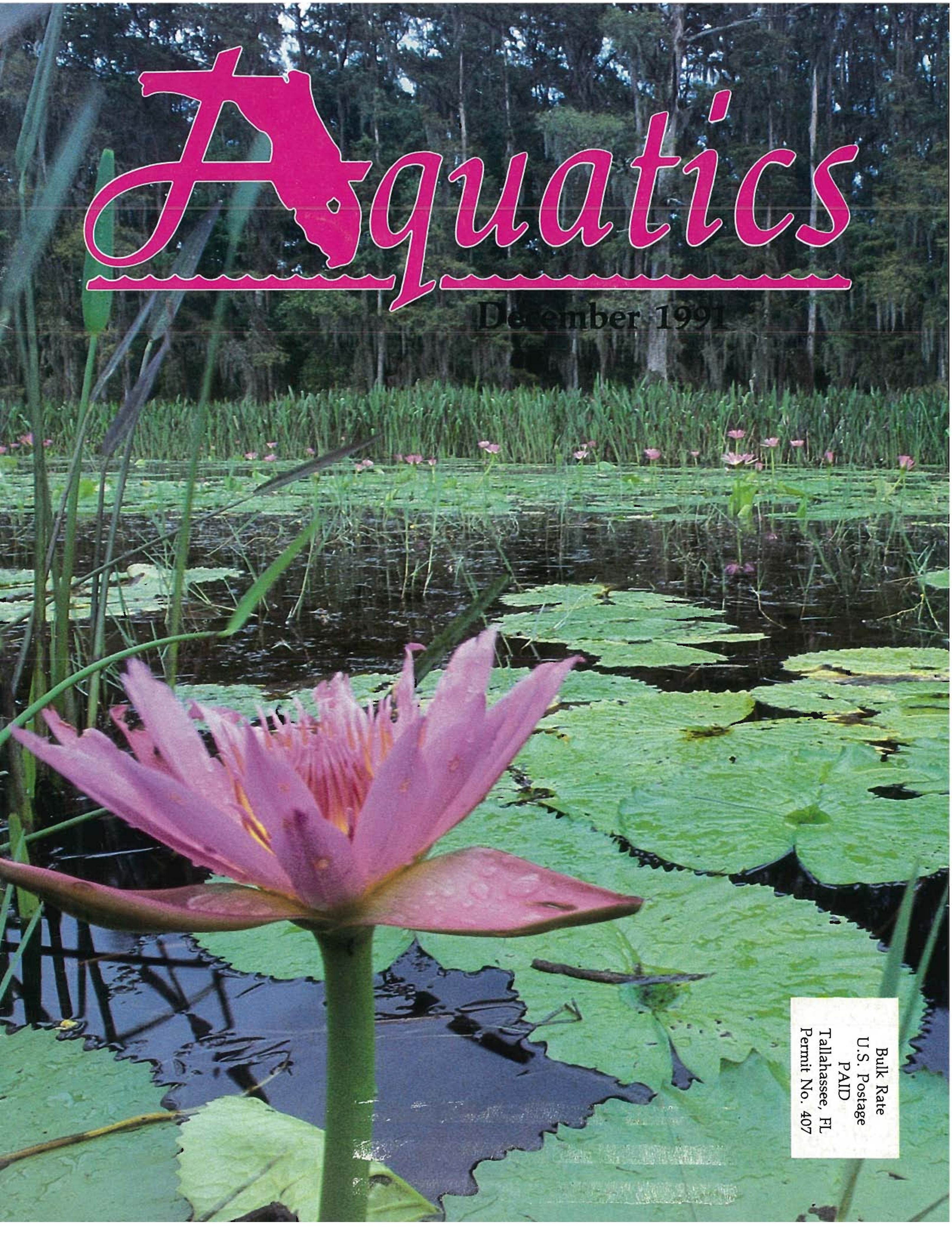
Aquatics

December 1991



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Editorial

UNFOUNDED FEARS

The late Walter Lippman once remarked, "When distant and unfamiliar things are communicated to great masses of people, the truth suffers a considerable. . .distortion. The complex is made over into the simple, the hypotetical into the dogmatic, and the relative into the absolute."

Lippman's observations are at the heart of the need to realign the thinking of many in our state who have sincere concerns about the environment, and the relationship of aquatic plant management activities to that environment. My growing concern is that we are losing the battle for the minds of these concerned citizens, not because of inappropriate action on our part, but rather because we have failed to act in this important arena. We have failed to convey the message of the significant environmental damage that would be caused by the failure to properly control exotic, invasive aquatic plants. We have also failed to convey the message of the safety of the control activities, and the care that is taken not to harm the environment. Like it or not, fear of what we are doing is rampant. Conventional wisdom holds that aquatic plant management is engaging in a host of dangerous and mysterious activities, and that they need to be stopped.

Many believe that all herbicides used in controlling aquatic plants are bad, and that we are simply dumping "poisons" into the water. Others believe that there is no need to control these plants at all, and if we would just leave them alone, nature would take care of things, and our lakes and rivers would return as they were a hundred years ago. Little is understood about the environmental consequences of failing to control invasive and noxious aquatic plants. Many fail to realize that if left uncontrolled, these invasive plants would make many of our lakes and rivers totally unusable in one short growing season, and the effects upon the diversity of native plants and wildlife would be devastating.

Also, please understand, we will not gain public trust and confidence in our control activities by listening to those who encourage policies that are contrary to the legislative mandates to regulate aquatic plants in an environmentally sensitive and safe manner. Those who are creating strife over the Bureau of Aquatic Plant Management's policies out of envy, pride or even greed, are not the friends of aquatic plant management, but rather are the profession's enemies, and to accept their views is to bring the wrath of the environmental community down on our heads. We must not allow egregious departures from common sense, by these negative voices of unenlightened self interest, prevail.

It is the Bureau of Aquatic Plant Management's intention to continue to conduct an integrated aquatic plant management program that is in keeping with statutory mandate, and with the highest of environmental concerns. Who is to argue that this is not in the best interest of us all?

Tom C. Brown, Chief
Florida Department of Natural Resources
Bureau of Aquatic Plant Managament

About The Cover
Waterlilies of the exotic kind brighten the Lake Arbuckle scene, Polk County.

Photo by Cindy Rezabeck, South Florida Water Management District, West Palm Beach.

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Southern Naiad - A Neglected Native

by
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Since their introduction and proliferation in Florida, hydrilla, water hyacinth, and other exotic aquatic species have received a great deal of attention and study. With the ever growing concern over these noxious invaders, the possible damage or benefits that can be created by less visible native species may be given little attention. In fact, in the 1940's, southern naiad, a species native to the U.S., was considered the major aquatic weed problem in South Florida canals. Although problematic in some areas, southern naiad is considered a primary waterfowl forage plant in many areas of the southeastern United States. Thus, a common species of native aquatic plant can create both problems and benefits. Therefore, it is important that this species and other native species of importance are not overlooked or ignored as attention is focused on the understanding and control of exotic species. As a case in point, hydrilla has only been in the U.S. since about 1960, yet the Aquatic Plant Information Retrieval Service (APIRS) of the Center for Aquatic Plants has approximately 1300 articles on hydrilla in its database and only 16 articles on southern naiad.

Southern naiad is a member of the Najadaceae (waternymph) family. Members of this family are characterized in a single genus as submersed aquatic herbs inhabiting fresh or brackish waters of temperate and tropical regions; usually rooting at the base with fibrous roots; slender greatly branched stems; opposite to whorled leaves being linear to lanceolate, either spined or toothed, finely serrate, or nearly entire; often with prominent stipules. Plants are monoecious or dioecious with imperfect, axillary, usually solitary and sessile flowers. The fruit is an achene. There are about 35 species of *Najas* occurring worldwide with eight species occurring in the United States and five occuring in Florida. Of these; *N. ginadalupensis* (southern naiad) is the most common and most valuable wildlife forage species, *N. marina* (marine naiad) occurs along coastal areas in brackish waters, *N. minor* (slender naiad) is an exotic species introduced from Europe, found in Lake Kerr and other sandhill lakes, *N. wrightiana* is a tropical species found in the Big Cypress Swamp, and *N. ancistrocarpa* is an exotic species introduced from Japan, found in only a few areas of the Panhandle.

Figure 1. Najas guadalupensis *plant, drawn by Grady Reinert and reprinted with permission from Godfrey, R.K. and J.W. Wooten, 1979.* Aquatic and Wetland Plants of Southeastern United States: *Monocotyledons. University of Georgia Press, Athens. 712 pp.*

Southern naiad is common throughout Florida and the southeast occuring northward into Quebec, westward to Colorado as well as Oregon and California. Reproduction is by seed and fragmentation. The plant is a prolific seed producer, although seed production is rare in the northern extremes of its range, most likely due to the fact that it is considered to be primarily a warm temperate or tropical species. After seeds are formed, or should have been formed, the individual plants separate easily at their nodes into fragments which float away to either disperse seed or establish vegetatively again in shallow water. Seed germination occurs during April to June but reproduction by fragmentation can occur throughout the year in subtropical to tropical climes. Both types of reproduction are common throughout Florida.

