

A Q U A P H Y T E

A NEWSLETTER ABOUT AQUATIC, WETLAND AND INVASIVE PLANTS

Center for Aquatic and Invasive Plants

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In the Classroom & In the Parks

A Teaching Package

About Non-Native Invasive Plants For Florida's Science Teachers and Park Biologists

For the first time, Florida's school students will be formally introduced to two subjects dear to our hearts: aquatic plants and invasive plants. Educational materials are being developed for teachers and students.

By the fall of 2006, based on what teachers will learn during in-service training conferences, we expect 800 science teachers to begin teaching these subjects to nearly 100,000 K-12 students per year. New Study Units, Lesson Plans, Labs and Activities will meet Florida's curricula requirements as defined in the "Sunshine State Standards and Benchmarks" and will be able to be folded into subject areas as diverse as environmental science, mathematics and even English composition.

A second focus of the initiative is workers in the state's 153 public parks and wild lands. Plant identification training is being offered to park biologists, rangers and lead volunteers; and educational materials, including regionalized plant identification fold-outs and other printed resources, are being created and printed for specific parks and regions.

These two programs are part of Florida's Invasive Plant Education Initiative, an effort of the Center for Aquatic and Invasive Plants (IFAS, University of Florida) and the Bureau of Invasive Plant Management (Florida Department of Environmental Protection). Vic Ramey (UF/IFAS) and Jeff Schardt (FDEP) are co-authors of the Initiative.

Using the expertise and source materials of UF/IFAS and FDEP, two award-winning curricula-writing teachers, Elaine Taylor and Cynthia Holland of the Alachua County School District (Florida), are authoring the teaching units, plans, labs and activities.

Publications experts Amy Richard and Emily Cunningham are producing printed educational materials such as plant ID guides to be given free to teachers, students, biologists, rangers, volunteers and tourists.

Web specialist Beth DeGroat is preparing the Initiative's web sites, which will feature interactive modules such as plant-knowledge card games; online coloring; crossword puzzles, prizes; etc.

All products of the Initiative are based on research found in the APIRS science library and online database; APIRS is the UF/IFAS collection of more than 65,000 science reports and books about aquatic plants and invasive plants. The APIRS collection is managed by Karen Brown, with cataloger Mary Langeland, and library specialists, Karen Marshall and Beth Noll.

This is the first year of Florida's Invasive Plant Education Initiative. With its success, we hope to continue the Initiative until every science teacher, every student, and every park biologist, ranger and docent volunteer are knowledgeable of the invasive plants in their areas, and have the resource materials necessary to help them identify, contain, control and prevent plant invasions in the natural areas of the Sunshine State.

Nearly 200 non-native plant species are invading Florida's natural areas, and more are being introduced. The trend won't be reversed until teachers and students, and park workers and visitors, know the issues, know the plants, and know what they can do to help save our wetlands and uplands.

VR



The Wetlands of Turuepano National Park, Orinoco Delta, Venezuela

by *Antonio Colonnello, Museo de Historia Natural La Salle, Caracas*
and *Walter Van Duzer*

The wetlands of Turuepano National Park are a landscape of exceptional beauty and are a part of the extensive strip of mangroves that runs along the northeastern coast of South America. The area is characterized by heterogeneous plant communities and is the habitat of a diverse and colorful bird population as well as for reptiles and mammals in danger of extinction, among them the manatee; it also contains valuable fish resources. The park is framed by courses of water that begin as small streams among mangrove roots and become channels of hundreds of meters wide in which tunas and occasionally dolphins may be observed. All of these factors make the park an excellent setting for nature tourism, environmental studies, and conservation.

Turuepano National Park is in the deltaic system of the Orinoco River, which is in the eastern coastal plains of Venezuela. These plains stretch from the Gulf of Paria in the north to the river San Juan in the south and occupy 508,886 ha. The delta is principally drained by the tidal channels named *Ajies*, *Turuepano*, *Guariquen*, and *La Palma*. The topography of the land in the park is similar to that elsewhere in the delta: the banks of the tidal channels are elevated and behind these banks the land is lower, so that islands in the delta have a characteristic bowl shape.

The vegetative communities of Turuepano National Park are largely determined by local geomorphology and topography. In higher areas which are not susceptible to flooding and which generally have mineral soils we see tall woody vegetation, while in the lower areas which are often flooded and whose soils are largely organic (at least on the surface), a herbaceous vegetation is typical. There is significant intrusion of salt water from the Gulf of Paria up the tidal channels of the delta, and this saline intrusion results in the colonization of halophytic vegetation along these channels almost to their sources in the delta. Thus mangroves of the genera *Rhizophora*, *Avicennia* and *Laguncularia* are common along these banks and occupy wide strips along the coast, for example around Turuepano Island; their density decreases higher in the tidal channels. Accompanying the mangroves are salt-tolerant herbaceous species such as the fern *Acrostichum aureum* and the reed *Rabdadenia biflora*. The salinity of the soil diminishes precipitously with any distance from the water, and thus non-halophytic species thrive in the interiors of the islands.

