AQUATIC WEEDS IN FLORIDA

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INTRODUCTION

The topography and semi tropical climate of Florida (latitude 25-31°N) are particularly conducive to the growth and proliferation of aquatic weeds. Warm temperatures result in plant growth nearly all year over much of Florida, and underlying phosphate and carbonate rock provides an abundance of naturally-occurring plant nutrients. Lakes in Florida are characteristically very shallow and contain large littoral areas. South Florida has extensive canal systems designed to control flood waters and allow agricultural use of the productive organic soil around Lake Okeechobee. In general, the majority of the one million hectares of fresh water is composed of fertile, shallow lakes and man-made canals.

The large proportion of littoral areas in Florida lakes provide a large forage base for largemouth bass [Micropterus salmoides floridanus (Lacepede)] and other sport fishes (Barnett and Schneider 1974). Freshwater recreational fishing has been estimated to consist of over 400 million dollars annually, including boat purchases, motors, bait, tackle, and other items. In the 10 year period (1967 to 1977), registration of recreational power boats has nearly tripled from 149,663 boats in 1967 to 422,398 in 1977 (Cato and Mathis 1979). In 1977, 1.33 million Florida residents purchased fishing licenses (or combined hunting and fishing licenses), providing a total of over one million dollars in annual license fees. In addition, many tourists visit Florida for the purpose of recreational fishing. In 1977, 192 thousand non-resident fishing licenses were purchased, bring the state an additional 1.3 million dollars in license fees.

Sport fishermen are not the only beneficiaries of clean Florida waters. Although it is not an extensive industry, a few commercial fishermen derive their livelihood from Florida's fresh waters. By far, the major value of water in Florida is derived from the aesthetics of living near water and the resultant increased land values, and recreational boating, swimming, and related water activities. Irrigation canals permit large-scale agricultural production of sugarcane, vegetables, and citrus, and drainage canals are essential for flood control. In summary, an abundance of clean fresh water is important to Florida's economy. Aquatic plants contribute to productive fish and wildlife populations and concurrently often interfere with navigation, flood control, and other water uses.

AQUATIC WEEDS

Although plants are important to the aquatic environment, an overabundance of plants becomes a hindrance to water activities. Native aquatic plants (Ceratophyllum, Najas, Typha, Pontederia, etc.) occasionally grow excessively and adversely affect water use. However, natural controls such as water level changes, weather extremes, turbidity, or other natural factors frequently maintain native plants at a desirable or tolerable level. If control or management are required, a single herbicide treatment often provides control for two to three years. Currently, the most serious weeds in Florida are the introduced or exotic species such as waterhyacinth (Eichhornia crassipes (Mart.) Solms) and hydrilla (Hydrilla verticillata Royle).

Waterhyacinth was introduced into Florida in the late 1800's and spread rapidly, causing navigation problems in the St. John's River within 10 years after introduction (Zeiger 1962). Hydrilla is a submersed plant which was first found growing in Florida in 1960. For several years it was sold as an aquarium plant and was also spread throughout Florida by boats and trailers (Haller 1976). Hydrilla has a lower light requirement than native submersed plants and consequently grows in deeper water where native plants cannot survive (Van et al. 1976). The vast, diverse littoral zone of Florida lakes, which is so important to sportfish production, is an ideal habitat for waterhyacinth and hydrilla. Hydrilla, because of its lower light requirement, can grow in deeper water than native species and often occupies 80 to 90% of the surface area of many lakes. This profuse growth in effect, increases the littoral zone dramatically, and hinders navigation, flood control, recreational use of water, and can adversely affect sportfish populations (Bennett 1948).

Waterhyacinths are currently under control throughout most of Florida as a result of intensive maintenance programs. These programs rely on the use of herbicides (primarily 2,4-D and diquat) and maintain small fringes of waterhyacinths which are not allowed to grow to troublesome extent. Recent data indicates that on a long-term basis, maintenance control programs result in the use of less herbicide and less detrital or sediment formation (Haller, Univ. of Florida, unpublished data). In order to further reduce the use of chemical control three species of insects (Neochetina brucchi Hustache, Neochetina eichhorniae Warner, and Sameoides albiguttalis Warren) have been released in Florida to retard the growth of waterhyacinths (Zeiger 1979). In addition, a fungal disease is being studied as an additional means of controlling waterhyacinth. Through a combination of effective and relatively inexpensive chemical control and the introduction and development of biocontrol agents, waterhyacinths are currently managed and kept under control.

