into native and non-native categories using the best available information (Table 4). Species richness in the 1m² subplots ranged from 3 to 12 species, including air potato. Non-native species generally represented 30-50% of that richness (Fig. 6). While a total of 67 native and 22 non-native species were identified across all plots (Table 4), the average richness remained constant at 4 to 6 native and 1 to 3 non-native species per sq m (Fig. 6). The number of native species, but not

Table 4. Taxa present in Miami-Dade County plots, 1992-1995.

1992 -NATIVES

Ardisia escallonioides
Arecaceae [1]
Bidens alba var. radiata
Blechnum serrulatum
Bursera simaruba
Calyptranthes pallens
Campyloneurum phyllitidis
Celtis laevigata
Chiococca alba
Chrysobalanus icaco
Citharexylum fruticosum
Coccoloba diversifolia
Coccoloba uvifera [2]
Dichanthelium spp.
Drypetes lateriflora
Eugenia axillaris
Exothea paniculata
Hamelia patens
Ilex cassine
Krugiodendron ferreum
Morus rubra
Myrsine floridana
Nephrolepis exaltata
Ocotea coriacea
Oplismenus hirtellus
Orchidaceae [3]
Parthenocissus quinquefolia
Persea borbonia
Pleopeltis polypodioides
Poaceae [4]
Psychotria nervosa
Psychotria sulzneri
Quercus virginiana
Sideroxylon foetidissimum
Sideroxylon salicifolium
Simarouba glauca

1992 -NATIVES

Smilax spp.
Tillandsia balbisiana
Tillandsia cf. *fasciculata*
Tillandsia recurvata
Tillandsia cf. *utriculata*
Toxicodendron radicans
Vitis rotundifolia
Zanthoxyllum fagara
Unknown

1992 -NON-NATIVES

Ardisia elliptica
Bischofia javanica
Clerodendrum speciosissimum
Dioscorea bulbifera
Epipremnum pinnatum
Eugenia uniflora
Jasminum fluminense
Kalanchoe spp.
Mangifera indica
Oeceoclades maculata
Roystonea spp.
Schinus terebinthifolius
Syngonium podophyllum

1993 -NEW NATIVES

Ambrosia artemisiifolia
Cyperaceae
Erythrina herbacea
Eupatorium serotinum
Ficus aurea
Ipomoea indica
Ipomoea spp.[5]
Lepidium virginicum
Melothria pendula
Mikania cordifolia

1993 -NEW NATIVES

Petiveria alliacea
Phytolacca rigida
Rivina humilis
Sabal palmetto
Trema micranthum

1993 -NEW NON-NATIVES

Carica papaya
Emilia fosbergii
Momordica charantia
Tridax procumbens
Urena lobata

1994 - NEW NATIVES

Callicarpa americana
Cyperus cf. *ligularis*
Desmodium incanum
Metopium toxiferum
Passiflora suberosa
Sida spp.

1994 -NEW NON-NATIVES

Arecaceae [1]
Jasminum dichotomum
Kalanchoe pinnata

1995 -NEW NATIVES

Cynanchum spp.
Desmodium spp.

1995 -NEW NON-NATIVES

Neyraudia reynaudiana

[1] Unidentified palm seedling; [2] Adventive native; [3] Unidentified orchid;
[4] Unidentified grass; [5] *I. alba* L.?

non-native species, increased over time (Table 5). When all four years of data were combined, differences in richness among sites and treatments diminished. However, more non-native species were found in the herbicide treatment plots than in the control plots (Fig. 6).

Density

Table 5. Summary of p-values from Kruskal-Wallis tests of treatment and site effects on native and non-native species richness and density, 1992-1995.

Factor	df	Richness		Density	
		Native	Non-native	Native	Non-native
Treatment	2	0.64	0.05	0.86	**0.0001**
Site	2	0.14	0.06	**0.04**	**0.0001**
Plot (site x tmt)	85	**0.0001**	**0.0001**	**0.0001**	**0.0001**
Year	3	**0.0001**	0.06	**0.0001**	**0.0001**
Year x tmt	6	0.1	**0.0006**	0.05	**0.0001**
Error	250				

Because of different responses of native and non-native species within and among the sites, only one significant pattern was detected between 1992 and 1993: the change in density of non-native species was treatment-dependent across the three sites (significant site by treatment interaction: df=4, F=3.01, $p<0.03$). While Deering 1 densities remained similar across the blocks, except for a decline in non-natives in the pulled plus Round-Up treatment, this did not occur in the other sites; non-natives increased in all plots in Deering 2 and Indian Hammocks (Fig. 7).