In areas where the salinity of the soil is low there are communities dominated by palms such as *Roystonea oleracea*, *Euterpe oleracea* y *Bactris*, and *Tabebuia rosea*. The giant arum *Montrichardia arborescens* grows in brush lands; this plant generally grows to be 2 or 3 meters high, but in certain conditions, for example in areas that have recently burned, it can reach a height of 6 or 7 meters. In these environments the water generally has a salinity of 3.4 PPT, a conductivity of 6210 ($\mu\text{S}/\text{cm}$), and a pH of 6.5.

In levees where the influence of the sea is stronger, the vegetation on the banks of the channels is a mangrove swamp with trees 15 to 20 meters high, in two strata. The swamp consists of a combination *Rhizophora mangle*, *R. harrisonii*, *R. racemosa*, *Avicennia germians* and *Laguncularia racemosa*, with the liliaceous plant *Crinum erubescens* growing in the lower strata. In the interior depressions of the islands there is a dense, permanently inundated shrubby swamp with plants 2 to 3 meters high. This community consists of woody and herbaceous species dominated by dogbane (*Rabdadenia biflora*) and the pteridophyte *Acrostichum aureum*, in addition to *Odontodia* sp., *Heteropterys orinocensis* with yellow flowers and the palm *Bactris* sp. Fires may change these communities so that they are dominated by Cyperaceae. In the lower areas grow the liliaceous plant *Crinum erubescens*. In these swamps the water has a salinity of 11.8 PPT, a conductivity of 19850 ($\mu\text{S}/\text{cm}$), and a pH of 6.3. However, in some areas closest to the Gulf of Paria the high salinity of certain lagoons creates communities of dwarf mangrove stands, 1 to 3 m tall.

Another type of woody plant community is a swamp forest of medium height (15 m) and density, with two strata. The dominant species are *Symphonia globulifera* and *Cassipoua guianensis*, which grow in levees with a clayey-muddy soil and an organic surface on the island of Turuepano. The second stratum grows to 8 or 10 meters and is dominated by *Euterpe precatoria*, *Rhizophora harrisonii* and *Ficus* sp. As one moves towards the interior of the island the forest turns into a shrubby swamp growing to 3-5 meters, and then one sees a dense herbaceous swamp dense with the fern *Blechnum serrulatum*. This fern is able to withstand the frequent fires that affect these communities because it has a subterranean rhizome. As the fire removes the trees and palms they are replaced by these ferns. This community grows about 1.5-2 meters high and contains few (8-10) species, among which the fern achieves coverage of 70-80%. Other species in this community include *Rhynchospora gigantea* and *Ludwigia nervosa*. The soil is organic and the water is completely fresh: the salinity is 0.1 PPT, the conductivity 281.6 ($\mu\text{S}/\text{cm}$), and the pH 4.3.



In the northern part of the park there are extensive grasslands with *Eleocharis interstincta*, *Eleocharis mutata* and shrubs growing on mineral soils. The species that compose this community are much more numerous, with a total of about 22; the plants grow in a mosaic of dense colonies on a matrix of *Eleocharis* ssp. The shrubby species here, such as *Sesbania emerus*, *Machaerium lunatum* and *Thalia geniculata*, form stands of one or a few species which stand out from their surroundings because of their greater height and distinct appearance.

The growth of aquatic plants in the tidal channels is limited by the salinity of the water. In the upper reaches of the Ajies channel it is possible to find aquatic macrophytes growing along the banks. The most common are *Echinochloa p-ramidatus*, *Panicum grande*, *Hymenachne amplexicaulis*, *Panicum mertensii* and *Paspalum maximum*, in addition to the lianas *Odontodenia* sp., *Paullinia pinnata* and *Cydista aequinoctialis*. Among the free-floating species, one sees *Eichhornia crassipes* which forms large communities at the heads of the channels, and also two species with roots fixed in the bottom and floating leaves, namely *Nymphaea rudgeana* in some pools and *Eichhornia heterosperma* in the middle of the current. We also found one species, *Ceratophyllum submersum*, growing submerged below 40 cm of water. In this sector the salinity is 0.3 PPT, the conductivity 632 ($\mu\text{S}/\text{cm}$), and the pH 7.1.

In this habitat it is possible to find communities with extensive populations of free-floating species (*Lemna perspusilla*); floating-leaf species (*Nymphaea* sp.); emergent species that are low in the water (*Sphenoclea zeylanica*, *Luziola subintegra* and *Leersia hexandra*); rooted species that rise well out of the water (*M. arborescens*, *Thalia geniculata*, and *Cyperus giganteum*); and climbing species (*Mikania congesta*). One uncommon species that is present in this community is *Hymenocallis venezuelensis*. In other parts of this area there are populations of *T. geniculata* and *C. giganteus* that measure 1-2 ha.