Peak growth of the plant generally occurs from July through October progressing from shallow areas to a depth of approximately three meters, depending upon water clarity. Dense infestations average about 5.2 kg wet weight or 0.3 kg dry weight per cubic meter. The

Clearly, it just makes good sense to be careful when controlling aquatic weeds!

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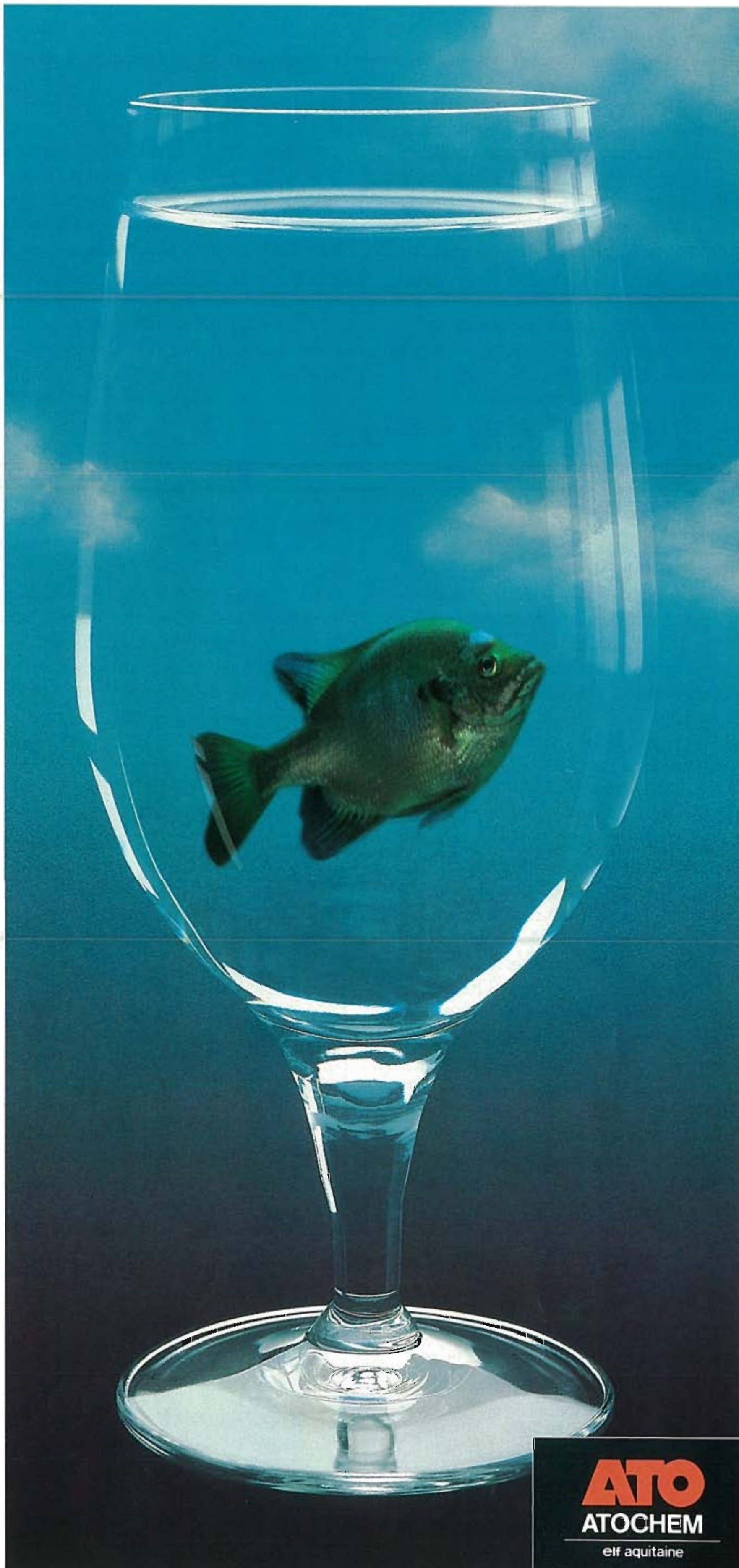

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main factors that affect growth and productivity are water depth, sediment load, turbidity, wave action, and phytoplankton and filamentous algae concentrations.

Light penetration is extremely important for the establishment and growth of southern naiad. In areas where light penetration is limited by water depth and turbidity or water clarity, growth is significantly reduced. High populations of phytoplankton or filamentous algae can also provide sufficient shading to weaken or destroy the plant. Wave action or water movement can easily uproot the weak fibrous root system and break the plant into fragments while not allowing for their reestablishment.

Experiments have shown that nutrient uptake apparently occurs from the root-sediment system rather than from the foliage-water system, therefore the sediment load is the major nutrient factor related to the growth of southern naiad. Growth is generally independent of the nutrient content of the water, except in cases where the diffusion from highly nutrient-rich water into the the sediment is sufficient to affect growth. It should be noted however, that water quality has a major impact on light penetration and water clarity which can limit growth, as noted above. The base content and alkalinity of the water is also related to growth with the major role of the water column providing a carbon source, largely HCO_3 ions, for photosynthesis.

As stated earlier, southern naiad was once considered an extremely troublesome aquatic plant in many southern waters. It still creates problems where infestations become dense, especially in drainage and irrigation canals where growth impedes water flow and restricts boat access. In these cases control may become necessary. Historically, in fish and aquaculture ponds, the water was fertilized in order to stimulate the growth of phytoplankton and filamentous algae which shade out the plant. However, the fertilization of lakes and rivers to reduce water clarity would not be a practical method of control. The use of dyes or shading agents which limit light penetration is an alternative to fertilization. Mechanical control is expensive, but in certain situations could be an adequate means of control, however the reestablishment of fragments is a concern with this method. The rate of biomass decline of southern naiad following mechanical harvest has been shown in Tennessee to be inversely related to the phosphorus content in the sediment, however phosphorus concentrations in Florida sediments may be considerably higher due to the high phosphorus content of Florida soils which would greatly decrease reductions in yield following harvest. There are a variety of systemic and contact herbicides which effectively control southern naiad. The choice of herbicide used depends upon water use and restrictions placed on the water following application. In fact, the high susceptibility of southern naiad to herbicides can result in naiad control in areas where the control of exotic species is desirable. Usually though, due to its large seed bank, southern naiad regrows quickly following treatments. Since southern naiad is a native species and considered ecologically valuable in many areas the feasibility of utilizing an effective biocontrol agent is limited. The use of sterile triploid grass carp is one option, although control cannot be limited to southern naiad.

Presently, southern naiad rarely becomes a problem and several options are available for its control. Yet, as attention is focused on hydrilla and other exotic aquatic species, southern naiad, because of it's prolific seed production and regrowth from plant fragments could become more of a widespread problem as competition with other plant species is decreased. Conversely, the full range of benefits that could be produced by southern naiad has not been fully investigated. Certainly, the control and understanding of exotic species is necessary, but a thorough understanding of native species, especially those as common as southern naiad, is equally important to insure that a healthy, well balanced ecological system can be maintained.

Literature citations available upon request.

