TAME Melaleuca

Inventory and Assessment Component

FINAL REPORT

Agreement No. 58-6629-2-0204

The Areawide Management and Evaluation of Melaleuca (TAME)

Inventory and Assessment Component

Boise State University

Department of Geosciences

Boise, ID

Chief Investigator: Amy Ferriter

Time period covered: Begin 9/06/2002, End 04/30/2007 (amended to 09/06/2007)

Summary

The development of effective and coordinated noxious weed management strategies at the national, regional, and local level depends upon accurate information concerning the extent, distribution, composition, and dynamics of populations of the problem species. Spatial data on melaleuca has been collected in Florida since the inception of the Melaleuca Management Program in the early 1990s. Aerial Systematic Reconnaissance Flights (SRFs) to monitor the distribution of the species have been conducted biannually since 1993 (Ferriter et al. 2005). This data has been valuable in establishing long term trend information and documenting the success of agency-sponsored herbicide and biological control programs for melaleuca.

TAME Melaleuca conducted baseline assessments of melaleuca populations in other areas of the world where melaleuca is nonindigenous. SRF flights were augmented in Florida to include the entire range of the plant in the state. In addition to the SRF surveys, a Digital Aerial Sketchmapping Pilot Project was flown for the Everglades area in 2005. In 2004, SRF surveys were flown in the Western Bahamas to determine the extent of the species on those islands and provide cost estimates for various control methods. Like Florida, melaleuca was also widely planted in the state of Hawaii. In the 1930s, an estimated 1.7 million trees were planted on the islands as part of Federal forestation efforts. Historical planting records were obtained and analyzed geographically. Spreading melaleuca populations on the island of Hawaii were evaluated as part of the TAME Melaleuca project.

A herbaria search of more than 70 herbaria in 20 countries augmented the available distribution data for melaleuca worldwide. The SRF survey data and the worldwide herbaria distribution data was consolidated in a Web-accessible spatial database that is available through the TAME Melaleuca website. Maps and shapefiles from Florida (1993-2007), Bahamas (2004) and Hawaii (2006) SRF flights were made available for download from the SRFer mapserver site.

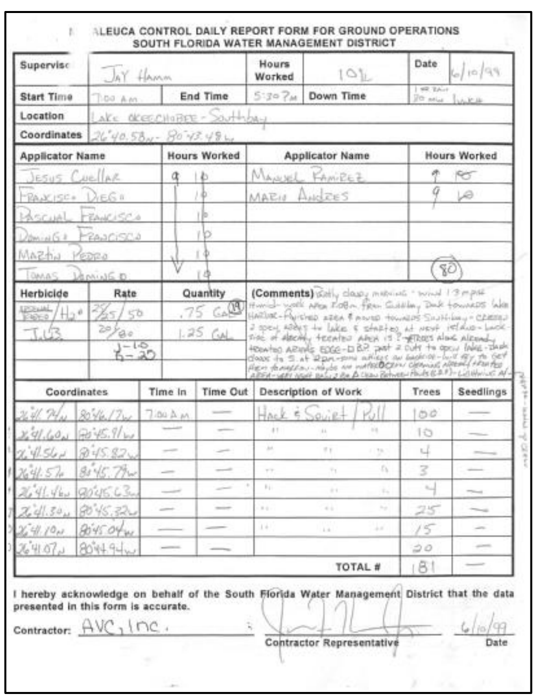
Description of Work Carried Out

The development of effective and coordinated noxious weed management strategies at the national, regional, and local level depends upon accurate information concerning the extent, distribution, composition, and dynamics of populations of the problem species. The South Florida Water Management District and the Department of Interior have been collecting various data associated with the distribution and control of Melaleuca since 1990. The objectives of the Geographical Assessment component of the TAME Melaleuca Project were to: 1) collect and consolidate all known spatial data on the occurence and control of melaleuca in Florida and develop a Web-searchable database of available spatial information. 2) Use historical (1990- present day) survey and ground-based control data to analyze trends in Florida's melaleuca population on public and private lands and 3) Determine the range of introduced melaleuca outside Florida and provide a Web-based database of its occurrence, density and introduction date, if known.

Results Obtained

Digitization of Past Control Efforts

In South Florida, control efforts have been underway against melaleuca and other exotic plant species for many years. Much of the work conducted prior to 2007 was recorded on hard copy treatment forms, sometimes with GPS coordinates and many times without. In 2007, these hard copy control treatment records were obtained from the South Florida Water Management District and the National Park Service. 13,269 sheets were scanned, and the resulting images stored on DVD. Virtually all of the information recorded on the data sheets was handwritten (**Figure 1**). The best scanning software


ALEUCA CONTROL DAILY REPORT FORM FOR GROUND OPERATIONS
SOUTH FLORIDA WATER MANAGEMENT DISTRICT

Supervis	JAY Hamm	Hours Worked	10½
Date	6/10/99		
Start Time	7:00 AM	End Time	5:30 PM
Down Time	[illegible]		
Location	LAKE OKEECHOBEE - Southbay		
Coordinates	26°40.58N - 80°43.48W		

Applicator Name	Hours Worked	Applicator Name	Hours Worked
JESUS CUELLAR	10	MANUEL RAMIREZ	10
FRANCISCO DIEGO	10	MARIO ANDRES	10
PASCUAL FRANCISCO	10		
DOMINGO FRANCISCO	10		
MARTIN PEDRO	10		
TOMAS DOMINGO	10		(80)

Herbicide	Rate	Quantity
[illegible]/H2O	2/25/50	.75 GAL
JLB	20/80	1.25 GAL
	J-10 B-20	

(Comments) [illegible]

Coordinates		Time In	Time Out	Description of Work	Trees	Seedlings
26°41.74N	80°46.17W	7:00 AM	—	Hack & Squirt / Pull	100	—
26°41.60N	80°45.91W	—	—	" " "	10	—
26°41.56N	80°45.82W	—	—	" " "	4	—
26°41.57N	80°45.79W	—	—	" " "	3	—
26°41.46N	80°45.63W	—	—	" " "	4	—
26°41.30N	80°45.32W	—	—	" " "	25	—
26°41.10N	80°45.04W	—	—	" " "	15	—
26°41.07N	80°44.94W	—	—		20	—
				TOTAL #	181	—

I hereby acknowledge on behalf of the South Florida Water Management District that the data presented in this form is accurate.

Contractor: AVC, Inc. Contractor Representative 6/10/99 Date

Figure 1. Sample scanned treatment sheet.

available in 2007 was unable to convert handwritten material presented in various ways on different forms into accurate, typed data. Consequently, the information stored on the data sheets had to be hand-entered into spreadsheets. This resulted in the creation of 60,611 treatment records. Prior to this project, the National Park Service had already stored 17,222 records of their own treatment data in spreadsheets. Their data was added to the hand-entered data, resulting in a total of 77,833 records. Much of the hard copy data reported multiple species per record, so while there were 77,833 records total, these represent far more than 77,833 individual infestations. 59,210 records identify infestations of melaleuca. A summary of select data can be found in **Table 1**.

Table 1. Select melaleuca treatment data summarized by year. Data are not representative of all treatments conducted, only treatments recorded on hard copy sheets.

Year	Records	Stems treated	Seedlings treated	Acres treated
1984	122	92,574		
1985	87	32,520		
1986	23	20,707		
1987	157	589,702		
1988	83	273,342		
1989	207	275,888		
1990	86	121,750		
1991	125	126,485		
1992	110	457,965		
1993	4,588	1,714,035	4,003,903	
1994	3,572	3,120,485	3,665,037	
1995	981	1,158,528		
1996	3,054	3,967,290	25,500	
1997	643	478,791		
1998	2,519	1,054,380	191,892	2,190
1999	4,379	1,335,217	384,967	1,193
2000	5,216	1,386,908	205,046	
2001	9,259	1,229,330	535,634	5
2002	7,377	2,603,260	1,435,520	17
2003	8,642	3,690,299	2,523,692	3
2004	6,004	2,660,322	1,170,191	9,480
2005	1,464	1,277,439		2,975
2006	512	191,174		
Total	**59,210**	**27,858,391**	**14,141,382**	**15,863**

Those records with coordinates included were converted into shapefiles so they could be visualized using a Geographical Information System (ArcMap 9.2). These were then checked for accuracy using major geographic features as a backdrop and altered when the need arose. Records with no coordinates included were still geo referenced by assigning coordinates obtained from the center of the project area. All records, now successfully geo referenced, were combined within a Geographical Information System (**Figures 2** and **3**).