Turuepano National Park is subject to various environmental threats. The most significant of these is the poverty of the local people, who are obliged to live off the natural resources of the wetlands and to farm within the limits of the Park, planting taro (*Colocassia esculenta*) in the flooded areas and plantains (*Musa* spp.) and cassava (*Manihot* spp.) in the dry areas. In addition, the harvesting of oysters and mussels as well as mangrove wood has increased. The people engaged in these activities sometimes start fires, as do the poachers who kill deer, peccaries and other species; these fires reduce the coverage of forests and shrubs and thus allow *Blechnum serrulatum* to spread excessively. The rate of deforestation has increased dramatically in the last 20 years, as is immediately evident from examination of historical aerial photographs. The main damage is the reduction of palm communities (*Mauritia flexuosa*), which were once extensively distributed in the lower-elevation areas of the park and of its surroundings. One possible way to manage the area would be to assess the wetlands and their resources, involving the local people in the management scheme, and to create "buffer zones" in the periphery of the park where controlled subsistence farming would be permitted, while strictly prohibiting all such activities in the central part of the park and enforcing these rules with enough personnel of the Venezuelan National Park Agency.



Mary's Picks!

Items throughout this issue marked with "*" are from articles that particularly piqued the interest of Mary Langeland, the reader/cataloger for the APIRS database.

* **What makes a weed a weed: life history traits of native and exotic plants in the USA.** 2004. By S. Sutherland. *Oecologia* 141(1):24-39.

The author compared ten life history traits for the 19,960 plant species that occur in the USA. He found that a) life span was the most significant life history trait for weeds - weeds were more likely to be annuals and biennials than perennials; b) weeds were more likely to be wetland adapted, toxic and shade intolerant; and c) weeds were more likely to be monoecious and trees.

* **Creation of *Spartina* plantations for reclaiming Dongtai, China, tidal flats and offshore sands.** By C.H. Chung, R.Z. Zhuo, G.W. Xu. 2004. *Ecological Engineering* 23(3):135-150.

China wanted to reclaim lost salt marshes. Through "ecological engineering" and "skillfully using *Spartina alterniflora* plantations," they are protecting their coastal areas by damping waves, reducing current velocity and accreting sediments.

* **A review of the occurrence of halophytes in the eastern Great Lakes region.** By P.M. Catling and S.M. McKay. 1981. *The Michigan Botanist* 20: 167-180.

Salt-tolerant plants don't occur just on the sea shore; inland salt springs and other sodium-rich habitats may occur far inland, along with plants usually associated with oceanic coastlines.

More of Mary's pics ~

* **Factors affecting the Agrobacterium-mediated transient transformation of the wetland monocot, *Typha latifolia*.** 2004. By R. Nandakumar, L. Chen and S.M.D. Rogers. *Plant Cell, Tissue and Organ Culture* 79:31-38.

This is about how to genetically transform cat-tail, a plant already useful for heavy metal decontamination, so that it can be made even more useful.

* **A fern that hyperaccumulates arsenic.** 2001. By L.Q. Ma, K.M. Komar, C. Tu, W. Zhang, Y. Cai, and E.D. Kennelley. *Nature* 409:579.

A non-native fern in Florida, *Pteris vittata* (Chinese ladder brake), was discovered growing in a site highly contaminated with chromated copper arsenate. It was found to take up a number of species of arsenic to concentrations as high as 22,000 ppm. The authors believe this to be the first known arsenic hyperaccumulator as well as the first fern found to function as a hyperaccumulator, a plant that could be used in arsenic remediation programs to restore contaminated sites.

* **Brahmi (*Bacopa monnieri* (L.) Pennell) - A Medhya Rasayana drug of Ayurveda.** 2004. By M Rajani, N Shrivastava and M. Ravishankara. In *Biotechnology of Medicinal Plants: Vitality and Therapeutic*, ed by K.G. Ramawat, Science Publishers, Enfield, NH, 302 pp; pgs 89-110.

This aquatic plant, apparently good for whatever ails ya, placed second on a priority list of the most important medicinal plants in India.

* **Intensive hydrochory uncouples spatiotemporal patterns of seedfall and seedling recruitment in a "bird-dispersed" riparian tree.** 2004. By A. Hampe. *J. Ecology* 92(5):797-807.

Seed dispersal and seedling abundance of the endangered Spaniard tree, *Frangula alnus*, is discussed. "Even complex, multistep dispersal systems may produce remarkably consistent year-to-year distributions of recruits . . ."

* **Nests and nest habitats of the invasive catfish *Hoplosternum littorale* in Lake Tohopekaliga, Florida: a novel association with non-native *Hydrilla verticillata*.** By L.G. Nico and A.M. Muench. 2004. *Southeastern Naturalist* 3(3):451-466.

In Florida, an invasive catfish from South America is using an invasive plant from Asia to construct its large dome-shaped nests.