Over the four years of this study, the density of non-native species was significantly dependent on treatment, site, and year (Table 5). Treatment differences resulted from significantly higher stem densities of non-native species in the control plots than in the removal plots of either method (Fig. 7). Site effects may have had more to do with hurricane impacts and local propagule availability than with the treatments. For example, Deering 2 may have had greater exposure to storm surge and salinity effects than the other sites. Densities of native species were independent of treatment, but did increase over time as well (Table 5). Prior to the hurricane and treatment establishment, high local densities of species were most likely to be of natives like *Psychotria nervosa* Sw. and *Nephrolepis exaltata* (L.) Schott. In 1993, high local densities were comprised of both natives and non-natives, e.g.,

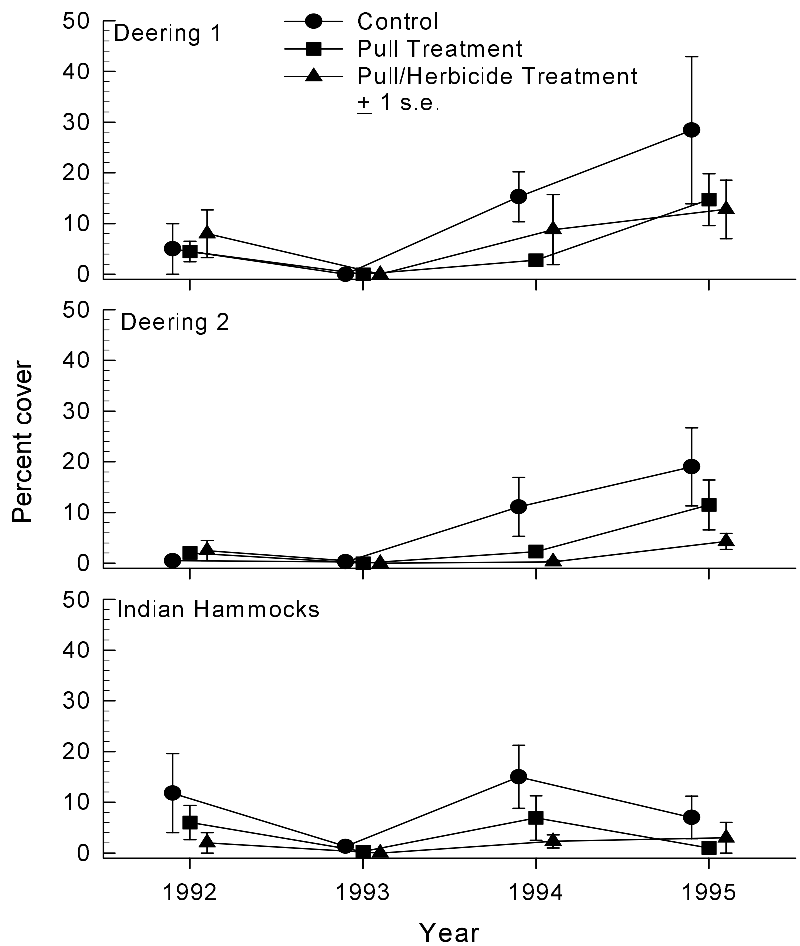

Figure 5. Percent canopy cover of *Dioscorea bulbifera* greater than 3 m in height, by site.

Celtis laevigata Willd., *Nephrolepis exaltata*, *Psychotria nervosa*, *Carica papaya* L., *Jasminum fluminense* Vell., and *Schinus terebinthifolius* Raddi.

Canopy cover

Spherical densiometer readings of canopy cover in 1992 showed cover not significantly different than 100% in all blocks. The percent total canopy cover decreased in 1993 by an average of 20%, but the height of that canopy also decreased. Similar data collected after the hurricane in three Miami-Dade County hammocks, including the Deering Estate, showed that the average canopy cover

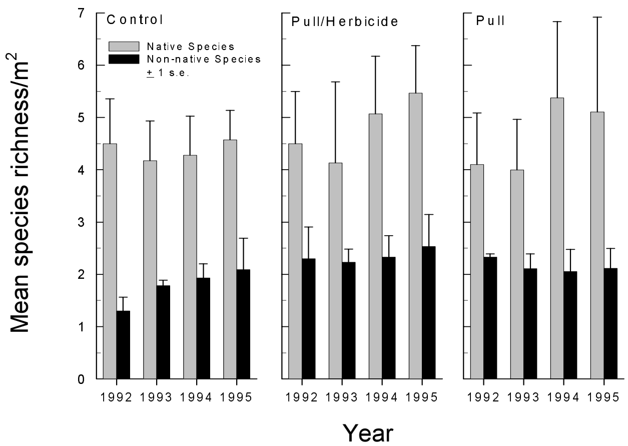

Figure 6. Native and non-native species richness for the control and *Dioscorea bulbifera* removal treatment plots; means are across