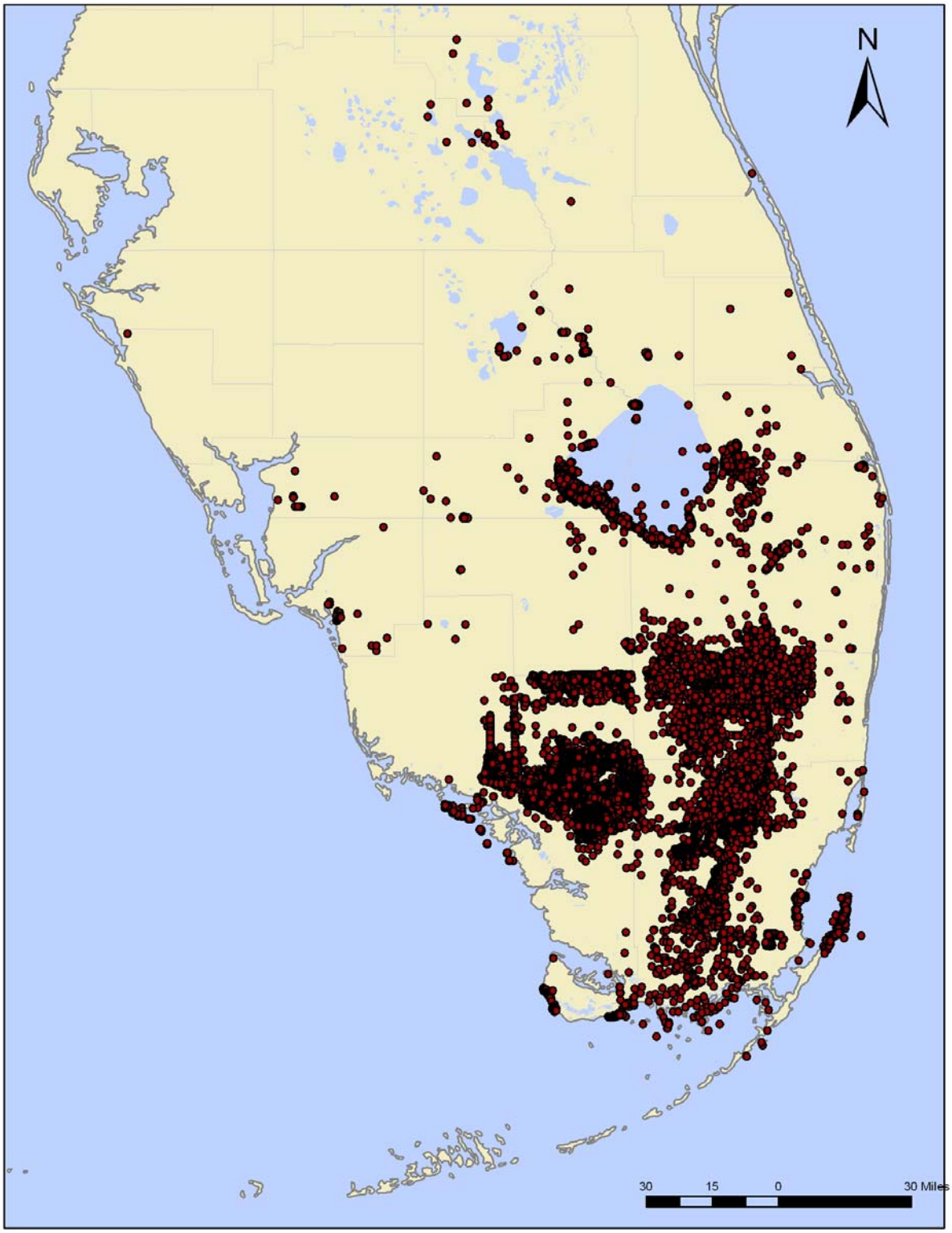


Figure 2. All exotic plant treatments recorded on scanned data sheets (1985-2006).

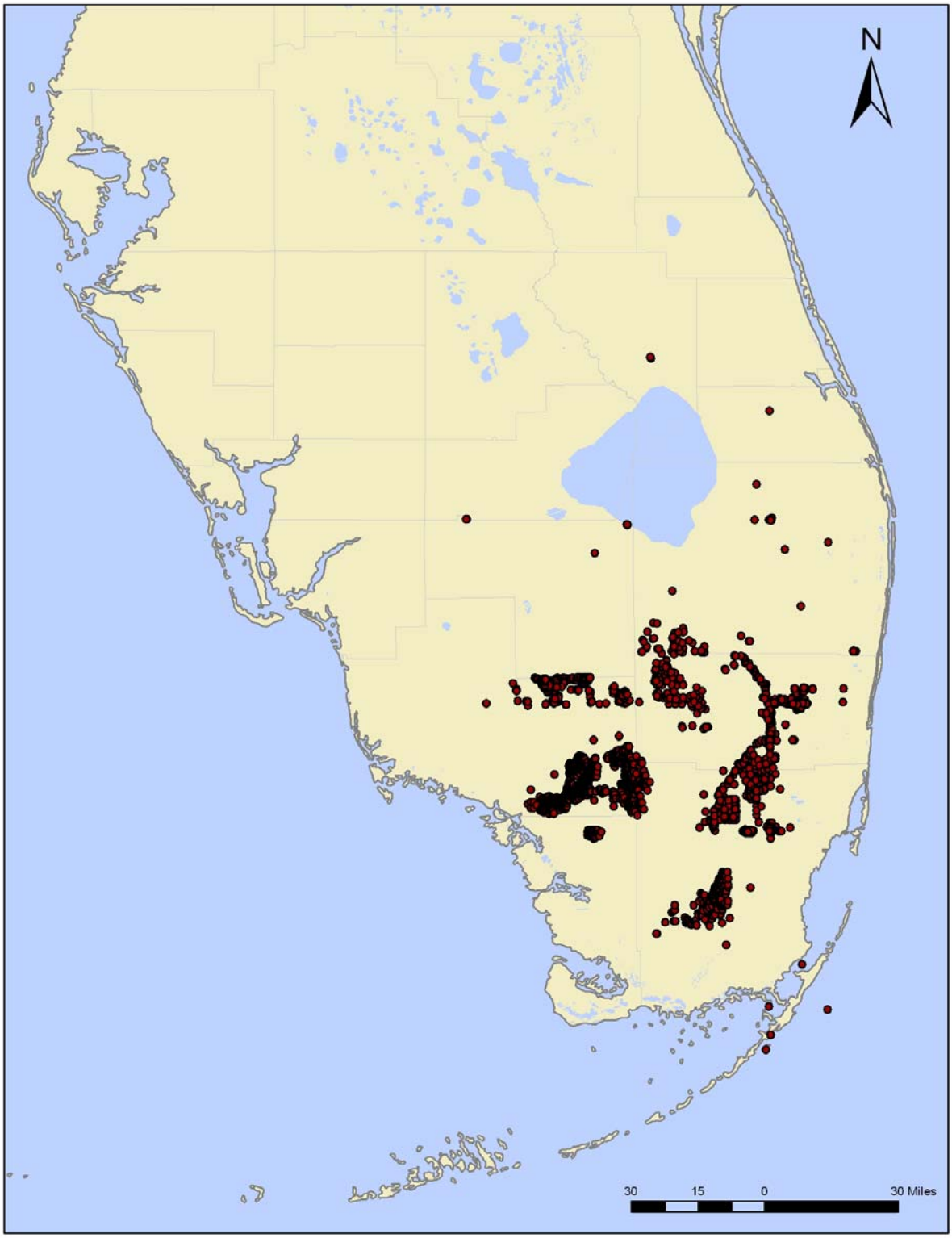


Figure 3. Sample melaleuca treatments recorded on scanned data sheets (2004).

These records have already proven, and will continue to prove, very useful for land managers across South Florida and elsewhere interested in tracking the progress and effectiveness of various control methods against melaleuca and other exotic plant species. The data that resulted from this project can be queried out or separated by species, year, treatment method, size of treatment area, and contractor. By combining this information with infestation data collected during Systematic Reconnaissance Flights, it is possible to track the effectiveness of treatments. Land managers can note areas of concentrated treatment efforts and determine if those infestations increased, decreased, or stayed the same in subsequent years. In this manner, it is possible to determine the most effective treatment method and the optimal time of year for that treatment method across the various ecological zones present in South Florida.