* **The effect of sex steroids and corticosteroids on the content of soluble proteins, nucleic acids and reducing sugars in *Wolffia arrhiza* (L.) Wimm. (Lemnaceae).** 2004. By I.K. Szamrej and R. Czerpak. *Polish J. Environmental Studies* 13(5):565-571.

Because *Wolffia* is able to use testosterone, cortisone and other organic substances as energy and carbon sources, the authors suggest the plant can be used in sewage treatment in small urban and rural environments.

* **Personal view - Seeds, seed banks and wetlands.** By M.A. Leck. 2004. *Seed Science Research* 14:259-266.

A nicely written reminiscence about how a researcher is a teacher.

* **Forensic palynology and ethnobotany of *Salicornia* species (Chenopodiaceae) in northwest Canada and Alaska.** 2005. By P.J. Mudie, S. Greer, J. Brakel, et al. *Can. J. Bot.* 83:111-123.

Kwaday Dan Ts'inchi (Long Ago Person Found) died on a British Columbia glacier 550 years ago. A team of researchers studied Chenopodiaceae pollen found in his stomach and robe using scanning electron microscopy (SEM). The stomach sample contained pollen grains from *Salicornia* (Tourn.) L. (glasswort), a succulent perennial salt marsh species, most likely *Salicornia perennis*.

* **Conservation team reveals 'floating' islands.** 2005. By J.L. Bartak. *Oryx* 39(2):126.

Members of a research and conservation initiative in Argentina found that marsh islands in the Parana River Delta float when the water level of the wetlands rise, providing shelter to resident marsh deer populations. The islands moved vertically carrying vegetation, 3-m trees and, in one high-level event, more than 30 deer.

* **Biogeography of discontinuously distributed hydrophytes: a molecular appraisal of intercontinental disjunctions.** By D.H. Les, D.J. Crawford, R.T. Kimball, M.L. Moody and E. Landolt. 2003. *Internat'l. J. Plant Sciences* 164(6):917-932.

Darwin noted in 1859 that many freshwater flowering plants have "enormous ranges." Why? Birds carry their seeds? Continental drift? The authors suggest that birds really might be the answer.

* **Wetlands of Central America.** By A.M. Ellison. 2004. *Wetlands Ecology and Management* 12:3-55.

This is a review of the literature about the 40,000 square kilometers of wetlands of Belize, Guatemala, Honduras, El Salvador, Nicaragua, Costa Rica and Panama. The five wetland types discussed are marine, estuarine, riverine, lacustrine and palustrine.

* **Alien aquatic plants naturalized in Japan: History and present status.** By Y. Kadono. 2004. *Global Environmental Research* 8(2):163-169.

The need for education and legal regulation is emphasized as the professor discusses over 40 species that have escaped and become naturalized in Japan.

* **Constraints in range predictions of invasive plant species due to non-equilibrium distribution patterns: purple loosestrife (*Lythrum salicaria*) in North America.** By E. Welk. 2004. *Ecological Modelling* 179(4):551-567.

What are some of the limitations of the models used to predict distribution patterns of plants outside their native range? Would incorporating "native range distribution" data into the models make a difference?

* **Introducing aquatic palms.** By J. Monteverde. 2005. *Water Garden Journal* 20(1):5-11.

This interesting article contains a list of 130 species of palms that like wet feet.

* **Reviving Iraq's wetlands.** By A. Lawler. 2004. *Science* 307(5713):1186-1189.

So as to better make war with each other, Iran and Iraq drained the ancient marsh lands that once divided their two countries. Most of the thousands of square kilometers of marsh were turned to deserts. Can they restore the Garden of Eden?

BOOKS/REPORTS

FLORIDA ETHNOBOTANY, by D.F. Austin.

2004. 909 pp.

(Published by CRC Press, 2000 NW Corporate Blvd, Boca Raton, FL 33431. ISBN 0-8493-2332-0. \$149.95 plus S/H. 1-800-272-7737. WWW: <http://www.crcpress.com>)

This huge compilation of the literature discusses the uses of nearly 900 plant species by the native peoples of Florida. In it, for example, we learn that "*Juncus*" comes from Latin "*iuncus*," meaning to tie or bind, which is what they used to do with these flexible-stemmed, tough-leaved rushes. What's more, we learn that the pith of *Juncus*, "when dried and oiled, will serve as a wick."

FEDERAL NOXIOUS WEED DISSEMINULES OF THE U.S. - An interactive identification tool for seeds and fruits of plants on the United States Federal Noxious Weed List, by J. Scher. 2005. Compact Disk.

(Published by the USDA Center for Plant Health Science and Technology, CDFA Plant Pest Diagnostics Center, 3294 Meadowview Road, Sacramento, CA 95832; (916) 262-3181. Email: julia.l.scher@aphis.usda.gov)

The title says it all: an information guide to the plant propagative units of 105 invasive or potentially invasive plant taxa on the US "federal noxious weed list." It includes lots of pictures (about 700), fact sheets, botanical descriptions, ID tips, and distribution.