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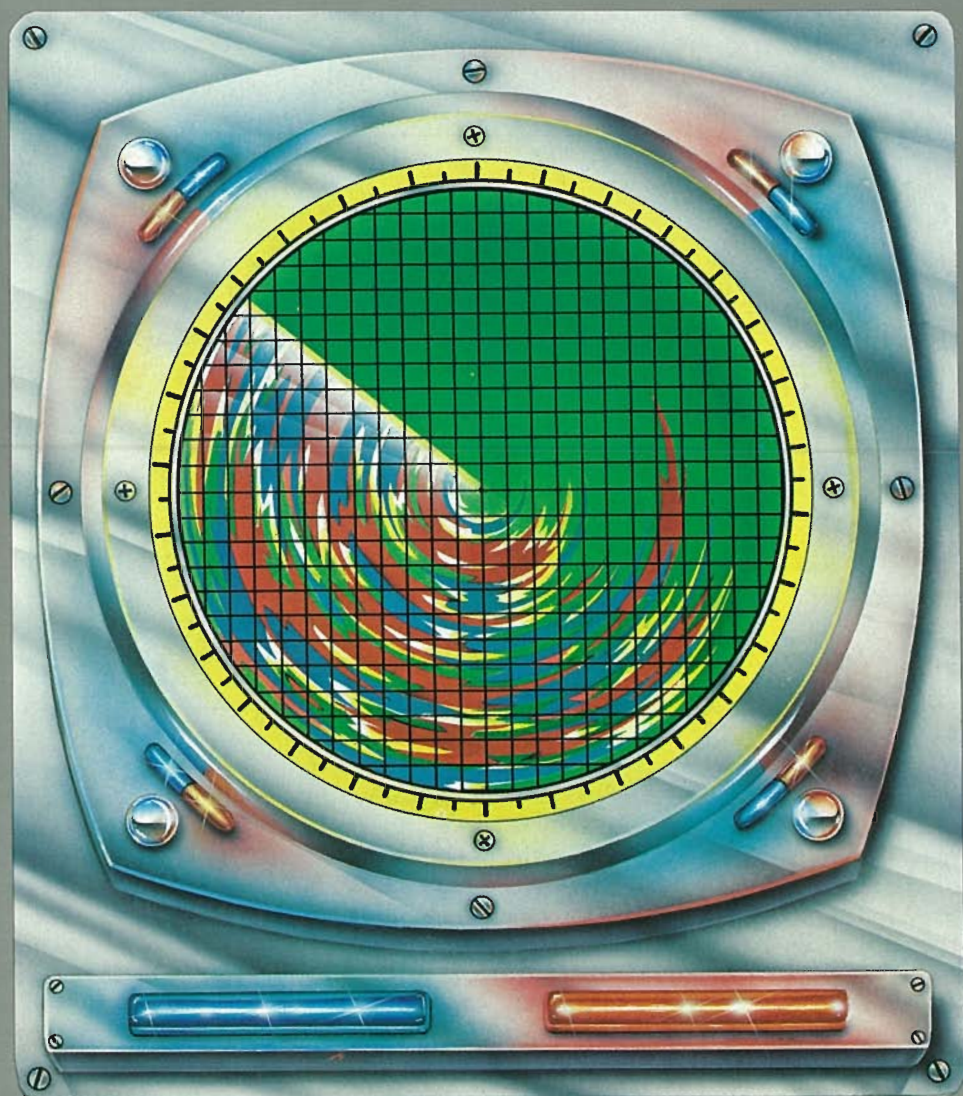
Weeds or desirable plants?



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Egeria: Biology and Management in Temperate Lakes

By
Kurt D. Getsinger
Research Scientist
U.S. Army Corps of Engineers
Waterways Experiment Station
Vicksburg, MS

Plant Description

The genus *Egeria,* originally described by Planchon (1849), contains only two species, *E. densa* and *E. najas.* Both are submersed, rooted perennials, native to east, central South America (St. John 1961; Cook and Urmi-Konig 1984). This discussion will be limited to *E. densa,* hereafter referred to as egeria, since it is the only one of the two species naturalized in the U.S. Another common name for *E. densa* is Brazilian elodea, derived from its native range and close physical resemblance to the genus *Elodea.*

The green, cylindrical stems of egeria grow erect through the water and can attain heights of over two meters. Once the stems reach the surface, they can intertwine to form dense canopies or mats. These surface mats can cover hundreds of hectares and can persist until senescence in fall. The thin, green translucent leaves of egeria are oblong to linear and pointed at the apex. Leaf margins are minutely serrated and the blade has a single midrib. Leaves are usually arranged in whorls of four at nodes along the stem (Fig. 1), although three to five leaves are occasionally observed. Nodes occur at regular intervals along shoots of equivalent age, with internodal lengths becoming greater in older parts of shoots.

Specialized nodal regions, described by Jacobs (1946) as double nodes are located at intervals of six to twelve nodes along the shoot. A double node actually consists of two single nodes separated by a short internode (Fig. 1). In most cases, two single nodes comprising the double node are virtually superimposed, resulting in a nodal region with eight to ten leaves in a whorl. This double node region is of primary importance with respect to growth and vegetative propagation of egeria, for it is within this region that lateral buds, branches, and adventitious roots are produced (Fig. 1). Moreover, only those fragments which contain double node regions can develop into new plants (King 1943; Jacobs 1946; Getsinger and Dillon 1984).

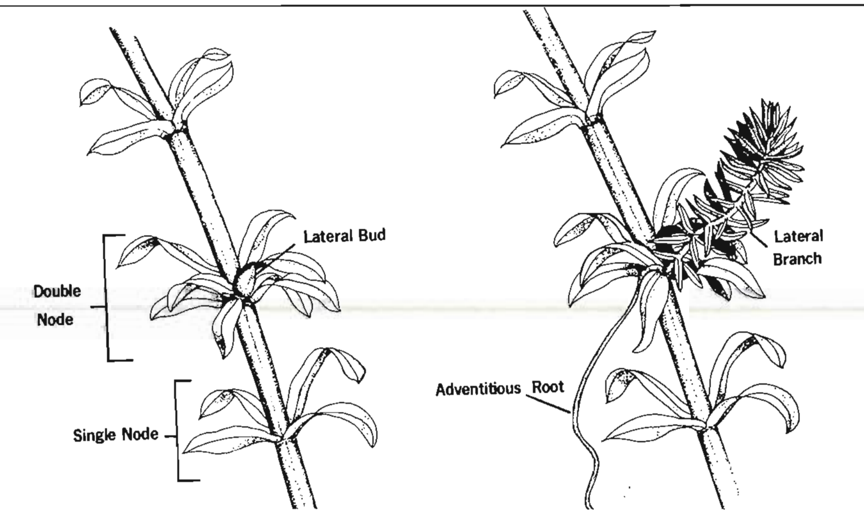

Figure 1. Dougle node region of Egeria *showing lateral buds, branches, and adventitious roots.*

When egeria shoots reach the surface of the water, some double nodes near the apical region, produce flowers. From two to five white, tripetallous flowers, extend from each spathe and rise several centimeters above the surface on a thread-like stalk (Fig. 2). Egeria is dioecious, i.e., male and female flowers are produced on separate plants. Although egeria produces female flowers in its native range, there are no reports of female flowers or seed production from populations established in the U.S. Thus, only male flowers are found in these naturalized populations. The absence of sexual reproduction emphasizes the importance of the vegetative growth phase of the plant, and its spread, due to this type of propagation. Egeria will develop flowers almost continually when the water temperature is between 15-25 C, and sufficient light and nutrients are present (Cook and Urmi-Konig 1984).

The rootcrown region of egeria develops from double nodes along old shoots. When an old shoot, or fragment, sinks to the bottom during fall senescence, a rootcrown may develop at one or several double node regions along that shoot. Numerous adventitious roots arise from the developing rootcrown, which eventually becomes a mass of meristematic tissue, producing many additional shoots and roots. The formation of rootcrowns in this fashion allows egeria to spread or creep along the bottom. Rootcrowns can survive for several growing seasons and are the primary overwintering structure.

Egeria growth ceases at water temperatures below 6° C and the plant overwinters in an evergreen condition (Getsinger and Dillon (1982). In Lake Marion, SC, Getsinger and Dillon (1984) reported two egeria biomass peaks: early summer and late fall. Maximum standing crop occurred in early summer, followed by a decline, and a second peak in autumn. The authors attributed the late summer biomass decline to high water temperatures. When temperatures exceeded 30° C, cessation of growth, deterioration of tissue and resultant reduction in biomass occurred. Barko and Smart (1981) were able to significantly reduce biomass production in growth chamber experiments with egeria by raising temperatures to 32 C. The bimodal biomass curve observed in Lake Marion has been reported for egeria in other temperate lakes (Tanimizu and Muira 1976; Schiller 1983).

Distinguishing Characteristics

In the field, egeria can easily be confused with elodea (*Elodea canadensis* L.) and hydrilla (*Hydrilla verticillata* Royle). There are a number of morphological characteristics that can be used to readily differentiate egeria from the other two species. One diagnostic feature overshadows all others: the stems of egeria contain double node regions, while the stems of elodea and hydrilla do not. Other distinguishing characteristics include: number of flowers per spathe, presence of spines on the midrib of the leaf, and production of turions and tubers.

The flowers of egeria are more prominent than those of elodea and hydrilla, and the spathe contains two to five flowers. Spathes of elodea contain one flower, rarely two (Cook and Urmi-Konig 1982), and spathes of hydrilla contain only one flower (Cook and Luond 1982). In egeria (also elodea), the midrib on the underside of the leaf is smooth; whereas in hydrilla, one or more small spines (visible to the naked eye) protrude from the midrib (Haller 1978). Turions (shortened, fleshy shoots) and tubers (enlarged stolons) are specialized structures which function as reproductive or overwintering propagules in some submersed macrophytes. Elodea produces rudimentary turions (Cook and Urmi-Konig 1985), while hydrilla produces well developed turions and tubers (Haller 1978). Egeria produces neither of these structures and, as mentioned previously, must rely upon stem fragments and rootcrowns for vegetative reproduction and winter survival.