Systematic Reconnaissance Flights

Before large scale control operations were initiated in Florida, the general distributions of exotic plants were not well-documented. To address the issues related to ongoing invasive species monitoring and in an effort to gather long-term trend information for these species, the South Florida Water Management District began using biannual Systematic Reconnaissance Flights (SRFs) to survey the region. The purpose of these flights is to use an inexpensive method to track broadscale trends in target invasive plant distributions - specifically *M. quinquenervia*, *Casuarina* spp., *S. terebinthifolius* and *L. microphyllum* (Cav.) R. Br. SRFs are widely used by the US Forest Service to inventory timber and detect insect pests in large forested areas. The National Park Service uses this methodology to target exotic plant control operations. Wildlife biologists also use the method to track animal species such as deer, marine mammals (Quang and Becker, 1999), elephant (Foley, 2002) bear (Barnes and Smith, 1997) and wading birds (Gawlik, 1999; Russell et al. 2001). While specific methodologies vary based on project objectives, the general approach is that an aircraft flies at a fixed height and speed across a study area on a predetermined transect while observers count targets (plants or animals) in a strip of land on either side of the aircraft (**Figure 4**). The South Florida invasive plant surveys have been flown consistently from 1993 to 2007. This project has provided the only long term trend data available for these species, documenting the rapid expansion of *L. microphyllum* in the Everglades and the effectiveness of robust agency-sponsored control operations for Melaleuca.

Figure 4. GPS used to record exotic infestations during SRF surveys.

The initial SRF survey for *Melaleuca quinquenervia* in Southern Florida was conducted by the United States Forest Service in 1980 (Cost and Craver, 1980). This survey was initiated by the USFS to estimate forested and non-forested land cover in the area south of Lake Okeechobee. As part of this work, the researchers measured the extent of melaleuca coverage and densities. This survey was conducted

before the use of GPS technology was available to the general public. Paper maps were used to record information along transect lines. The transects were spaced 2.5 miles apart, east and west across the southern part of the state of Florida. The data derived from this survey was valuable in documenting the problems associated with melaleuca in the Everglades, and helped legitimize the issue in the State.

In the early 1990s, the South Florida Water Management District and the National Park Service began conducting independent, parallel SRF surveys for exotic plants in the region. The District surveys covered the entire peninsula south of the north rim of Lake Okeechobee. The transects were modeled after the USFS 1980 survey and were spaced at 2.5 mile intervals, east and west across the state. The Park Service surveys focused on National Park lands in the region. The transects were finer - 1 km apart - and observers deviated from the transect when they encountered exotic plant populations (**Figure 5**). Both surveys recorded both plant species and density classifications. In 1999, the District and the Park Service began collaborating in conducting the bi-annual surveys. The surveys are now nested - the District survey uses 4 kilometer transects, and the Park Service uses 1 km transects – and the transects overlap on Park Service lands.

Figure 5. Grand Bahama island monoculture along beach

Through the TAME Melaleuca project, the District and the National Park Service were able to extend the boundaries of the ongoing South Florida SRF program to include the majority of the range of Melaleuca (north to Gainesville) in Florida and the Bahamas (**Figure 6**). Results of the Florida and Bahamas SRF surveys are shown in **Figure 7** and **8**, respectively.

Figure 6. Bahamas survey team

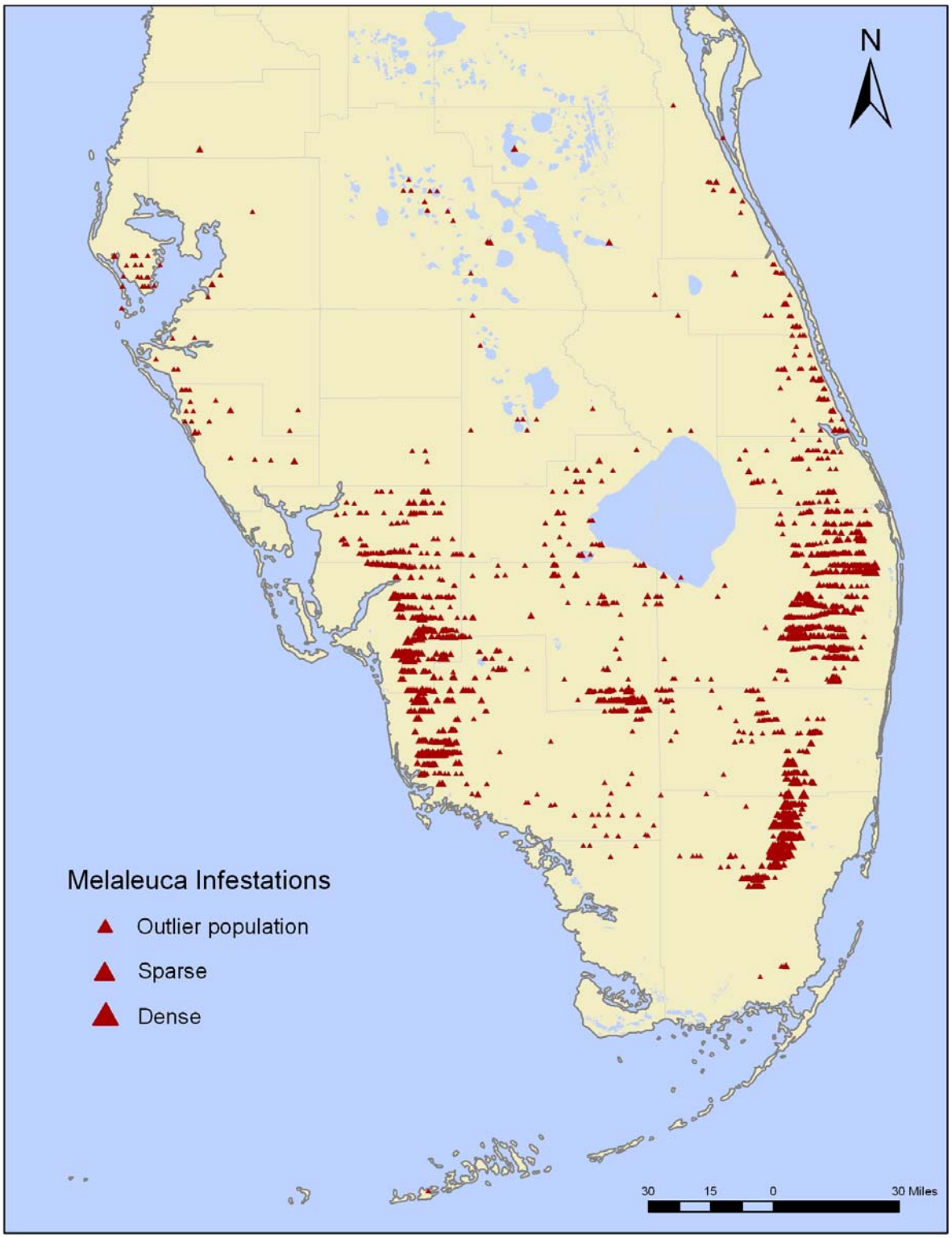


Figure 7. Melaleuca infestations in South and Central Florida, recorded during 2006/2007 SRFs