An unequalled resource, for those who need it.

OUT OF EDEN - AN ODYSSEY OF ECOLOGICAL INVASION, by A. Burdick. 2005. 325 pp.

(Published by Farrar, Straus and Giroux, 19 Union Square West, New York, 10003; (212) 741-6900. ISBN 0-374-21973-7.)

Another in the recent cascade of "invasives" books, this one updates us on the most recent insights and codewords of invasions experts: we're now in the "Homogocene," where the "homogenization of the world" is resulting in a "creeping sameness" which threatens to render all our home territories indistinguishable from one another. Is this true, really?

The book is an ironically aware 300-page report/philosophical tract about the "ineffability" of the problem: "Do ecological communities that formed over a geological timespan differ in some fashion - in productivity, in potential stability - from those that were tossed together last month, last year, last century? Do recombinant communities differ from "normal" ones? Does time matter?"

As the author points out, "... humans have yet to devise a technique for making concerted measurements of ecological communities over time periods longer than the average human life span." So what do we really know about eco-invasions and their long term effects? What policies can we adopt when we don't know the answers to basic questions?

Oddly, there's no table of contents, nor an index.

THE ROLE OF DISPERSAL, PROPAGULE BANKS AND ABIOTIC CONDITIONS IN THE ESTABLISHMENT OF AQUATIC VEGETATION, by G. Boedeltje. 2005. 224 pp.

(Ph.D. Thesis. In English. Aquatic Ecology and Environmental Biology, Department of Ecology, Radboud University, Nijmegen, The Netherlands. ISBN 90-9019528-9. Email: g.boedeltje@science.ru.nl)

This book includes seven journal papers that are based on Ph.D. research in The Netherlands, and includes a "Synthesis." The author determined that certain plant species are dispersed by generative and vegetative diaspores; that water flow pulses significantly affect plant dispersal in stream and river systems; that plant diversity is unlikely in newly created backwaters; and that certain plant species provide for invertebrate diversity.

ISSUES IN BIOINVASION SCIENCE, EEI 2003: A Contribution to the Knowledge on Invasive Alien Species, edited by L. Capdevila-Arguelles and B. Zillett. 2005. 147 pp.

(Reprinted from *Biological Invasions, Volume 7, No. 1, 2005*. Published by Springer, 101 Philip Drive, Norwell, MA 02061. ISBN 1-4020-2902-0.)

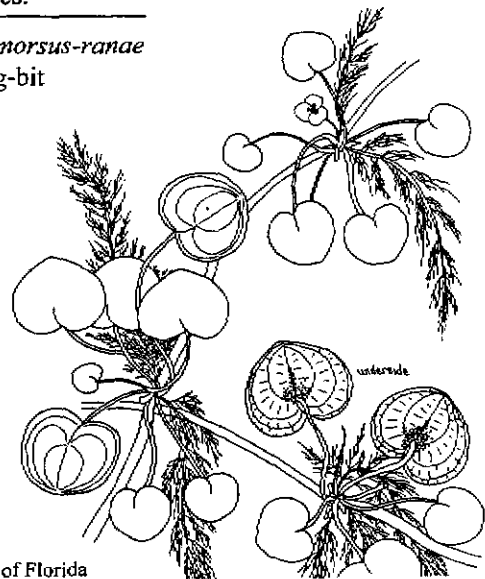
This book is a collection of 14 papers from *Biological Invasions*. Research topics include invasive fungi, weeds, shrimp, crayfish, mosquitoes, fish, rodents and other animals.

DOCUMENTATION, CHARACTERIZATION, AND PROPOSED MECHANISM OF DIQUAT RESISTANCE IN *LANDOLTIA PUNCTATA* (G. MEYER) D.H. LES AND D.J. CRAWFORD, by T.J. Koschnick. 2005. 110 pp.

(Ph. D. Thesis. Agronomy Department, University of Florida, Gainesville. Email: tjkoschnick@ifas.ufl.edu)

These studies documented the first aquatic plant to become resistant to the bipyridylum herbicides, and suggest that the resistance mechanism is related to reduced herbicide transport across cell membranes.

Hydrocharis morsus-ranae
European frog-bit



Aquatic Herbicide Resistance in Hydrilla

- a review by Karen Brown

The world of aquatic plant managers in Florida was rocked when the number one submersed aquatic weed in the state, *Hydrilla verticillata*, began showing signs of resistance to fluridone, the only EPA-approved systemic herbicide for large-scale hydrilla control. Research biologist **Dr. Michael Netherland** (pictured) worked for the manufacturer of fluridone at the time of this discovery. He has since returned to a research position with the U.S. Army Engineer Research and Development Center, and is stationed at the University of Florida IFAS Center for Aquatic and Invasive Plants.