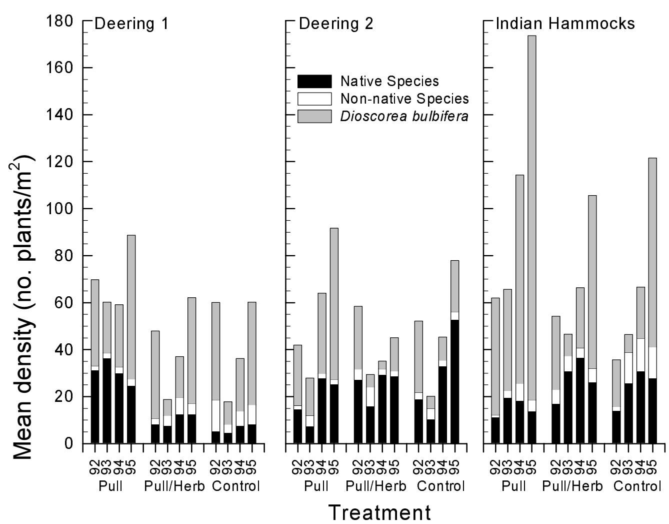

Figure 7. Native species, non-native species, and *Dioscorea bulbifera* densities versus time for the control and *D. bulbifera* removal treatment plots; means are across all three sites.

ranged from 50% (Deering) to over 75% (Horvitz et al. 1995). After 1993, total percent cover recovered in our study, but it was generally at substantially lower canopy heights. Because we did not document the average height of the cover measured, these measurements proved to be increasingly uninformative over time and will not be discussed further. However, similar results have been reported for canopy closure after Hurricane Hugo in Puerto Rico: 14 months after the storm, pre-hurricane cover had been re-established at the site at significantly lower canopy height (Fernandez and Fetcher 1991).

Composition of the canopy was also categorized as native and non-native and determined for the 1-3 m layer (Fig. 8) and the >3 m layer (Fig. 9). In 1992, native species dominated both levels of the canopy in all sites. The percent of non-natives increased significantly in the 1-3 m layer by 1993 and in the greater than 3 m layer by 1994. These effects presumably reflect hurricane impacts. There were no treatment dependent differences in canopy composition at the lower level, but in the upper stratum, natives and non-natives showed significantly higher representation in the control and treatment blocks, respectively.

Discussion

The results indicate that hand-pulling of air potato stems is effective at removing young plants over the short-term. Plants that reach heights above 1 m apparently are able to resprout from tubers and reach similar heights within a year after treatment. However, the majority of the stems are derived from bulbils in the litter that had not sprouted prior to the initial treatment and not from resprouting tubers. Additionally, the results are influenced by significantly higher numbers of stems in the 0-1 m height class than in higher classes (see Table 2). Interestingly, there were no differences between the two removal treatments in affecting air potato numbers or cover. While these results need to be interpreted in the context of the hurricane disturbance, it appears that if treatments are not intended to be repeated in a particular site, herbicide use following hand-pulling is no more effective than hand-pulling alone.

Responses of other species to the treatments in the sites are difficult to evaluate. We believe that the length of this experiment and the confounding effects of the hurricane preclude conclusions. We found no evidence that the single Roundup treatment had negative impacts on the species richness of either native or non-native species as compared to the control or the hand-pulled treatments. The treatments appeared not to create a disturbance such that native species were lost or non-natives became dominant. Any shifts in species composition are more likely due to the hurricane than to the treatments. For example, the increase in non-native species representation in the canopy may have been facilitated by the hurricane, as the predominantly native larger trees may have been the most significantly impacted. It is possible that, without control, one long-term effect of Hurricane

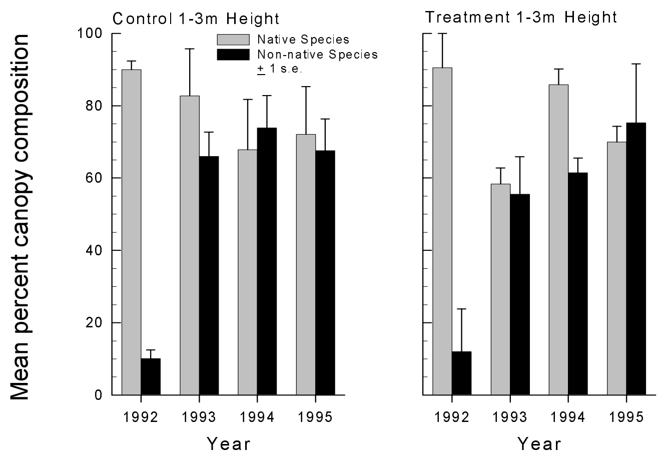

Figure 8. Percent canopy composition of native and non-native species in the 1–3 m stratum for the control and *Dioscorea bulbifera* removal treatment plots; means are across all three sites.