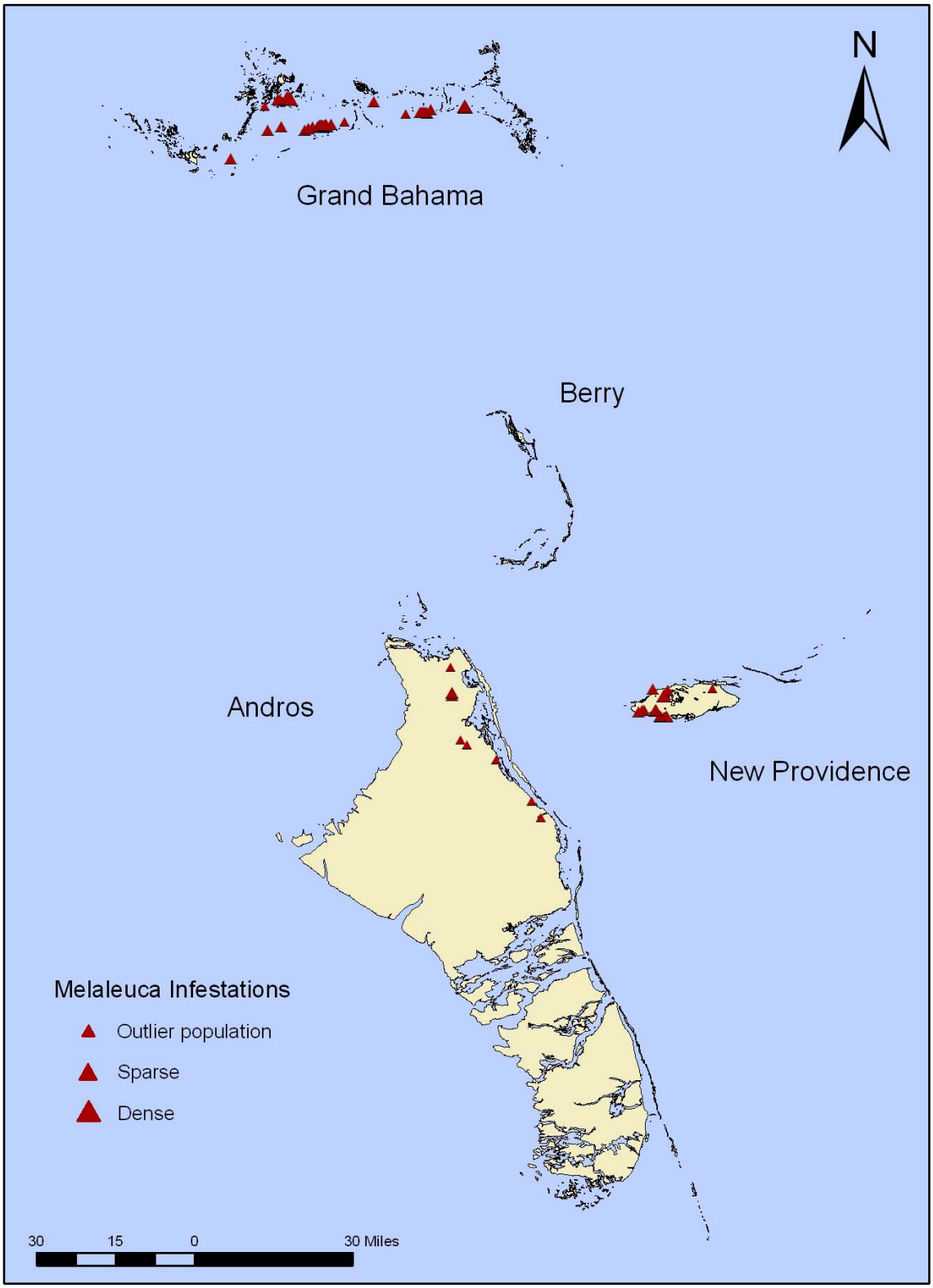
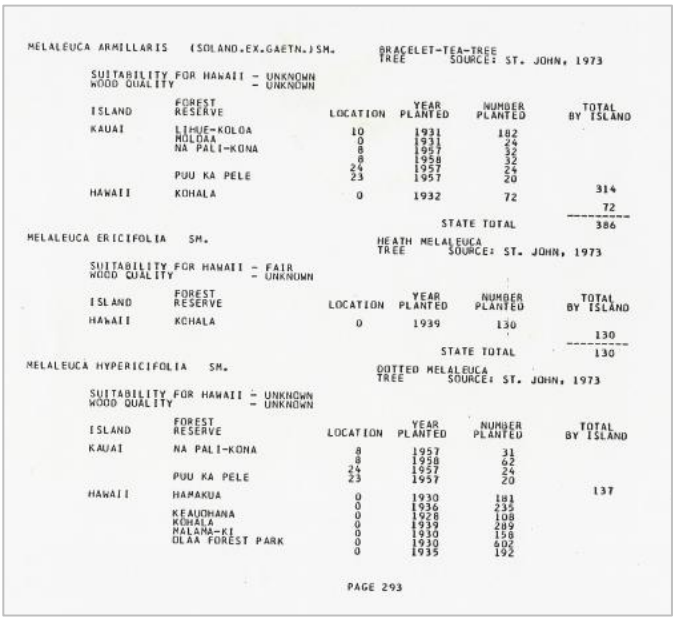


Figure 8. Melaleuca infestations in the Bahamas, recorded during 2004 SRFs

Hawaii Historical Melaleuca Plantings and SRFs

At least 6 separate Melaleuca species were planted in Hawaii from 1917-1958. Historical planting records were obtained in paper format (**Figure 9**). These records indicated the number of trees planted by year for individual Hawaiian Forest Reserves. Some planting records included a "location name" within the Forest Reserve. USGS Quad sheets were used to refine planting locations using local names, where possible. These planting site locations were estimated and a shapefile was produced to display original plating locations through time on all Hawaiian Islands (**Figure 10**). Total number of *Melaleuca quinquenervia* planted from 1917-1958 was 1,730,942 (**Table 2**). Many of these original planting sites are still evident, and *M. quinquenervia* is spreading from these original planting sites. Systematic Reconnaisance Flights were flown on the island of Hawaii in October, 2006 to document the occurrence of *M. quinquenervia* in original planting sites and beyond, illustrating its ability to spread in this environment (**Figure 11**). All SRF data for Florida, Hawaii and the Bahamas was made available for download on the TAME Melaleuca SRFer website. As of October, 2007, there were 4,126 visitors to the TAME SRFer mapserver (**Figure 12**). A total of 248 individuals downloaded GIS SRF shapefiles from the mapserver.



MELALEUCA ARMILLARIS (SOLAND.EX.GAETN.) SM. BRACELET-TEA-TREE
TREE SOURCE: ST. JOHN, 1973

SUITABILITY FOR HAWAII - UNKNOWN
WOOD QUALITY - UNKNOWN

ISLAND	FOREST RESERVE	LOCATION	YEAR PLANTED	NUMBER PLANTED	TOTAL BY ISLAND
KAUAI	LIHUE-KOLOA	10	1931	182	
	MOLOAA	0	1931	24	
	NA PALI-KONA	8	1957	32	
		8	1958	32	
	PUU KA PELE	24	1957	24	
		23	1957	20	
					314
HAWAII	KOHALA	0	1932	72	72
			STATE TOTAL		386

MELALEUCA ERICIFOLIA SM. HEATH MELALEUCA
TREE SOURCE: ST. JOHN, 1973

SUITABILITY FOR HAWAII - FAIR
WOOD QUALITY - UNKNOWN

ISLAND	FOREST RESERVE	LOCATION	YEAR PLANTED	NUMBER PLANTED	TOTAL BY ISLAND
HAWAII	KOHALA	0	1939	130	130
			STATE TOTAL		130

MELALEUCA HYPERICIFOLIA SM. DOTTED MELALEUCA
TREE SOURCE: ST. JOHN, 1973

SUITABILITY FOR HAWAII - UNKNOWN
WOOD QUALITY - UNKNOWN

ISLAND	FOREST RESERVE	LOCATION	YEAR PLANTED	NUMBER PLANTED	TOTAL BY ISLAND
KAUAI	NA PALI-KONA	8	1957	31	
		8	1958	62	
	PUU KA PELE	24	1957	24	
		23	1957	20	
					137
HAWAII	HAMAKUA	0	1930	181	
	KEAUOHANA	0	1936	235	
	KOHALA	0	1928	108	
	MALAMA-KI	0	1939	289	
	OLAA FOREST PARK	0	1930	158	
		0	1930	402	
		0	1935	192	

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Figure 9. Sample USFS Planting sheet

Table 2. Historical melaleuca plantings in Hawaiian Forest Reserves (1917-1958)

Species	*Number of Trees Planted*						*Years planted*
	Hawaii	Kauai	Maui	Molokai	Oahu	**Total**	
Melaleuca spp.	297					**297**	1928
M. armillaris	72	314				**386**	1931-1958
M. ericifolia	130					**130**	1939
M. hypericifolia	1,938	137				**2075**	1928-1958
M. parviflora	20					**20**	1932
M. quinquenervia	233,539	123,666	819,515	47,392	506,830	**1,730,942**	1917-1958
M. stypheloides	1,125	713				**1,838**	1927-1939