H hydrilla (Hydrocharitaceae; *Hydrilla verticillata* (L.f.) Royle) is one of the worst exotic aquatic weeds in the southern United States, with millions of dollars spent annually to control large infestations in all types of water bodies. The most successful aquatic herbicide to date has been fluridone, sold under the tradename of Sonar. Within the last several years, however, at least three hydrilla biotypes have been discovered with a two- to six-fold higher resistance to fluridone than the wild type. The discovery of this herbicide resistance was a shock to aquatic plant managers, researchers, and herbicide manufacturers alike, as it jeopardizes the ability to manage hydrilla in a cost-effective and selective manner.

Hydrilla occurs around the world with reports from Europe, Asia, Africa, Australia and the Americas. Accessions from Florida, Texas and California are believed to have one common origin close to Bangalore, India. Hydrilla was introduced to Florida from Asia in the late 1950s, probably as an aquarium plant, and first recorded in a Florida lake in 1959. By the 1970s, it had spread throughout Florida water bodies, and by the 1990s, it infested approximately 140,000 acres in 288 water bodies of Florida. Hydrilla hampers flood control by filling drainage canals, rivers and lakes; it restricts navigation, clogs irrigation systems and water control structures in reservoirs and other impoundments, and impacts the recreational use of water bodies. It also affects nutrient cycles, water quality, and fish and other aquatic animal populations. It threatens even human safety by entangling swimmers, and deaths have been reported.

"While resistance development makes sense in hindsight, it was unexpected that a vegetative plant would develop somatic mutations that would confer resistance to fluridone."

Hydrilla has low light and CO² compensation points and a low light saturation point, enabling it to grow in only 1% of full sunlight. This competitive advantage, in addition to the ability to shift between C3 and C4-type photosynthesis depending on the environment, enables hydrilla to combat adverse conditions such as high temperature and irradiance, high oxygen concentration and limiting carbon dioxide. Dioecious hydrilla (male and female flowers occur only on separate plants) in Florida can grow from the substrate to the water surface and reach up to 15m in length. It "tops out" to form thick, impenetrable mats. Root crowns in the sediment develop horizontal above-ground shoots that form new plants. Stems branch out with leaf whorls at the nodes, each of which can regenerate to a new plant. However, the primary reproductive method is by turions that form in the leaf axils (axillary turions) and at the end of rhizomes in the substrate (subterranean turions). Subterranean turions can remain viable in the substrate for as long as 5 years. Approximately 2,000 to 3,000 turions per m² have been recorded in Florida lake sediments within a four month period, and almost 3,000 turions per m² (millions/acre) were recorded during a single winter season. Axillary turions are smaller and generally form on floating mats of hydrilla that have broken off from the parent plant, allowing for dispersal of a population. Axillary turions remain viable for approximately one year once they drop off and fall to the substrate.

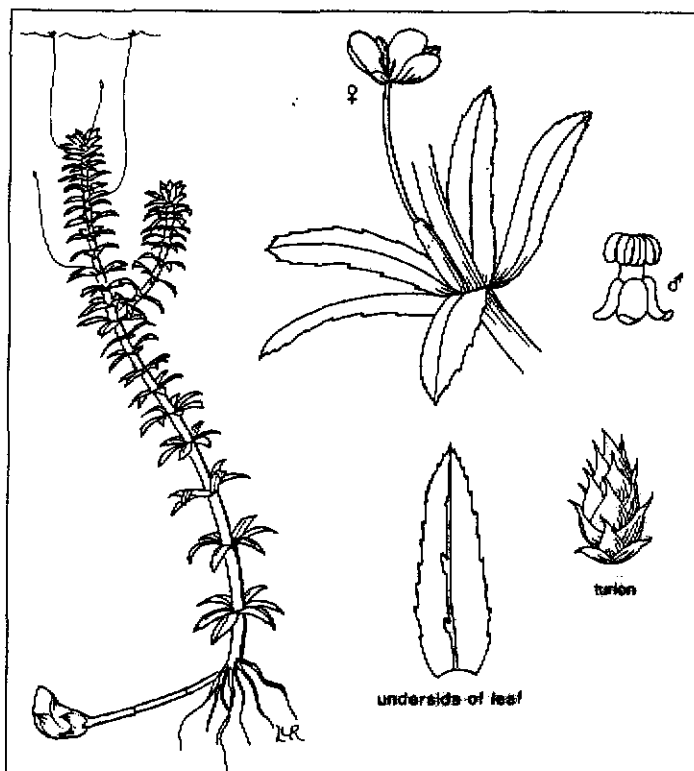
Hydrilla Control

Many methods of hydrilla control have been investigated, including mechanical, biological and chemical means. Drawdowns, fungal pathogens, introduced insects, large dredging machines and more have been used to attempt to control the explosive growth of the weed. Contact herbicides (endothall, diquat, and chelated copper) have been used to control hydrilla since the mid-1960s. Typically they are used for smaller or new infestations, while the systemic herbicide fluridone is used for large-scale control. Fluridone is the only cost-effective systemic aquatic herbicide for the large systems typically found in Florida. It has been approved by the US Environmental Protection Agency for aquatic systems since 1986. In fiscal year 2003-2004, more than \$15 million was spent managing hydrilla in more than 27,000 acres of Florida's public water bodies. Many treatments in 2005 were suspended due to issues with high water flow, inability to maintain the desired treatment concentrations, and lack of phytotoxic impact on hydrilla.