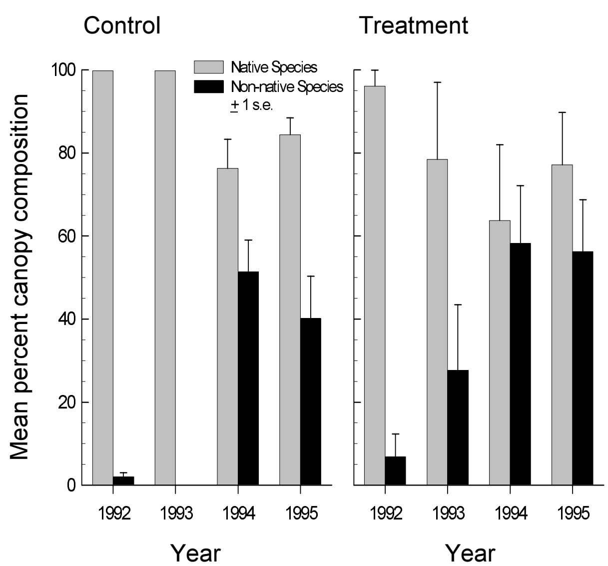

Figure 9. Percent canopy composition of native and non-native species in the greater than 3 m stratum for the control and *Dioscorea bulbifera* removal treatment plots; means are across all three sites.

Andrew will be to shift the canopy species dominance to non-native species.

The results indicate no differences in the effectiveness or effects of the hand-pulled or herbicide treatments on air potato or the tropical hardwood hammocks. However, recovery of the density and cover of this invasive exotic species was slower in the treatment plots than in the controls. Rate of increase in the abundance of air potato was, therefore, greater in the control plots. As a result, post-hurricane management of this invasive species could be more difficult in areas in which no species control efforts had been conducted prior to this event than in those where this and other species had been removed.

Recommendations

This study suggests that an initial non-native species control treatment in these hammocks results in a significant sprouting of air potato bulbils in the litter layer. As a result, we recommend that any plan to control this species incorporate at least two hand-pulling treatments per year, separated by four to six weeks. Our data indicate that this double hand-pulling of stems is a fairly effective control method over the short-term, with no additional gain of using chemical control with Roundup. However, we were unable to determine whether the herbicide would be more effective in killing the plants that continued to resprout from tubers than was the double hand-pulling treatment in this experiment. As removal of these continuing sources of bulbils will be necessary for long-term effectiveness, further study of methods for killing these robust plants is indicated. Such methods might include repeated pulling, and the use of different herbicides and herbicide concentrations. Miami-Dade County Parks and Recreation Department staff report success in killing older plants using a basal application of 10% Garlon 4 in oil (S. Wells, pers. comm., 1996).

Clearly, however, hand-pulling or other control methods will be necessary on a continuing basis to remove newly sprouting plants. We recommend continued hand-pulling every four to six weeks until all sprouting plants have been removed. We also recommend that mechanical pruning and removal of all or most non-native plants and native vines be incorporated into the control efforts to maximize efficiency and effectiveness. The increased post-hurricane response of non-native species highlights the need to control non-native species. In the control blocks, three years post-hurricane, one of the effects of air potato appears to be to impede the recovery of vertical canopy cover. The vine is creating and maintaining gaps in the tropical hardwood forest canopy, changing ecological conditions and community structure. Similar post-hurricane observations were documented for other vine species (*Jasminum* spp.) in southern Florida subtropical hammocks (Horvitz et al. 1995). Thus, these non-native vines appear to modify the resilience of this community to hurricanes, an impact that may have long-term implications for community maintenance if non-natives are not controlled.

Acknowledgements

This work could not have been accomplished without the technical assistance and support of the Miami-Dade County Parks and Recreation Department, Miami-Dade County Department of Environmental Resources Management, Florida State Parks within the Department of Environmental Protection, and Ecohorizons, Inc. Other individuals, including Joe O'Brien and Cynthia Olmstead, assisted with field data collection and data analysis, respectively. Use of registered trademark names, e.g., Roundup, Garlon 4, throughout this paper does not constitute product endorsement by either the authors or their affiliated organizations.

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