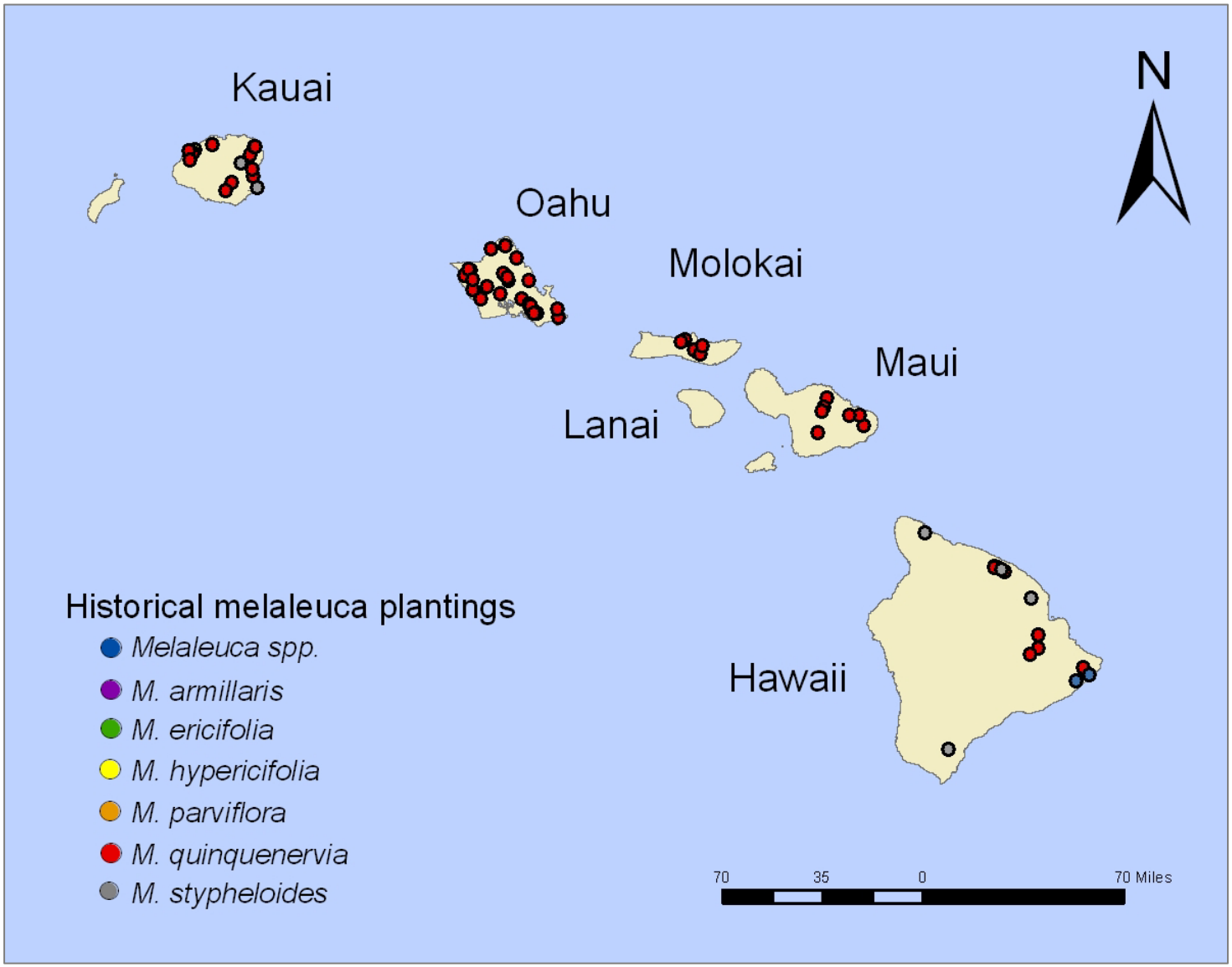

Figure 10. Historical melaleuca plantings in Forest Reserves (1917-1958). Many plantings not visible because multiple species often planted at same site (symbols overlap)

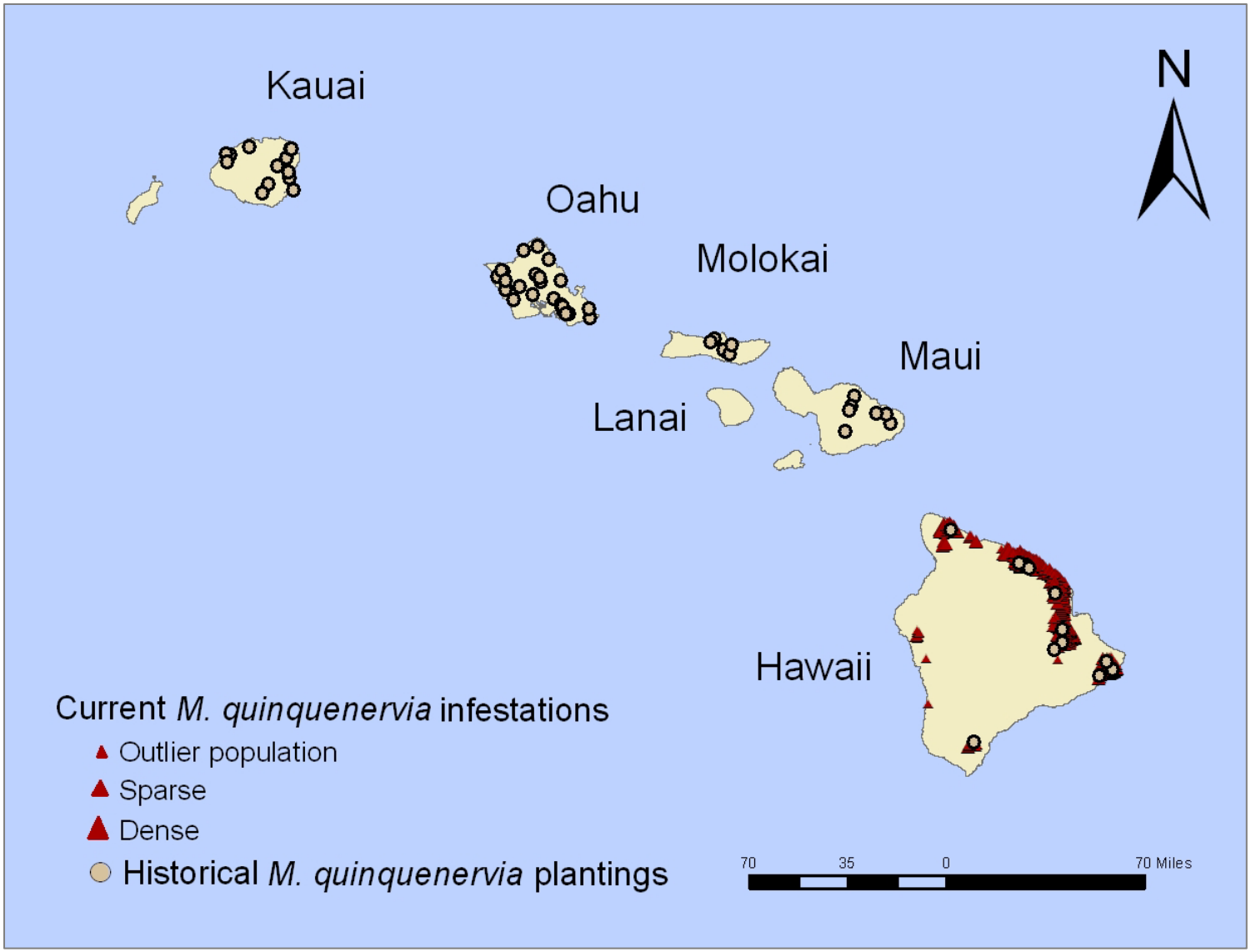

Figure 11. Melaleuca infestations in Hawaii (recorded during 2006 SRFs) and historical *Melaleuca quinquenervia* planting sites