Hydrilla Resistance to Herbicides

"Factors likely to accelerate the selection of resistant biotypes are the repeated use of the herbicide in large areas, no use of alternative mode of action herbicides, high efficacy of the herbicide on the sensitive biotype at the rate used, and residual herbicide activity." Due to the lack of alternative compounds that could be used for large-scale control efforts and the nature of the fluridone molecule, this is exactly how fluridone is used to control hydrilla. Weed management with fluridone is accomplished by maintaining a constant herbicide concentration in lakes over several weeks to months.

Hydrilla had been susceptible to very low concentrations of fluridone. The first signs of fluridone resistance were in 1999. Major sampling efforts were conducted in 2001-2002. Studies revealed that hydrilla phenotypes with two- to six-fold higher fluridone resistance were present in several water bodies. The mutations were directly related to fluridone resistance and researchers concluded that they were the result of any one of three independent somatic mutations at the molecular target site of fluridone. Fluridone is an enzyme inhibitor, and the molecular target site is phytoene desaturase (PDS), one of the key enzymes in carotenoid biosynthesis. In the absence of protective carotenoids, photobleaching of newly emerging green tissue results. Hydrilla may be particularly susceptible to mutations caused by ultraviolet light because a hydrilla leaf blade is only two cell-layers thick. Treatments with fluridone are more effective toward the surface (high light intensities) than in deeper water (low light intensities). This type of selection predicts that if a mutation provides an adaptive advantage to the plants regenerated from the mutated cell, the trait can rapidly spread through the population. This could be the case of the resistant biotypes observed in Florida lakes. In hydrilla, somatic mutations transmitted in either the apical or any of the numerous axillary meristems do not necessarily die with the rest of the plant, as would be typical in terrestrial systems, but fragments of hydrilla possessing a meristem can regenerate into entire plants. Hydrilla is a polyploid plant (chromosome counts vary widely within a vegetative population). Researchers suggest that the variable ploidy of hydrilla could contribute to its adaptation and rapid development of herbicide resistance. These scenarios may have enabled the resistant hydrilla biotypes to become the dominant populations within each lake.



Hydrilla verticillata
© 1990, University of Florida, Center for Aquatic and Invasive Plants

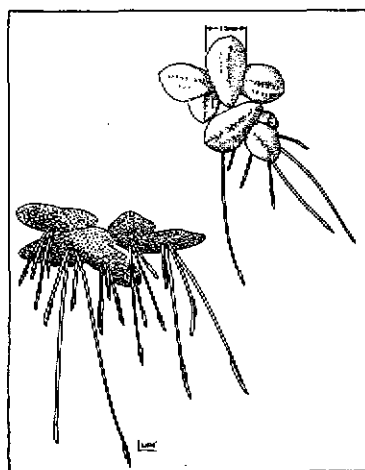
For a more in-depth publication on this topic, see *Somatic mutation-mediated evolution of herbicide resistance in the nonindigenous invasive plant hydrilla (Hydrilla verticillata)*, 2004, A. Michel, R.S. Areas, B.E. Scheffler, S.O. Duke, M. Netherland, F.E. Dayan, *Molecular Ecology* 13:3229-3237. Contact Michael Netherland at: MDNether@ifas.ufl.edu

Much more information on *Hydrilla verticillata* can be found on the **APIRS** web site at: <http://plants.ifas.ufl.edu/seagrant/hydver2.html>

An in-depth review of hydrilla management options, and the issue of fluridone resistance, can be found as a PDF document, *Hydrilla Issues Workshop*, Final Report, Gainesville, FL, December 2004, at: <http://lakewatch.ifas.ufl.edu>

More information on herbicide resistance in plants may be found from the International Survey of Herbicide Resistant Weeds: <http://www.weedscience.org/in.asp>

Aquatic Herbicide Resistance in Landoltia



Landoltia punctata
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Dr. Tyler Koschnick recently received his Ph. D. through the Agronomy Department here at the University of Florida. He currently is a visiting assistant professor at the Center for Aquatic and Invasive Plants and is continuing his research into the resistance of *Landoltia punctata* to the aquatic herbicide, diquat.

Trials conducted with *Landoltia punctata* (G. Meyer) D.H. Les and D.J. Crawford collected from a canal in Lake County, Florida showed a 50-fold resistance to diquat, and a cross resistance to paraquat. The resistance was independent of photosynthesis and the response to the diquat was delayed compared to a non-resistant biotype. It is presumed that less diquat was transported into the protoplast. Copper applied in combination with diquat overcame the resistance. It is thought that copper may alter the transport mechanism for diquat across the plasmalemma or open a secondary site for transport. These relationships warrant further study relating to diquat transport and potential resistance mechanisms.