Hydrilla, on the contrary, is spreading throughout Florida and the United States, and presently there are no methods that are economically feasible to stop its spread. From its initial discovery in Florida in 1960 (Figure 1), it spread to several areas by 1967 (Figure 2), covering an estimated 2,000 ha. In 1977 (Figure 3), hydrilla was present in virtually every major watershed in Florida and was commonly found in about 25% of Florida's fresh waters (250,000 ha). Essentially all waters in the state are threatened by this competitive submersed species. Hydrilla is now present in Alabama, Mississippi, Georgia, South Carolina, Louisiana, Texas, California and Iowa (Figure 4).

There are two major reasons why hydrilla cannot be effectively controlled. Primarily, hydrilla is a submersed species and grows under water where dilution of herbicides requires higher application rates. Hydrilla, therefore, is virtually impossible to control chemically in flowing water. The second reason is the profuse vegetative reproduction and regrowth of hydrilla (Haller 1976). Hydrilla produces underground tubers which are unaffected by control methods and remain viable for many years (Miller et al. 1975). Chemical treatments essentially shear and kill most of the plant biomass in the water column, leaving viable plant crowns, rhizomes, stolons, and plant fragments on the bottom as a source of re-infestation. The rate of regrowth depends upon local conditions of turbidity, water temperature, and etc., but often three chemical treatments a year are required for satisfactory hydrilla control in central Florida.

Ditchbank, emergent, and semi aquatic plants which grow in the transition zone on pond berms and canal banks are also a major problem, particularly in agricultural canals. These plants significantly reduce water flow, provide habitat for mosquitoes, and periodically require control as a part of canal and ditch management.

COST OF AQUATIC WEED CONTROL

It is virtually impossible to determine the precise costs of weeds to society due to the intangible values placed on recreation, aesthetics, health problems, and other values related to weed growth. The economic impact of aquatic weeds is particularly difficult to assess, and likewise, the level of funds to be expended for an economically productive aquatic weed control program cannot be accurately determined. For example, as a lake becomes overcome with a submersed weed, recreational boating, fishing and swimming are greatly reduced. In the immediate lake area, boat sales, gasoline, fishing supplies, food and beverages and a myriad of other items are reduced. The question which arises is, "How much funds should be expended to sufficiently control weeds in the lake to provide an economic return on the weed control effort?" The answer is different for each body of water and is unknown totally.

An estimate of the funds expended for aquatic weed control in Florida has been compiled for 1977 (Table 1). These values combine the cost of all control methods, however, approximately 70% of aquatic weed control is accomplished with herbicides. The remaining 30% is by mechanical means, the majority of which is spent for mowing, cleaning canals and mechanical control of ditchbank vegetation. Submersed weeds are mechanically harvested or mowed in some canals and lakes, but this has not been extensively practiced. More modern, efficient equipment is being developed, however, and mechanical harvesting of hydrilla is becoming more economically feasible in some situations (McGehee 1979). Mechanical control of waterhyacinth is seldom used due to the bulk (up to 150 m.t./ha) and high cost of physical removal. The type of control used in Florida is dictated by economics, or simply the cost of control per hectare per year, and environmental safety. Herbicides are available which are more effective and less expensive than those currently used in aquatic weed control. However, environmental safeguards require that aquatic herbicides have low toxicities and be rapidly biodegradable.

The data presented in Table 1 is an approximation of funds expended for aquatic weed control. Data from public agencies is accurate, however, it is entirely possible that monies spent by the private sector has been underestimated. The $20,810,000 spent in 1977 is best described as a conservative estimate, due largely to the fact that many large (2,000 ha and larger) citrus, vegetable, and sugarcane farms implement their own aquatic weed control programs in irrigation and drainage canals.

Surprisingly, ditchbank weed control is a very significant problem in relation to other weed problems, and there are no major research programs in progress to study the chemical, mechanical, or biological control of these weeds. Individually, ditchbank weeds require little control, however, collectively, they total a significant 8 million dollars.

Expenditures for ditchbank weeds and waterhyacinth have remained stable over the past 10 years. The rapid expansion of hydrilla has nearly doubled the weed control budget and has brought tremendous attention to aquatic weed control problems.

CHEMICAL CONTROL

There are 113 trade named herbicides registered for use in or near Florida waters. Most of these are formulations of only 8 to 10 active ingredients. For example, 2,4 dichlorophenoxy acetic acid (dimethyamine formulation) is primarily used in waterhyacinth control. In 1977, 304 kl (80,000 gallons) of 2,4-D[1/] was used by public (state, local and federal) agencies in waterhyacinth control programs. The cost of waterhyacinth chemical control programs was estimated to be $95/ha in 1977, which was divided roughly into three portions; one-third for chemical purchases, one-third for equipment, and one-third for labor expenses.