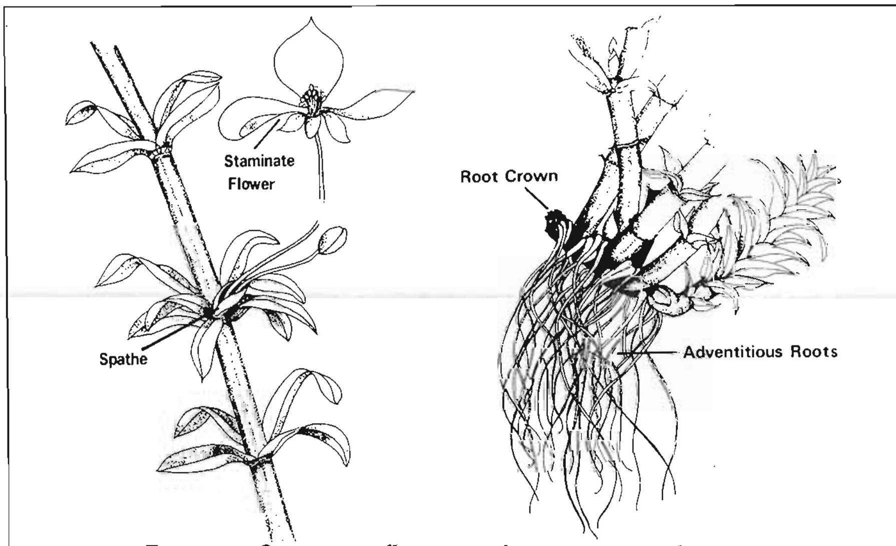

Figure 2. Staminate flower and root crown of Egeria.

Distribution

In a recent revision of the genus, Cook and Urmi-Konig (1984) reported that egeria has been naturalized around the world, including portions of Africa, Asia, Australia, New Zealand, and North America. Cook and Urmi-Konig are probably correct when they attribute the cosmopolitan status of egeria to its popularity as an aquarium plant and laboratory research specimen. Once established in a waterbody, egeria can easily be disseminated downstream via fragmentation. Man is a primary factor in spreading the plant to previously uninfested waterbodies. Clumps of egeria clinging to boat propellers and trailers can be transported overland to other water systems.

The earliest record of naturalized egeria in the U.S. is from Millneck, Long Island, in 1893 (Weatherby 1932). Today, egeria can be found in nearly all of the eastern States from New England to Florida, and westward to Nebraska, Texas, New Mexico, Arizona, Utah, Oregon and California (Cook and Urmi-Konig 1984). The largest infestation in the U.S. occurs in the Santee-Cooper river basin of South Carolina, where egeria covers hundreds of hectares of Lake Marion (Inabinet, personal communication, 1987) and over 1000 hectares of the Cooper River and adjacent, antebellum rice fields (Johnson, personal communication, 1987).

Environmental and Economic Importance

The ecological importance of submersed plants to aquatic systems has been well documented (Wetzel and Hough 1973; Wetzel 1979; Carpenter 1981; and others). Conversely, uncontrolled growth of submersed plants can cause serious problems with respect to human use of waterbodies (Holm et al. 1969). Egeria could be beneficial to an aquatic system if its growth is limited to small, scattered patches or narrow bands along the shoreline. In these situations the plant may increase dissolved oxygen levels, strip nutrients from the water and sediment, and provide refuge and substrate for a variety of organisms. If the growth of egeria is unchecked, the plant can create negative impacts on an aquatic system. Large, monospecific stands of the plant may disrupt predator-prey relationships, increase sedimentation rates, and cause severe fluctuations in chemical and physical parameters of a waterbody. In addition, extensive surface mats of egeria can impede navigation, block water intake structures, and interfere with some recreational uses, particularly fishing and swimming (Corning and Prosser 1969; Roach 1977). On the other hand, certain types of waterfowl (e.g., widgeon, canvasbacks, ringnecks, scaup, and coots) are attracted to, and feed heavily in, large stands of egeria (personal observation). This is not surprising since wintering waterfowl prefer foods rich in carbohydrates, and shoots of egeria contain high concentrations of starch during fall and winter (Getsinger 1982).

The abundance of egeria in South Carolina stimulated local interest in the feasibility of converting this problem species into a cash crop. Peterson and Dillon (1982) proposed research to evaluate the potential of egeria for use in the production of ethyl alcohol fuel. These investigators determined that 1.6 metric tons of starch per hectare were present during periods of peak biomass in Lake Marion, SC. If all of the egeria in the lake were harvested and its starch converted to alcohol, nearly 36,000 barrels of 95% ethanol could be produced. Maurice et al. (1984) demonstrated the potential of egeria may be used as a feed supplement with no ill effects and may be used to lower the cost of poultry feeds.

Management

Various methods, including biological, mechanical/physical, and chemical, can be used to control egeria. Prior to the selection of a control technique, a management strategy should be developed which considers the design and use of the waterbody, amounts of vegetation acceptable in the system, and environmental impacts and costs associated with managing the vegetation.

The only practical biological method for controlling egeria in most temperate lakes is the grass carp (*Ctenopharyngodon idella* Val.). The grass carp prefers tender, submersed vegetation and Avault (1965) showed that the fish can control egeria. According to Sutton and Vandiver (1986), egeria ranks high on the grass carp's food preference list. Although the grass carp may provide adequate control when used alone, an integrated approach, using the fish with herbicides or mechanical harvesters, may be the most efficient and cost effective management technique (Canfield 1983; Sutton and Vandiver 1986). Fitzpatrick et al. (1981) and Schiller (1983) demonstrated the potential of tilapia (*Tilapia zillii* Gerv.), another herbivorous fish, to feed upon and control egeria. The main disadvantage in using this fish is its sensitivity to temperature. Tilapia will perish at temperatures below 10° C (Chimits 1957) and, unless year-round water temperatures exceed 16° C, annual restocking may be required (Hauser 1977). However, the fish can survive and control egeria in lakes warmed in winter by thermal discharges from power plants (Schiller, personal communication 1987).

A wide variety of mechanical/physical techniques can be applied to the control of submersed vegetation: cutting and harvesting; placement of bottom-covering barriers (screens); uprooting with mechanical sediment agitation; drawdowns (lowering of water levels); and dyes (Sabol et al. 1985). Two studies have been conducted on the operational use of mechanical harvesters to control egeria (Johnson and Bagwell 1978; Schiller 1983). The authors of both studies suggested that harvesting may provide immediate control of egeria in limited areas. However, they concluded that this relatively slow technique may not keep pace with regrowth in waterbodies with large infestations, and that new infestations could occur via cut plant fragments. Exposing egeria to desiccation and cold temperatures by drawdowns in winter and spring will result in acceptable levels of control (Manning and Sanders 1975). Application of herbicides, following drawdown, can enhance drawdown techniques (Manning and Johnson 1975). Unfortunately, the herbicide of choice for this method, fenac, has recently been removed from federal registration. This author is unaware of any literature pertaining to egeria control using the other previously listed mechanical/physical methods. Yet, it is reasonable to assume that if any of these techniques control other rooted, submersed species, they would also control egeria.

Despite the fact that the list of registered aquatic herbicides has declined in recent years, chemicals are the most widely used technique for controlling egeria. The herbicide diquat, or diquat plus copper, has given the most effective and consistent control of egeria in nonturbid waters (Blackburn and Gangstad 1976; Foret et al. 1976; Schiller 1983). Diquat, in combination with the herbicide endothall, has also provided satisfactory egeria control in some situations (Corning and Prosser 1969; Berry et al. 1975; Blackburn and Gangstad 1976; Schiller 1983). Endothall alone is not recommended for the control of egeria. The reason for this is twofold: at labelled rates the potassium salt formulation of endothall is simply not effective on the plant; and, while the amine salt formulation can be efficacious, the rates required for control may be toxic to fish (Walker 1963; Corning and Prosser 1969; Blackburn and Gangstad 1976; Pennwalt 1984). The inability of the potassium salt formulation of endothall to control egeria is peculiar, since labelled rates of this formulation can provide excellent control of hydrilla (Blackburn and Weldon 1970; Blackburn et al. 1971). Egeria is also susceptible to fluridone, when this herbicide is used in static water conditions (Elanco 1985).

Space limitation prevented printing literature citations accompanying this article. They are available from the author at U.S. Army Engineers Waterways Experiment Station, 3909 Halls Ferry Road, Vicksburg, Mississippi 39180-6199.