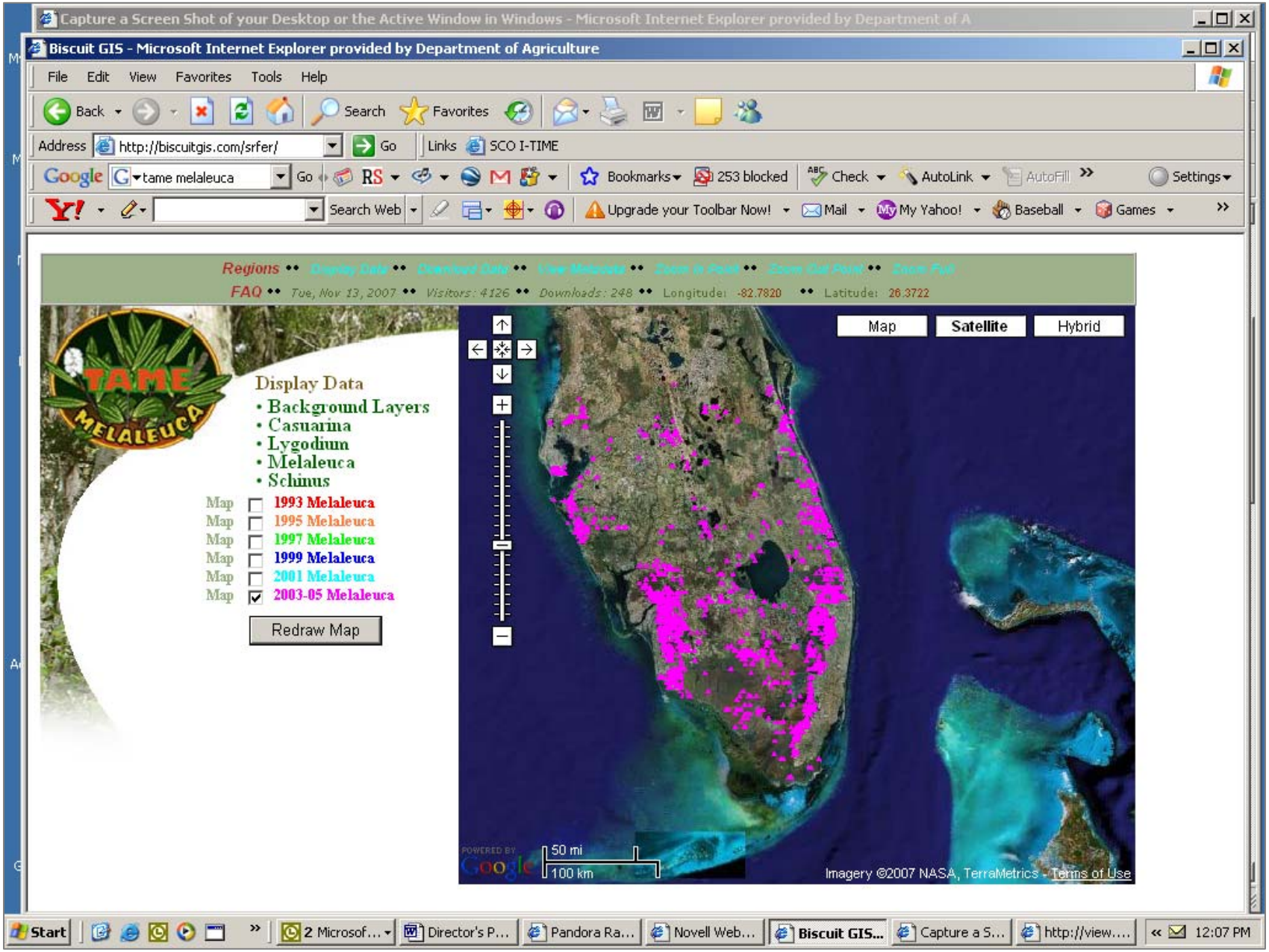

Figure 12. TAME Melaleuca SRFer mapserver website

Sketchmapping

In 2005, TAME Melaleuca funding also allowed the District and the National Park Service to conduct a pilot project to evaluate the use of US Forest Service Digital Aerial Sketchmapping (DASM) technologies to track melaleuca and other invasive plants in the Greater Everglades. This technology was developed by the US Forest Service to provide a tool for tracking forest health. It combines the use of trained observers and mobile maps - allowing observers to use high resolution images as a background while they "sketch" observations onto a digital map (**Figure 13**). Results of this pilot project are still being evaluated for future use in lieu of or in conjunction with the ongoing District/NPS SRF program.

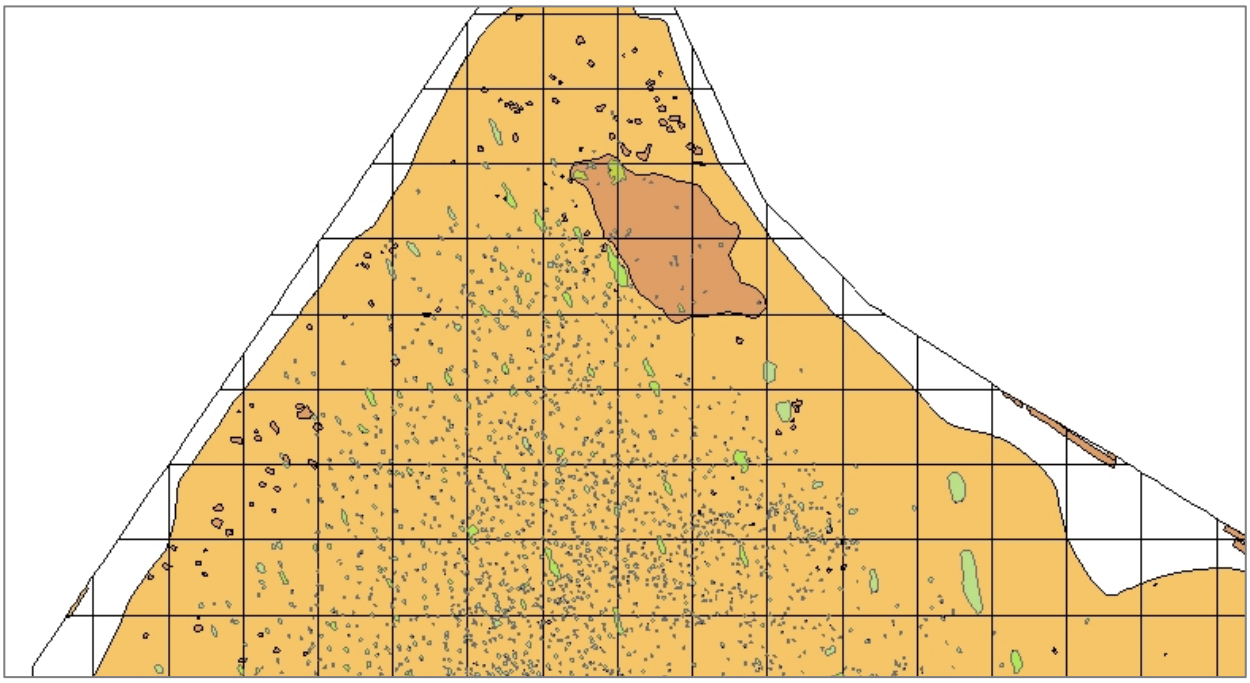

Figure 13. Sketchmap of northern portion of Loxahatchee National Wildlife Refuge

Systematic Reconnaissance Flights Data Analyses

The SRF data are useful for identifying where infestations of exotic plant species are across South and Central Florida, the size of those infestations, and how those change over time as observational flights are repeated. Performing additional analyses have made these data even more useful and informative. South Florida is a very diverse region ecologically, and can be divided into 8 major ecological zones or modules. Invasive species infestations may behave differently and follow different trends in these various modules. In order to explore this idea further, it was necessary to overlay a grid on top of South Florida so that various trends could be adequately determined given a set unit area. Two grid systems were devised for this; cells either measured 12 by 12 kilometers, or 8 by 8 km (**Figure 14**).