Hydrilla is the predominant submersed weed requiring chemical control in Florida. Approximately 15,000 ha of hydrilla were treated chemically in 1977 by public agencies. The cost of hydrilla control varies greatly depending upon the herbicide selected, site, density of infestation, etc. Basically, the costs vary between $190 to $625/ha with an average expense including labor, equipment and chemicals of approximately $500 per hectare per treatment. Three herbicides are primarily used; diquat in combination with copper (ratio of 19 l of diquat: to 38 l of liquid chelated copper/ha) or 38 to 52 l of endothall per hectare. In 1977, public agencies used approximately 190 kl (50,000 gallons) of diquat in submersed weed and hyacinth control, 266 kl (70,000 gallons) of copper compounds, and 190 kl (50,000 gallons) of endothall based compounds.

Ditchbank and emergent chemical weed control involves the use of many herbicides but the primary ones used are dalapon (23,000 kg of formulation) on monocots, and various phenoxy compounds on dicots (10- to 15,000 kg formulation). The cost of chemical control of ditchbank weeds is quite variable, but $190 to $225/ha is a valid estimate.

1/ The active ingredient content of the commonly used formulations are: 2,4-D - 50%, diquat - 35%, liquid copper complexes - 8 to 9%, and endothall 40 - 50% active ingredients.

BIOLOGICAL CONTROL

It is apparent that of the aquatic weeds in Florida, hydrilla is spreading most rapidly and is by far the most expensive to control. The prospects for development of new, inexpensive herbicides or more efficient mechanical harvesting equipment within the immediate future are not great. Consequently, research has to formulate more effective weed control programs with current technology or develop new, alternative control methods.

The discovery and successful widespread use of the alligatorweed flea beetle (*Agasicles hygrophila* Selman and Vogt) for control of alligatorweed (*Alternanthera philoxeroides* (Mart.) Griseb.) in the 1960's has provided impetus to study biological control of other aquatic plants (Maddox et al. 1971, Spencer and Coulson 1976). Three insects have already been studied and released on waterhyacinths in the United States, and a host specific fungal pathogen (*Cercospera rodmanii* Conway) is currently being developed (Freeman 1977, Charudattan 1979).

There are literally hundreds of thousands of insect species in the world, however relatively very few inhabit the submersed aquatic habitat where hydrilla thrives. The search for insect biocontrols for hydrilla has not yet yielded any significant insect candidates (Zeiger, personal communication). Recently, a fungal pathogen (*Fusarium culmorum*) was isolated from plants from Holland and is most promising for hydrilla control. Extensive field studies are planned beginning in 1979 (Charudattan 1979).

Biological control studies of hydrilla with snails (*Marisa cornuaretis* L.) has been extensively studied in Florida. It was found that *Marisa* was not a significant biological control because it was temperature sensitive and very high stocking densities were required (Blackburn, Taylor and Sutton 1971).

Several species of fish have been considered as candidates for the biological control of submersed aquatic weeds (Blackburn, Sutton and Taylor 1971, Legner et al. 1975). The species receiving the most attention for hydrilla control in Florida is the Chinese Grass Carp or White Amur (*Ctenopharyngodon idella* Val.).

The first field research in Florida was initiated in three small (0.08 ha) earthen ponds in central Florida in 1971. This nonreplicated study (completed in January, 1973) showed that the grass carp at stocking rates of 50 fish/ha was capable of controlling hydrilla without catastrophic effects on the aquatic environment (Haller and Sutton 1976).

Further major research was undertaken by the Florida Department of Natural Resources and the Florida Game and Fresh Water Fish Commission in 1972 (4 pond study). Four natural ponds in widely scattered geographical locations were stocked with grass carp after a one year collection of baseline data. The diverse interpretation of the results of these nonreplicated studies has become widely known by the world's fishery scientists (Beach et al. 1976, Gasaway et al. 1978).

In 1974, six lakes (over 50 ha each) and one reservoir (2,000 ha) were stocked with grass carp to further determine their weed control capabilities and potential environmental impact. This research is still incomplete as three of the lakes have become entirely weed free and three other lakes still contain hydrilla infestations. In one lake, at least, the apparent lack of biocontrol resulted from low residual grass carp populations (Colle et al. 1978). Restocking programs have begun on the remaining vegetated lakes and the reservoir.