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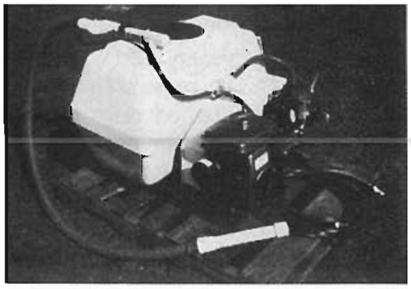

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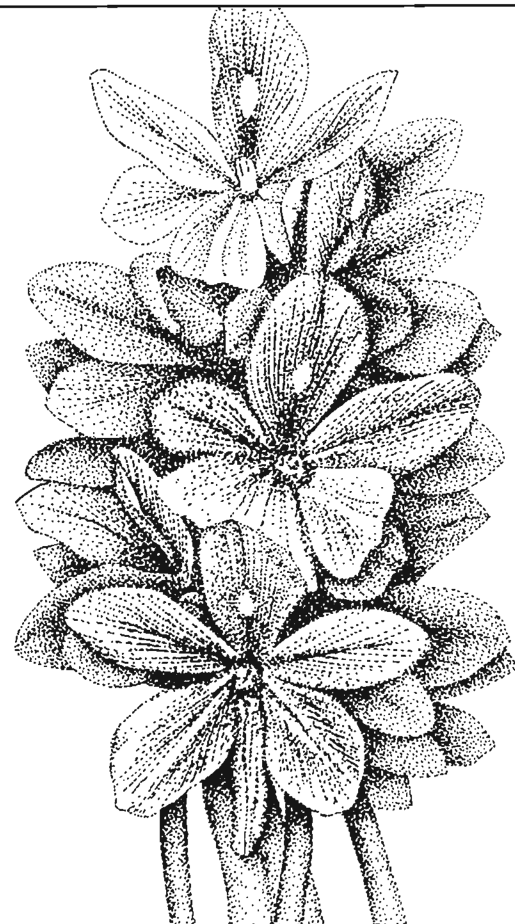

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Florida's Cooperative and State Aquatic Plant Management Funding Programs 1988 Through 1990

By Brian Nelson[1] and Anne Galloway[2]

The majority of aquatic plant management operations on Florida's public waters are conducted under the Cooperative Aquatic Plant Control Program (Cooperative Program) or the State Funding for Aquatic Plant Control Program (State Program). The primary species controlled are waterhyacinth, waterlettuce and hydrilla. These three exotic species comprised approximately ninety-six percent of the vegetation controlled during 1990.

Overall funding for operations under these publicly funded programs has declined since 1988. State funds spent to match local dollars under the State Program decreased from approximately $2.5 million in 1988 to $0.7 million during 1990. U.S. Army Corps of Engineers (Corps) funds allocated to and matched by Florida for operations under the Aquatic Plant Control portion of the Cooperative Program decreased from $2.25 million federal navigation project areas under the Removal of Aquatic Growths Program in Florida increased during this same period from $2.5 to $2.7 million.

Even though hydrilla first appeared in Florida more than thirty years ago, the impact of new and expanding hydrilla populations continues to be tremendous. Between 1988 and 1990, hydrilla expanded in several large lakes where it had not previously been a problem. The largest increases occurred in Lakes Istokpoga, Hatchineha and Arbuckle. While little or no hydrilla management money was spent in these systems prior to 1988, more than $3.0 million has been has been spent since then to maintain the usability of lakes Hatchineha and Istokpoga. Adequate funds were not available to treat Lake Arbuckle and hydrilla covered almost the entire lake.

Table 1 lists the plants controlled under the Cooperative and State Funding Programs. The 1988 amount includes some work in man-made waters under the State Program which were no longer eligible for funding and thus not included in the 1989 and 1990 amounts. Therefore, it is difficult to compare the 1988 totals with the other years. The acreage of hydrilla controlled decreased between 1989 and 1990 due to the reduced amount of funding available. Operations were either curtailed or cancelled on several lakes. Less acres of floating plants were also controlled during 1990 due to low water levels and an increased level of maintenance control achieved throughout the state.

Table 2 lists the types and amounts of herbicides used. The total amount of diquat and 2,4-D used primarily, but not exclusively, to control waterhyacinth and waterlettuce, decreased along with the acres of floating plants requiring control. This, of course, is one of the main benefits associated with a successful maintenance control program. By dividing the total amount of 2,4-D and diquat used under the Cooperative Program by the total hours of spray time, the average amount of herbicide used per hour of spray time can be estimated. The amount of diquat and 2, 4-D used decreased from approximately one gallon per hour of spray time in 1988 to three quarts per hour in 1990. The fact that spray crews are spending more time searching for and treating small, isolated populations of floating plants rather than spraying more extensive mats probably accounts for the majority of this decrease.

Of the 16,397 gallons of complexed copper used during 1988, 12,489 gallons were used under the State Program, mostly in man-made waters. The 1989 and 1990 totals represent only the amount of copper used in natural waters. Copper use under the funded programs declined sharply after 1986 and has decreased annually ever since. Most of the decline since 1986 is due to the fact that control operations in man-made waters were no longer reimbursed or reported under the State Program. However, the need to maintain boat trails, open fishing areas and to conduct other spot treatments using copper and contact herbicides also diminished after 1986 as lake-wide hydrilla management began with fluridone. More recently, concern by the Department of Natural Resources and other state and federal agencies over the use of copper in natural waters has resulted in the increased use of alternative control methods.

The acreage and plants harvested appears in Table 3 along with the dollars spent and cost per acre totals for all control methods utilized. Cost figures appearing in this article represent total program costs including but not limited to equipment rental, herbicides, salaries, administrative costs and travel.

Based on the cost per acre information in Table 3, it appears that the cost of managing hydrilla using harvesters or herbicides differs by less than $100 per acre. This is not the case, however, as the cost of maintaining an area utilizing these methods is very different. The cost per acre for mechanical control represents the cost of removing the top growth of hydrilla (or other plant) from one acre one time. Because regrowth normally occurs, this cost is incurred several times each year for the same acre. In contrast, the herbicide control cost

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TABLE 1. Plants Controlled Under The State And Cooperative Aquatic Plant Control Programs.

Plant	Acres Controlled 1988	1989	1990
Hydrilla	18,358	11,397	8,771
Floating Plants *	40,768	42,188	26,373
Cattail	493	699	289
Algae	370	288	165
Grasses	328	266	159
Pondweed	150	104	76
Chara	223	0	0
Cabomba	179	146	68
Spatterdock	202	135	275
Pennywort	83	77	64
Salvinia	30	50	69
Duckweed	27	39	30
Naiad	34	10	15
Alligatorweed	55	21	33
Bladderwort	25	17	4
Frogsbit	294	223	158
Tussocks	139	90	27
Other Plants	173	183	222

* Waterhyacinth / Waterlettuce

TABLE 2. Herbicides Used Under The State And Cooperative Aquatic Plant Control Program

Herbicide	Year 1988	1989	1990
Aquathol *	93,855	53,432	104,512
Aquathol K	36,327	22,151	11,096
Banvel 720	31	5	0
Copper Chelate	16,397	3,239	2,678
Copper Chelate *	1,100	360	0
Copper Sulfate	1,162	75	0
Diquat	14,353	8,312	6,530
Rodeo	1,562	995	674
Sonar A.S.	1,920	907	1,606
Sonar 5P/SRP *	86,660	180,075	54,901
2,4-D	12,427	12,778	8,464
2,4-D *	6,992	5,561	4,342

* Reported as pounds, other products listed in gallons

represents the cost of treating one acre of plants. The difference is that the treated plants may be controlled for up to two years depending on the herbicide used. In addition, when large-scale hydrilla treatments are conducted using fluridone, three to five acres or more are often controlled for each acre treated. For these reasons, harvesting is limited to areas where herbicides are not effective or feasible such as fast flowing rivers and areas adjacent to potable water intakes. Harvesters are also utilized to maintain boat trails on lakes densely vegetated with native plants and to revome floating tussocks.

The total cost of operations conducted under each program appears in Table 4. Under the Cooperative Program, the Corps provided 100% funding for operations in federal navigation project areas and 50% funding for other work, except during 1989. In 1989, an increase in the amount of state funds spent reduced the federal match to 40 percent. Corps funds are matched by state dollars when a water-body forms the border between two or more counties or is connected to an eligible water-body in another county. Local dollars are required to match federal funding for intra-county waters. Operations conducted under the State Program were equally funded by state and local dollars.

The cost of managing floating plants on Florida's natural waters under the Cooperative Program has averaged approximately $2.2 million since 1984. This is a relatively small amount to spend when you consider the growth potential of waterhyacinth and the fact that more than three hundred water-bodies totaling in excess of 1.25 million acres are being effectively managed. Most water managers realize that the biological integrity as well as the income and enjoyment resulting from the utilization of the state's fresh water resources is dependent on the successful management of this troublesome species. Reduced funding levels have not yet affected floating plant management as this operationis a program priority. Adequate funding is allocated for the management of floating plants before other management activities are considered.

Nearly $5 million, the largest amount to date, was spent during 1989 to manage hydrilla in public lakes and rivers. Due to the success of several large-scale hydrilla management operations, the estimated acreage of hydrilla present in Florida's public waters was reduced from 52,600 acres in 1988 to 41,600 acres in 1989. This was the most significant decrease (21%) in hydrilla abundance ever as a result of ongoing hydrilla management operations. During 1990 only $4.1 million was spent leaving several areas untreated. Consequently, hydrilla expanded to cover more than 57,000 acres.