These studies document the first aquatic plant to develop resistance to the bipyridylum herbicides.

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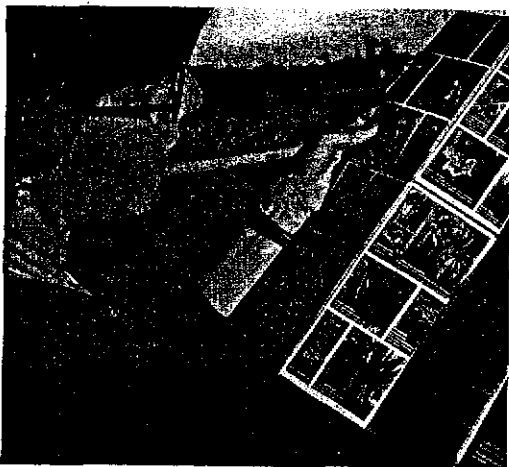
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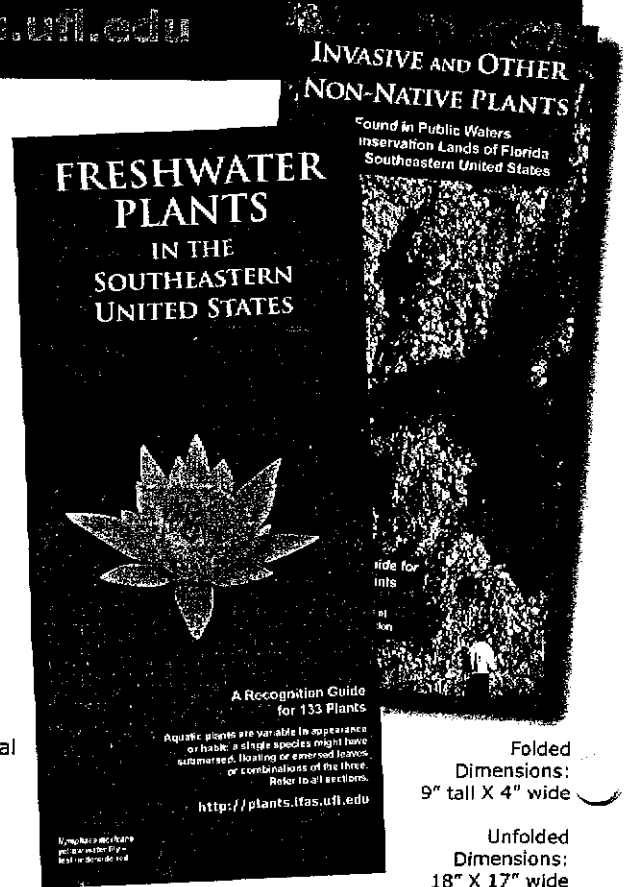
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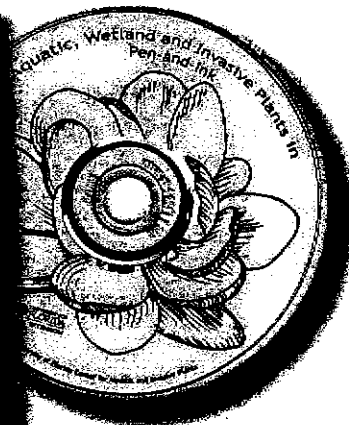
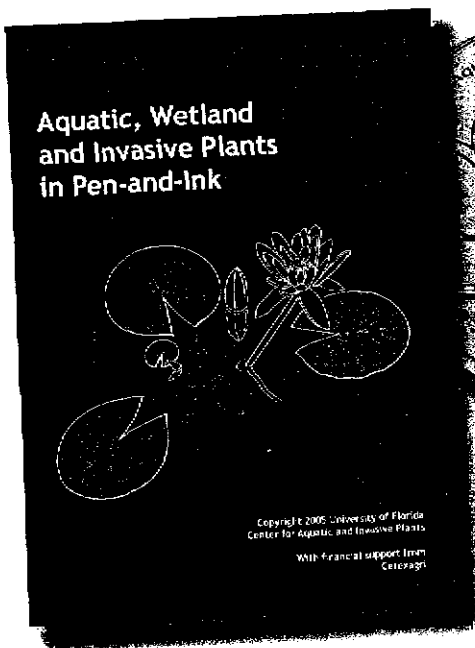
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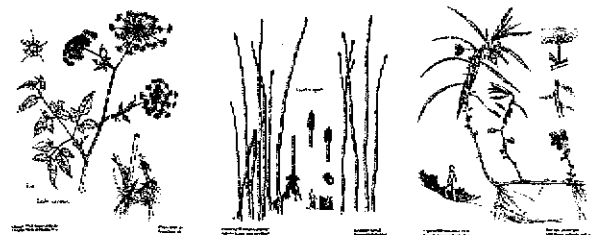
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