Due to the unpredictable results obtained with grass carp, and the unanswered questions concerning its possible impact on sport fish populations, there remains considerable controversy among Florida biologists with regard to the widespread use of the fish in hydrilla control programs. The purpose of this conference is to share our knowledge with the world's experts in the culture, production and biology of the grass carp. The most important questions that arise in the use of the grass carp in Florida are:

1. Will the grass carp reproduce under natural conditions in Florida, and if they do, what are the likely environmental consequences?

2. Can the grass carp be "managed" so that it controls only hydrilla or a portion of the hydrilla in the littoral zone, or will it remove all vegetation from a lake, including emergent plants?

3. Native fish populations in Florida are often found to be nearly 200 to 300 kg per hectare. What is the effect of the addition of twenty- 10 kg grass carp or a doubling of the fish biomass going to have on the carrying capacity of the native fisheries?

4. Finally, how will aquatic weed control by grass carp affect phytoplankton, nutrient cycling, and other aspects of water quality?

Currently, the State of Florida allows private possession of the grass carp by individuals with weed problems in lakes of 10 ha or less which are not connected to other water bodies. The rules (16 C-21) allow stocking by permit only in private waters which meet specific criteria (size, weed problems, lack of infall or outfall). Thus, the grass carp is currently in use in golf course ponds, fishery ponds, and waters of similar nature.

The widespread application of the grass carp to solve hydrilla problems in large lakes has been deferred until further studies are conducted. The problem is, that hydrilla continues to spread and cause problems, current control measures are expensive, and the answers to the four questions posed earlier may take several years to answer.

ACKNOWLEDGMENTS

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Table 1. Expenditures for various types of aquatic weed control in Florida in 1977.

Agency	Hydrilla (x 1000)	Ditchbank[1/] (x 1000)	Waterhyacinth (x 1000)
Florida Department of Natural Resources[2/]	$1,500	$1,200	$ 200
District, city, county[3/]	5,500	5,000	800
Florida Game and Freshwater Fish Commission[4/]	100	10	1,200
U. S. Army Corps of Engineers[5/]	0	0	800
Private enterprise[6/]	2,000	2,000	500
TOTAL	$9,100	$8,210	$3,500

1/ Ditchbank weeds include many species of emergent and semi-terrestrial plants such as cattails (*Typha* sp.), reeds (*Phragmites*), grasses and sedges (*Cyperus*, *Paspalum*, *Panicum* spp., etc.), pickerelweed (*Pontederia* sp.), brush (*Melaleuca*, *Cephalanthus*, *Myrica*, *Schinus*, *Salix* spp., etc.), and others. Mechanical control (draglines, shovels, etc.) is often used for ditchbank weed control and serves a duel purpose of weed control and cleaning, widening, and deepening canals and ditches.

2/ The Florida Department of Natural Resources Bureau of Aquatic Plant Research and Control was established in 1970 and directs the state funding program in cooperation with local city, county, and district agencies.

3/ This category represents the local weed control authorities which raise money through local taxes for matching (obtaining) state monies from the Department of Natural Resources.

4/ The Aquatic Plant Control Section of the Florida Game and Freshwater Fish Commission is the operational agency for the state. Funds from state, local, and federal agencies provide the Commission with personnel and equipment to control all types of weeds.

5/ The U.S. Army Corps of Engineers by public law is charged with maintaining navigation and is the major source of federal funds for aquatic weed control. In 1977 the Corps was only authorized to control waterhyacinths; however, approval for control of additional weed species (*Hydrilla* and *Pistia*) was recently received.

6/ Private enterprise is the most difficult category to estimate because individuals do not apply for state matching funds. This category includes commercial weed control businesses, corporations, private landowners, etc. Estimates in the Table are undoubtedly conservative, particularly for ditchbank weeds.