Due to the continuing expansion of hydrilla, increased control costs and the lack of significant funding increases since 1984, hydrilla management needs have outstripped the funding available. Funding is no longer adequate to provide the level of hydrilla management that the public has become accustomed to on all waters. Program managers are being faced with the decision to provide adequae control on a few waters or to provide a much lesser degree of control such as boat trails on all affected waters.

Funding for the control of plants other than hydrilla, waterhyacinth and waterlettuce has been reduced to offset the shortfall in hydrilla management funding. However, some control of cattail and other species is required to maintain access and navigation around boat ramps, navigational channels and other public access areas. Limited boat trail systems are also maintained on lakes exhibiting an extensive coverage of native species to allow reasonable utilization by boaters.

During 1991, several program cooperators elected to contribute local dollars to ensure that the necessary

TABLE 3: Summary of Management Costs by Plant Type and Control Method During Fiscal Year 1990

Control Method	Plant Type	Acres Controlled	Dollars Spent	Cost Per Acre
Herbicide	Floating*	27,867	2,015,723	$72
	Hydrilla	6,966	3,271,402	$470
	Other	1,158	256,470	$221
	Total	35,991	5,543,595	$154
Harvester	Floating*	0	0	$0
	Hydrilla	1,558	870,866	$559
	Other	291	117,403	$403
	Total	1,849	988,269	$534

* Waterhyacinth and Waterlettuce

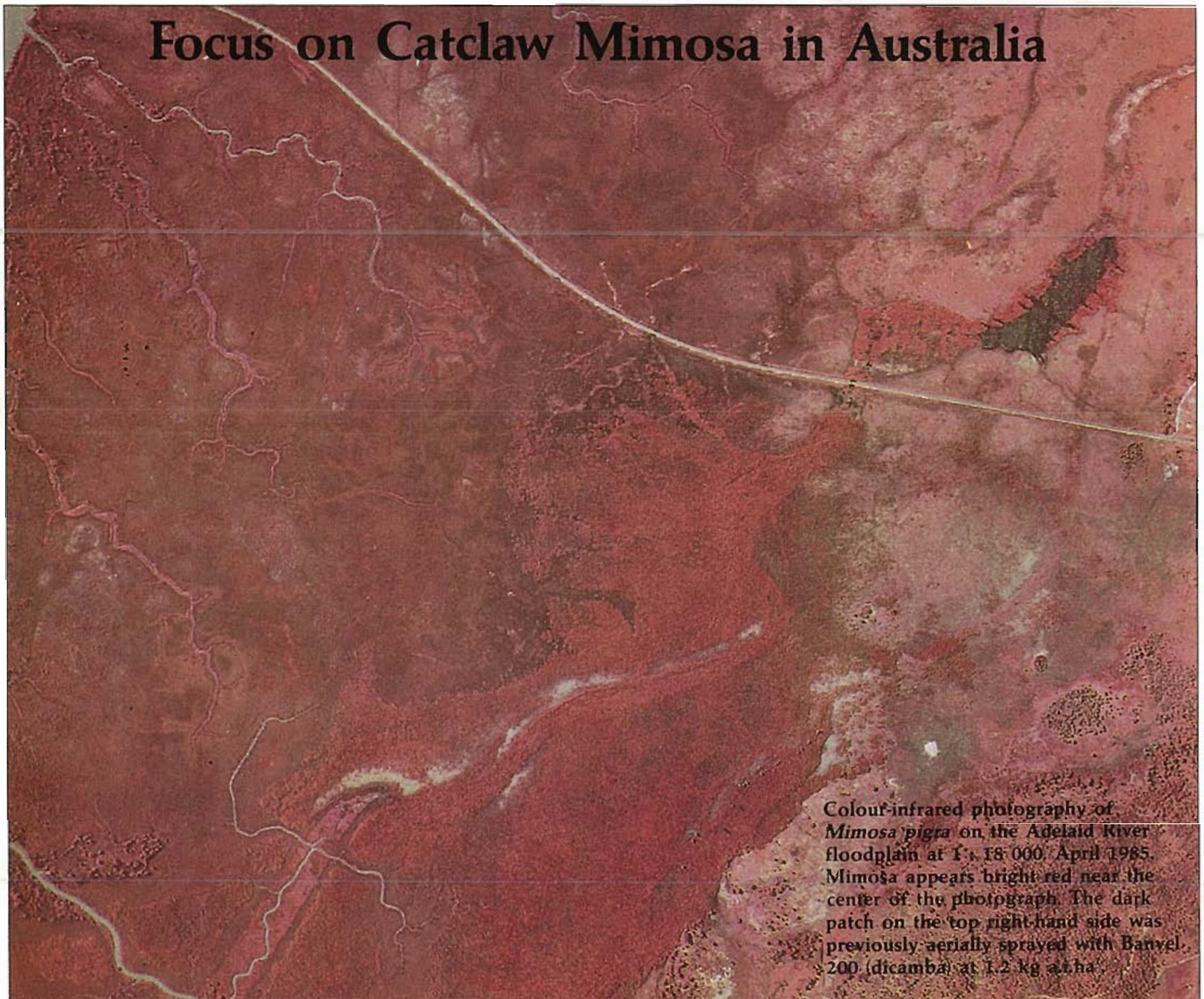
TABLE 4: Public Funds Spent Under The Cooperative And State Funding Programs

Program	Plant	Dollars Spent Per Year 1988	1989	1990
Cooperative	Floating*	2,399,700	2,136,393	1,951,973
State	Floating*	323,550	53,986	63,750
	Subtotal	2,723,250	2,190,379	2,015,723
Cooperative	Hydrilla	3,624,106	4,865,390	3,573,838
State	Hydrilla	2,937,650	101,331	568,440
	Subtotal	6,561,756	4,966,721	4,142,278
Cooperative	Other	90,896	300,120	86,307
State	Other	525,533	434,240	287,566
	Subtotal	616,429	734,360	373,873
	Total	9,901,435	7,891,460	6,531,874

* Waterhyacinth and Waterlettuce

hydrilla management operations could be conducted in their areas. Whether or not these funds will be available in the future is yet to be determined. Several bills were also introduced this past legislative session which could have provided additional state funds for aquatic plant management operations. None of the bills passed. At this time, it appears that federal funding levels will also remain unchanged.

Focus on Catclaw Mimosa in Australia



Colour-infrared photography of *Mimosa pigra* on the Adelaid River floodplain at 1 : 18 000, April 1985. Mimosa appears bright red near the center of the photograph. The dark patch on the top right-hand side was previously aerially sprayed with Banvel 200 (dicamba) at 1.2 kg a.i.ha^{-1}.

By
Ian L. Miller[1] and I. Wendy Forno[2]

Introduction

Ten to 15 years ago little was known about the invasive, prickly shrub *Mimosa pigra*, commonly known in Florida as catclaw mimosa. Since then it has been the subject of intensive research to find control methods particularly for use in Australia and Thailand. It also occurs in, and poses a threat to other Asian countries and has been found in Florida. It will grow on upland sites but wetlands are its favoured habitat.

Classification and Description

Catclaw mimosa is a legume belonging to the family Mimosaceae. There are 400-450 species in the genus *Mimosa* and two varieties of *Mimosa pigra:* var. *pigra* and var. *berlandieri*. The variety in Australia, Asia, Africa and Florida is var. *pigra*. The *berlandieri* is a native of Texas and north-eastern Mexico. *M. pigra* has many different common names in various parts of the world but the most common anglicised names are "mimosa" and "giant sensitive plant." The name used in Florida, "catclaw mimosa," could confuse some people as it is the same common name as that given to *Mimosa biuncifera* in Texas (Vines, 1960)[1].

Miller (1988) and Lonsdale *et al.* (1989) summarized the description of *M. pigra* var. *pigra* from a number of authors. Features of the leaves, flowers and pods are shown in Figure 1.

Distribution and Importance

The native range of catclaw mimosa extends from Mexico through Central and tropical South America. There is a record of seed being sent from Mexico to the Bogor Botanic Gardens in Indonesia in the middle of the last century (Teysmann and Binnedijk, 1866),

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[1]The list of references related to this article is available from the authors.

and there are records from botanic gardens in East India, New Guinea and Australia (Bentham, 1875; Verdcourt, 1979; Miller and Lonsdale, 1987). It seems likely that it was transported to other parts of the world as a botanical curiosity and it now occurs in Australia, Indonesia, Singapore, Malaysia, Thailand, New Guinea, the Philippines, Laos, Vietnam, Myanmar, Africa and the United States.

It is believed to have been introduced to Australia in the late 1800s either with animals or in seed samples (Miller and Lonsdale, 1987). It was not until 1952 that it was reported away from the Darwin city area and since the 1970s it has formed dense monocultures on wetlands. Approximately 80,000 hectares in the Northern Territory are infested, but it would occupy a much larger area if it spread to eastern Australia.