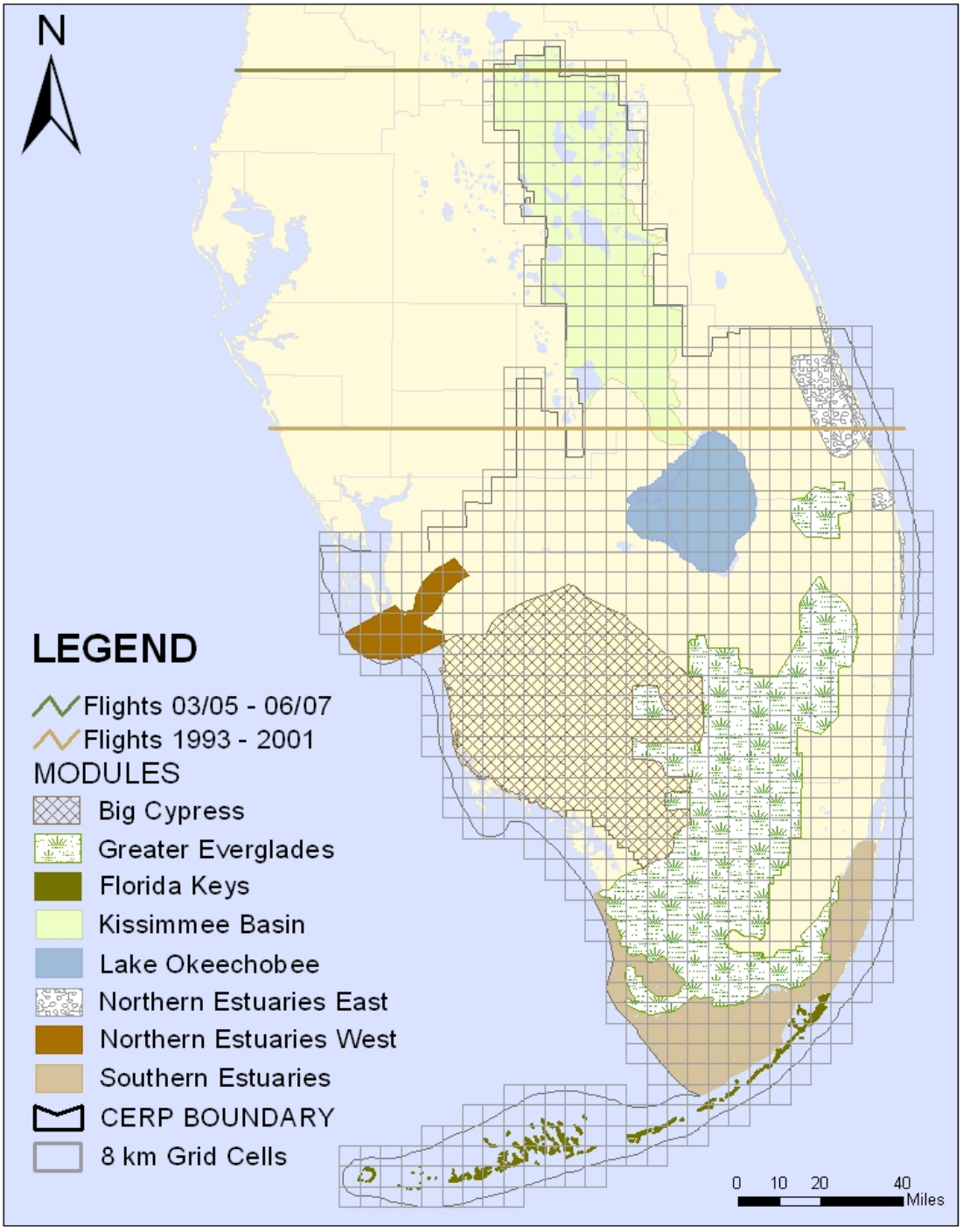

Figure 14. 8 x 8 km grid cell overlaid upon map of Florida Modules. Horizontal "flights" lines represent northern boundaries of Systematic Reconnaissance Flights in respective years.

For each grid cell, the total number of possible flight observations was combined with actual infestations observed for each species (**Figure 15**) and graphed over multiple years using regressions. Resulting graphs help explain, visually, the trends of invasive plant infestations in various regions of South Florida (**Figure 16**). Although this project is concluding, we hope to continue utilizing the resulting data. Our next project entails adding land use into the equation to determine if that variable has an influence on infestation characteristics in each grid cell and Module.

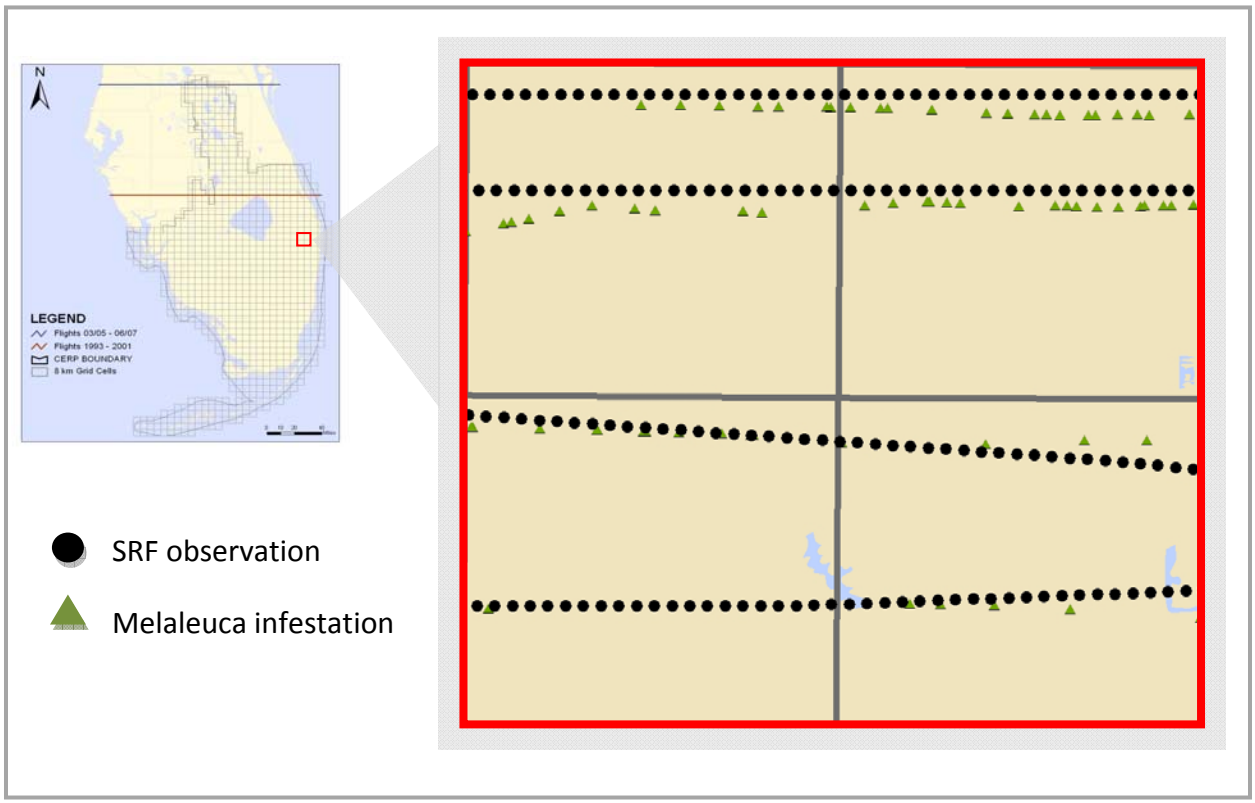

Figure 15. Enlargement of four 8 x 8 km grid cells demonstrating observations and infestations

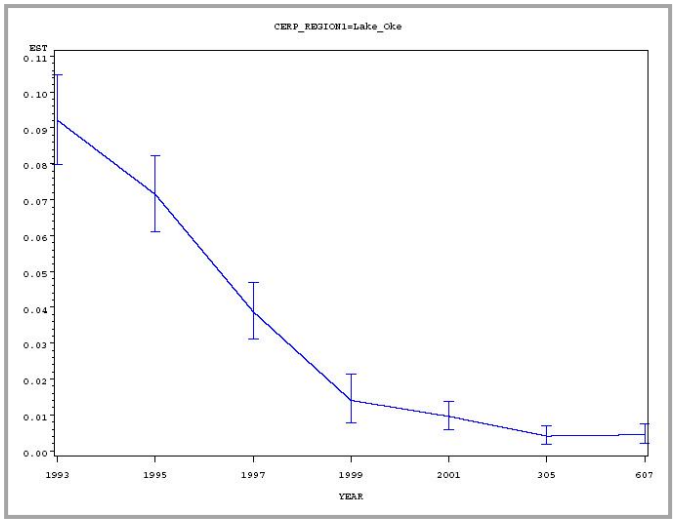

Figure 16. Sample regression showing trends of Melaleuca in the Lake Okeechobee Module from 1993 to 2006/2007

Worldwide Herbaria Search

Qualified plant taxonomists studied all herbaria material outside *Melaleuca quinquenervia*'s native range to document range and verify identifications. As part of this project, regional and major herbaria were searched for collections in Florida, Louisiana, Texas, California, Hawaii, Puerto Rico, and the Bahamas, and other applicable areas of the Caribbean. TAME Melaleuca also communicated between individuals who are monitoring melaleuca outside Florida and used cooperators in the Caribbean to document *Melaleuca quinquenervia* populations in that region and elsewhere (**Table 3**). This data was compiled in an Access database and is presented visually in **Figure 17**.