Chemical control has been carried out in Australia since 1965 and has slowed the spread of catclaw mimosa by eradicating small infestations, by keeping it away from roadsides and by controlling the expansion of large infestations. If this was not being done, the current situation would be a lot worse and catclaw mimosa would almost certainly have spread to other states in Australia.

Its detrimental effects in Australia are well documented (Miller *et al.*, 1981; Miller, 1983; Wilson, 1987; Braithwaite *et al., 1989; Lonsdale et al.*, 1989). It competes with native pastures, blocks off access and interrupts livestock mustering. It is also a problem for persons using rivers and floodplains for recreation, for the tourist industry and for conservation of the natural environment.

Catclaw mimosa was introduced to Thailand from Indonesia in 1947 as a green manure and cover crop (Wara-Aswapati, 1983; Napompeth, 1983). The worst infestations are in the northern provinces, where it obstructs and diverts water flow, causes sedimentation in rivers, canals and reservoirs, and increases the severity of flooding and erosion. It is also a safety hazard along roads and interferes with access to power lines (Robert, 1982; Napompeth, 1983; Thamasara, 1985). It is not important in intensively cultivated agricultural land in Thailand but it does greatly increase production costs when clearing it from fallow land (B. Napompeth, pers. comm.).

The first report of catclaw mimosa in Florida was in 1953 (Schmitz, 1990). The area currently infestated is less than 150 hectares and is being contained with herbicides (Westbrooks and Eplee, 1987; R. Kipker, pers. comm.) . Because of its importance as a weed, catclaw mimosa has been given noxious weed or similar status under weed or quarantine legislation in Australia, Thailand, Malaysia and the United States.

Dispersal and Growth

The hairy seed segments float and floodwaters readily disperse the seeds. Seeds are also distributed in the faeces of animals and in mud on their bodies, on vehicles and as a contaminant in river sand moved for construction purposes.

The seed fall in dense Northern Territory populations is about 9000 seeds per m² per year (Lonsdale, 1988). Most flowering and seeding occurs in the mid to late wet season, and when seed-fall coincides with a flood, infestations rapidly expand. The doubling time of populations is about one year (Lonsdale *et al.*, 1989).

Much of the seed becomes hard or dormant, which allows for germination to take place over a long period from a single crop of seeds. The half-life of seeds depends on soil type, varying from 9.4 weeks at the surface of a black cracking clay to 99.0 weeks at a 10 cm depth in a light sandy clay (Lonsdale *et al.* 1988). Observations in a sandy soil suggest that seeds can germinate over at least 25 years (S.E. Pickering, pers. comm.), hence control of seedlings needs to be maintained for many years after eradication of mature plants.

There is a strong seasonality in growth rate in areas where there is a marked wet and dry season (Miller 1988), but it will grow and flower year round when temperature and moisture are favorable (Miller, 1983; Wara-Aswapati, 1983) Maximum growth rates recorded by Miller (1988) were 40 cm per month in seedlings and 33 cm per month in plants more than 12 months old. These plants germinated and matured in the same wet season and flowered when only 5-6 months old.

Control

Catclaw mimosa is not an easy plant to control. There are many characteristics of the plant, the environment, land use and the types of herbicides used that have impeded the success of control (Miller 1988).

Integrated control methods are being developed and used in Australia and Thailand (Harley *et al.*, 1985; Miller, 1988; Lonsdale *et al.*, 1989; Forno *et al.*, 1990). Small, isolated plants can be removed manually, but manual removal of large plants or dense thickets is not practical. Cutting the stems off at ground level is ineffective as the plants will regrow rapidly.

Many herbicides and application methods for use in different situations have been tested. The methods used include foliar application from the ground and air, soil application, cut stump, stem injection and basal bark applications. The latter three methods are useful for small infestations and where drift may damage nearby susceptible crops. Spot applications of residual herbicides to the soil have similar advantages where a small area can be sacrificed or where a herbicide with some selective action is used such as tebuthiuron.

The herbicides currently recommended for control of catclaw mimosa in Australia and Thailand are dicamba, glyphosate, fluroxypyr and metsulfuron methyl as foliar sprays; dicamba, hexazinone, imasapyr and triclopyr as cut stump applications; triclopyr as a basal bark spray; dicamba and hexazinone as stem injections; and ethidimuron, hexazinone and tebuthiuron as soil applications. Details of the rates of application for these herbicides and the land use situation where they are recommended were reported by Forno *et al.* (1990).

In Australia large areas (7,000 hectares in 1989/90) of catclaw mimosa have been treated by aerial application of tebuthiuron at 1.5 kg a.l/ha and fluroxypyr at 600 g a.i./ha. Some dicamba as the dimethyl amine salt at 1.2 kg a.l/ha is also used. Landholders are assisted by an aerial spraying subsidy scheme. Large parts of the wetlands dry out in the dry season, hence enabling the dry pellet formulation of tebuthiuron to be used. Miller (1988) found that the response of catclaw mimosa to tebuthiuron varies between land systems and soil types. At one site it persisted for 18 months and reduced seedling density in the following year. In commercial applications its residual effect seems to vary and areas require retreatment to kill seedlings. With the use of foliar applied dicamba, a more rapid defoliation response and a higher level of kill is obtained when it is applied in the wet season than in the dry season.

Herbicides for use on catclaw mimosa in Florida must be labelled for aquatic use if the plants are found in wet areas (W.T. Haller, pers. comm.). The only two herbicides which are effective and so labelled are dicamba + 2,4-D combinations and glyphosate.

There are many insects and fungal pathogens which severely damage catclaw mimosa in its native range. Several of these are host specific to mimosa and are therefore safe for release into the introduced range of this weed. The most promising biological control agents include moths whose larvae tunnel and weaken stems, weevils which destroy flower buds and green seed pods, beetles which destroy mature seeds and fungal pathogens which cause severe leaf drop, die-back of the plant and produce cankers on the stems which debilitate it. The combined action of these agents should weaken the plant, reduce the densities of infestations and allow other plant species to compete with this weed.

Research is well advanced for the introduction of biological control agents into Australia and Thailand. The bruchida beetles, *Acanthoscelides puniceus* and *A. quadridentatus* were released in Thailand and Australia in 1983, and although they have had little impact to date they may become more effective as the plant is stressed by other biological control agents. The moth, *Neurostrota gunnniella* (Gracillaridae) was released in Australia in 1989, became established and spread rapidly during the first year (Wilson and Flanagan 1990). It prefers thin stems and more than 90% of tips may be damaged on a plant. Another stem-boring moth, *Carmenta mimosa* (Sesiidae), was released during the same year (Figure 2). It has established, is spreading naturally and it is anticipated that it will complement the damage caused by *N. gunniella.*

The weevil, *Apion aculeatum* (Apionidae) destroys flower buds and should be released in Australia and Thailand during 1991. Several other weevils which attack the reproductive parts of the plant are being studied. The host range of the fungi, *Diabole cubensis* and *Phloeospora sp.,* are currently being assessed and both are potentially safe and effective agents.

Fire has been investigated as a control method in Australia (Miller, 1988; Miller and Lonsdale, 1990) but green catclaw mimosa is difficult to burn. It also possesses adaptive traits which stimulate it to regrow after fire. A higher percentage of seedlings are killed, but they too are resistant, with more than 50 regrowing after a fire. Fire results in a higher level of seed germination on the soil surface, or within 5 cm of the surface, by scarifying the hard seed coat. Some of the seed on the surface is killed by fire (Miller, 1988). Fire alone will not control catclaw mimosa but it can be most useful to clean up sprayed areas and to enhance the kill of plants which have been stressed by herbicides or some other control method.

The dominance of catclaw mimosa in Australia was probably facilitated by overgrazing of the floodplains by feral water buffalo (Lonsdale *et al.* 1989) and by removal of the floodplain flora by fires. The seedlings of catclaw mimosa are susceptible to competition from grasses (Miller, 1988), so a logical sequel to application of herbicides and successful burning is to plant competitive pastures or to allow recolonization by native herbaceous species. This should help suppress regeneration from seed.

The practice of planting pastures may also be important for successful biological control. Burdon *et al.* (1981) pointed out that if the use of competing pasture plants is integrated with the use of natural enemies, then ecological control of the weed is more likely.

The Future

We know a lot about catclaw mimosa: its history, distribution, biology, its detrimental effects and methods of control. There now needs to be a commitment to practical implementation of this knowledge and a continuation of the research to give more effective control than at present. In Australia, the spread of catclaw mimosa and its detrimental effects on primary industry (agriculture) and the environment were predicted in the 1960s and 1970s (Miller *et al.*, 1981; Miller 1983) and the problem may have been averted if recommendations for larger control programs had been implemented at that time (Miller and Pickering, 1983).

In the 1990s it is fortunate that it is politically wise to be aware of environmental issues. It is finally being recognized in Australia that catclaw mimosa is potentially a national problem—not just a Northern Territory problem—and increased resources are being devoted to control efforts. This impetus must continue until effective biological control is achieved.

In the short-term, catclaw mimosa is certain to become more widespread in Asia and Australia unless the current chemical control programs are expanded. In the immediate future there must therefore be continuing financial commitments by governments and private landholders to chemical control. The aims of the chemical control programs are to slow down its spread while biological control research is progressing, to eradicate new isolated infestations, to control it where the land is required for traditional aboriginal uses, conservation reserves, livestock grazing or for more intensive development, and to have a back-up of alternative technology in case natural enemies do not achieve the desired level of control.

Leaves, flowers and pods of catclaw mimosa.

In Thailand there are eight heavily infested northern Provinces. It is important that isolated infestations in the center and south of the country be eradicated to prevent rapid expansion in these areas. To this end a mobile team has been established in Thailand under a collaborative project between Australia and Thailand, funded by the Australian Centre for International Agricultural Research.

In other parts of Asia catclaw mimosa will become increasingly important, particularly in and around water reservoirs and irrigation systems. Small infestations can be eradicated with the judicious use of chemicals. However, the integration of chemical and biological control must be used against larger infestations. Results of the collaborative project between Australia and Thailand are available to all countries (Forno *et al.* 1990).

In Florida, where there are fewer and smaller infestations than in Australia and Thailand, it is important that these be eradicated if possible, before the situation worsens and the weed becomes established in Florida's wetlands. However this weed has proved notoriously difficult to eradicate, either manually or with the use of chemicals, often because of limited resources.

Future research needs to refine rates and methods of herbicide application, test selective herbicides with residual action, monitor the action and the fate of herbicides in floodplain ecosystems, continue the search for a complex of biological control agents that attack different parts of catclaw mimosa and test the ability of native and introduced pastures to compete with seedlings.

In all countries the continuation of publicity on the dangers of this plant, and the implementation of recommendations to prevent its further spread, will greatly assist in limiting catclaw mimosa to its present geographic range.

Larva of *Carmenta mimosa* tunnelling in a stem of catclaw mimosa.

Acknowledgments

We appreciate the valuable comments made on the manuscript by Dr W. M. Lonsdale of CSIRO Division of Entomology, Mr C. G. Wilson, Department of Primary Industry and Fisheries and Dr. W. T. Haller of the Center for Aquatic Plants, University of Florida.

AQUAVINE

GOODBYE AND HELLO DEPARTMENT

Adios to Anne Galloway

Ms. Anne Galloway has resigned from the US Army Corps of Engineers aquatic plant section in Jacksonville. We'll all miss Anne's capable assistance and quick wit as she moves on to fully dedicate herself to her family. Anne, there'll always be a seat on the airboat kept warm for you!

Adios to Matt Beaver

Clewiston Corps biologist Matt Beaver is packing up some hyacinths and transferring to another Corps project, Tioga-Hammond Lakes in northern Pennsylvania. His work there will be alot like his work here, only much colder and easier. Matt's been a big help on Lake Okeechobee in particular and the Lake Okeechobee interagency group has, by unanimous proclamation, elected him Grand Poobah Beaver Plenipotentiary. Happy Trails, Matt!

Buenos dias to Catherine Robbins

Greetings to biologist Catherine Robbins who is joining the Corps' aquatic plant section. Catherine is transferring from the Corps' regulatory and permitting section. We hope she'll enjoy this new and eccentric field. As points of interest, Catherine's favorite color is blue, she likes quiet walks in the moonlight, Mongo Jerry albums and poorly-dubbed Italian Hercules movies.

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EARLIER THE FREEZE, LONGER 'TIL WINTER WILL CEASE

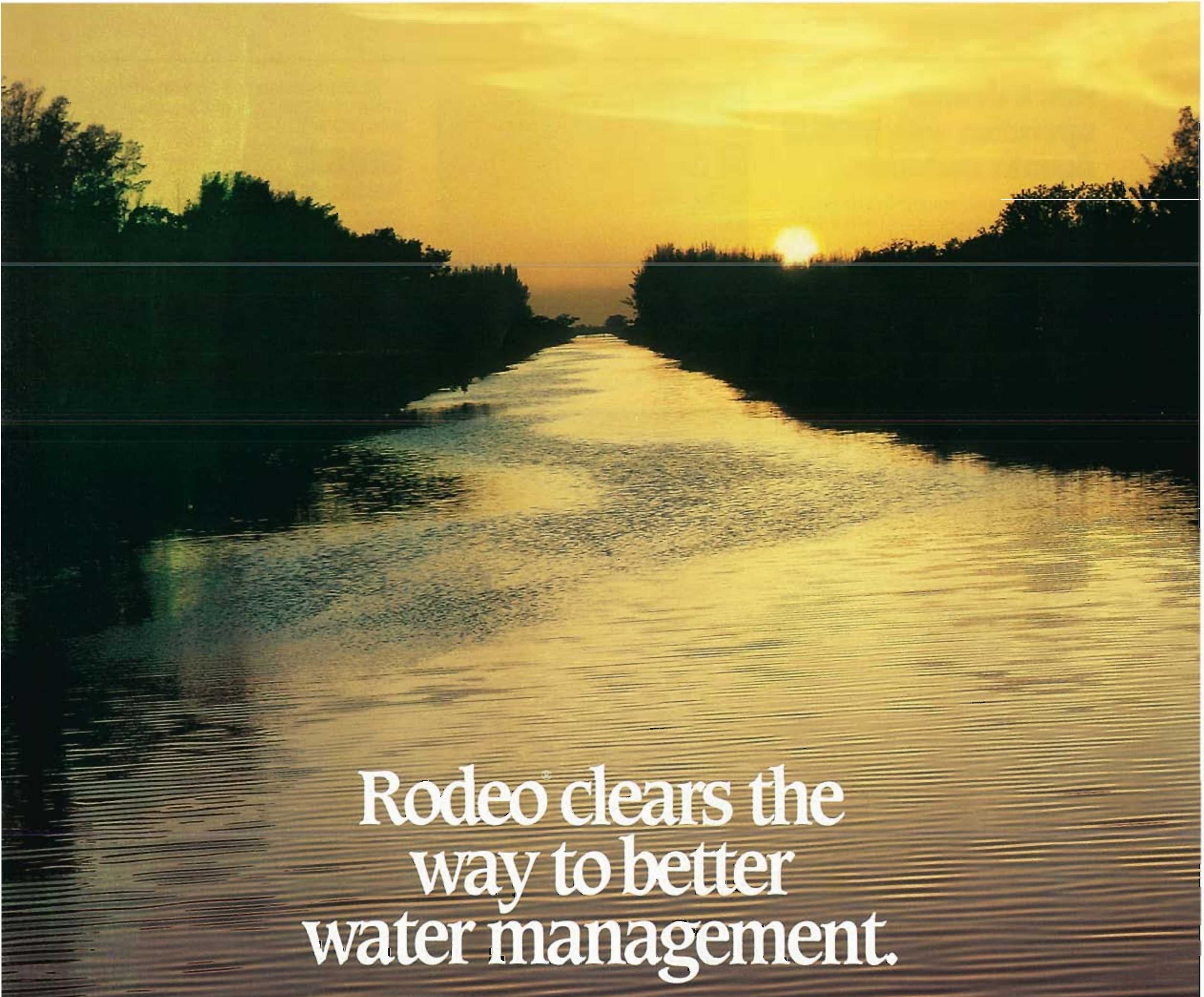
The earlier the first freeze, the more likely Florida will have a severe winter, a new University of Florida (UF) study finds. UF geographer Steve Hilfiker studied 40 years of winter temperatures recorded at 55 weather stations throughout Florida. He found that early freezes were harbingers of the winters to come.

"Early freezes are a much better omen than the groundhog, whose shadow is supposed to predict the weather to follow," he said. "Records show that winters with early freezes generally had a greater number of freezes and more severe freezes than other winters."

AQUASCAPING AND EXOTIC SPECIES CONTROL MANUALS AVAILABLE

Aquascaping: Planting and Maintenance, Circular 912 is a new University of Florida Institute of Food and Agricultural Sciences (IFAS) publication. The manual addresses the recent surge in interest in landscaping in and around water. Planting and maintenance are highlighted as the authors hold that these, "two areas account for most of the problems people encounter in landscaping." The manual introduces concepts of aquascaping, describes dozens of recommended plants, and warns of plants to avoid and those legally prohibited from use. The manual is available from:
IFAS Publications, University of Florida, Building 664, Gainesville, FL 32611, (904) 392-1764

Also, the ever-popular IFAS manual *Exotic Woody Plant Control, Circular 868* has been reprinted. It details control methods for four of Florida's woody pest plants: melaleuca, Australian pine, Brazilian pepper, melaleuca, Asiatic colubrina and melaleuca. You can get it from the above IFAS address.



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