Table 3. Herbaria surveyed for specimens of *Melaleuca quinquenervia*

Herbarium Name	State	Country
Nassau Botanical Gardens, Bahamas		Bahamas
Embrapa Amazônia Oriental		Brazil
Fundação Zoobotânica do Rio Grande do Sul		Brazil
Instituto Anchietano de Pesquisas/UNISINOS		Brazil
Instituto de Botânica		Brazil
Instituto Nacional de Pesquisas da Amazônia		Brazil
Jardim Botânico do Rio de Janeiro		Brazil
Museu Paraense Emílio Goeldi		Brazil
Universidade de São Paulo		Brazil
Universidade de São Paulo		Brazil
Universidade Estadual de Campinas		Brazil
Universidade Federal de Minas Gerais		Brazil
Universidade Federal de Ouro Preto, Campus Universitário		Brazil
Universidade Federal do Rio de Janeiro		Brazil
Universidade Federal do Rio de Janeiro		Brazil
Universidade Federal do Rio Grande do Sul		Brazil
Universidad de Antioquia		Colombia
Universidad Nacional de Colombia		Colombia
Instituto Nacional de Biodiversidad, Costa Rica		Costa Rica
Museo Nacional de Costa Rica		Costa Rica
Universidad de Costa Rica		Costa Rica
Academia de Ciencias, Cuba		Cuba
Centro de Investigaciones de Medio Ambiente, Cuba		Cuba
Jardin Botanico Nacional, Cuba		Cuba
Jardin Botanico Nacional Dr. Rafael Moscoso, Dominican Republic		Dominican Republic
Royal Botanic Gardens, Kew, England		England
The Natural History Museum, England		England
Muséum National Histoire Naturelle		France
Institut de Recherche pour le Developpement, French Guiana		French Guiana
University of Guyana		Guyana

Table 3. (continued)

Herbarium Name	State	Country
Escuela Agricola Panamericana, Honduras		Honduras
Universidad Nacional Autonoma de Honduras		Honduras
Instituto Politecnico Nacional, Mexico City, Mexico		Mexico
Universidad Nacional Autonoma de Mexico		Mexico
Herbario Nacional de Nicaragua		Nicaragua
Universidad Nacional Autonoma de Nicaragua		Nicaragua
Universidad de Panama		Panama
National Museum, Philippines.		Philippines
University of the Philippines Los Baños		Philippines
University of Suriname		Surinam
Conservatoire et Jardin botaniques de la Ville de Genève, Switzerland		Switzerland
Makerere University, Uganda		Uganda
Archbold Biological Station	Florida	USA
Bishop Museum, Hawaii	Hawaii	USA
Botanical Research Institute of Texas	Texas	USA
Fairchild Tropical Botanical Garden	Florida	USA
Field Museum of Natural History	Florida	USA
Florida Department of Agriculture and Consumer Services	Florida	USA
Florida Gulf Coast University	Florida	USA
Florida Southern College	Florida	USA
Florida State University	Florida	USA
Harvard University Herbaria	Massachusetts	USA
Louisiana State University	Louisiana	USA
Marie Selby Botanical Gardens	Florida	USA
Miami University, Ohio	Ohio	USA
Missouri Botanical Garden	Missouri	USA
National Tropical Botanical Garden, Hawaii	Hawaii	USA
New York Botanical Garden	New York	USA
Stetson University	Florida	USA
U.S. National Herbarium	Washington, DC.	USA
University of Central Florida	Florida	USA
University of Florida	Florida	USA
University of Hawaii	Hawaii	USA
University of South Florida	Florida	USA
Departamento de Recursos Naturales y Ambientales		USA- Puerto Rico
Puerto Rico Botanic Garden, University of Puerto Rico		USA- Puerto Rico
University of Puerto Rico, Mayaquez		USA- Puerto Rico
University of Puerto Rico, Rio Piedras		USA- Puerto Rico
Fundacion Instituto Botanico de Venezuela Dr. Tobias Lasser		Venezuela
Universidad Central de Venezuela		Venezuela

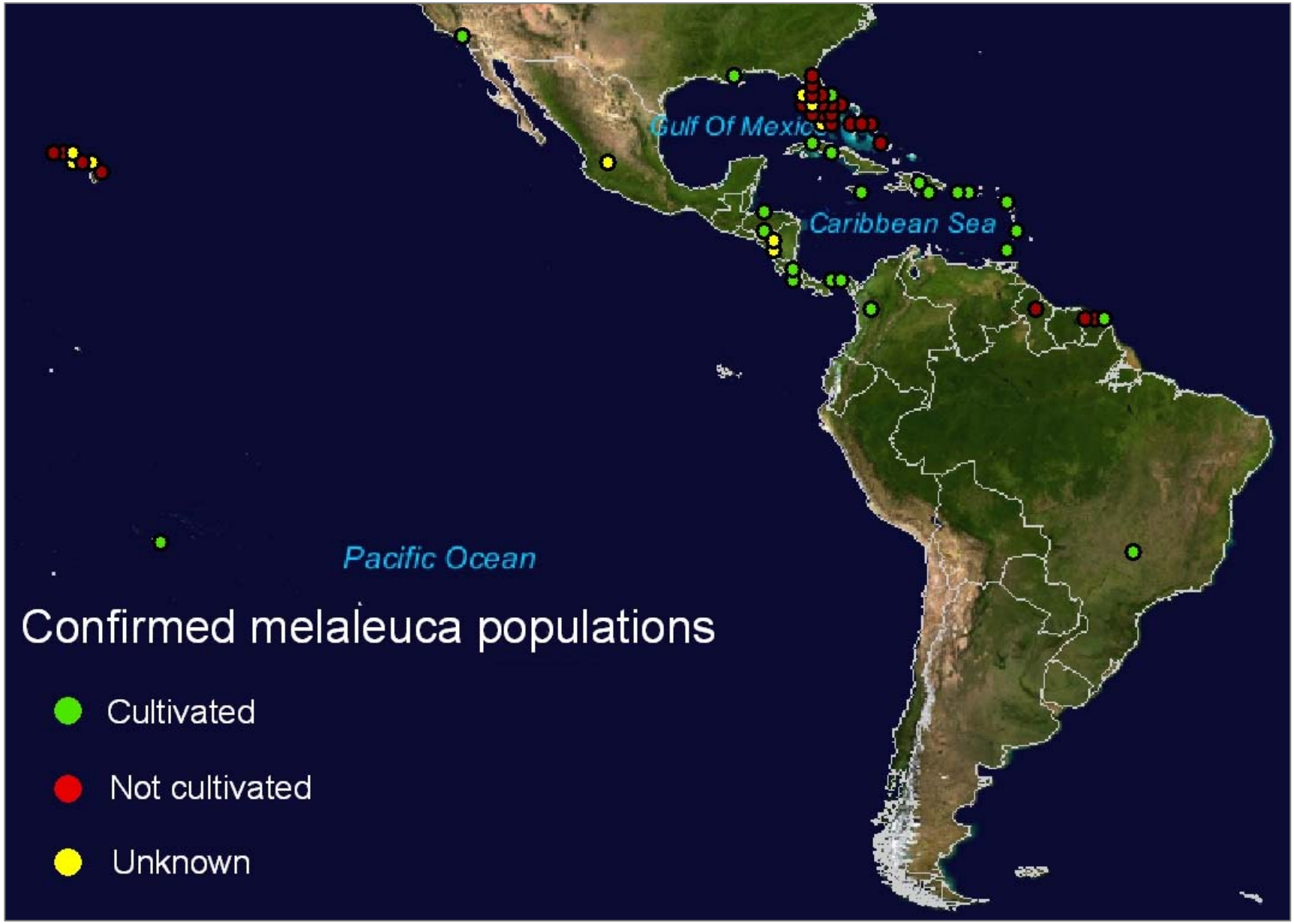

Figure 17. *Melaleuca quinquenervia* populations as confirmed by herbarium specimens

Publications

TAME Melaleuca – An Areawide Pest management Initiative *in* F. J. Espinosa-García, T. R. Van Devender, T. Hubbard, and B. L. Harper-Lore (eds.) Invasive Plants on the Move. Controlling them in North America, Univ. Arizona Press, Tucson. In Press.

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International melaleuca alerts

Anonymous. Undated. Weeds of Natural Areas: Melaleuca (*Melaleuca quinquenervia* (Cav.) Blake).

Anonymous. Undated. Melezas de las areas naturlaes del Caribe: Melaleuca (*Melaleuca quinquenervia* (Cav.) Blake).

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