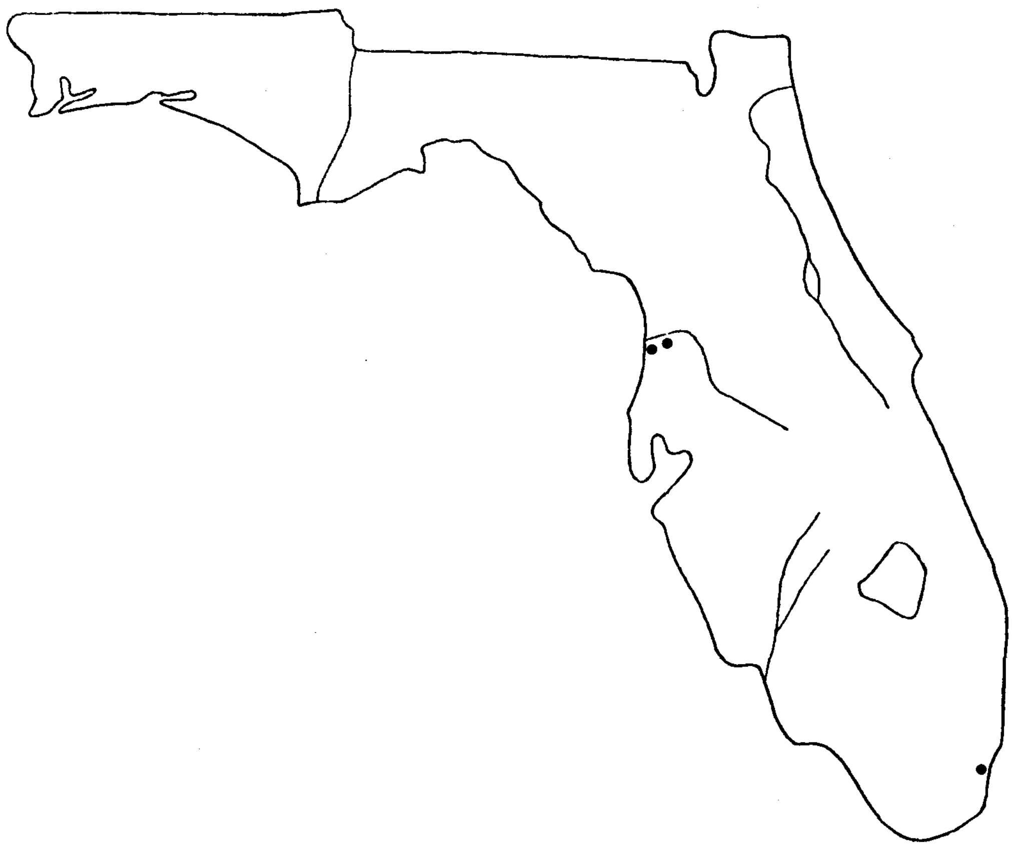

Figure 1. Known distribution of hydrilla in Florida in 1960. The total infestation in both Crystal River and the Miami River was approximately 10 ha.

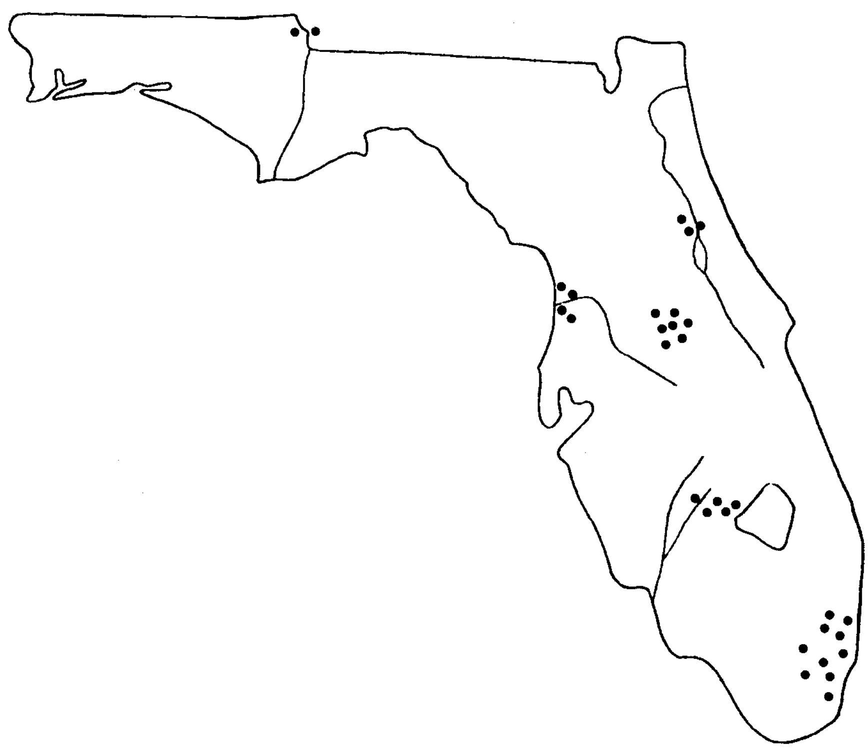

Figure 2. Distribution of hydrilla in Florida in 1967. Total area infested was estimated to be 1,500 to 2,000 ha.

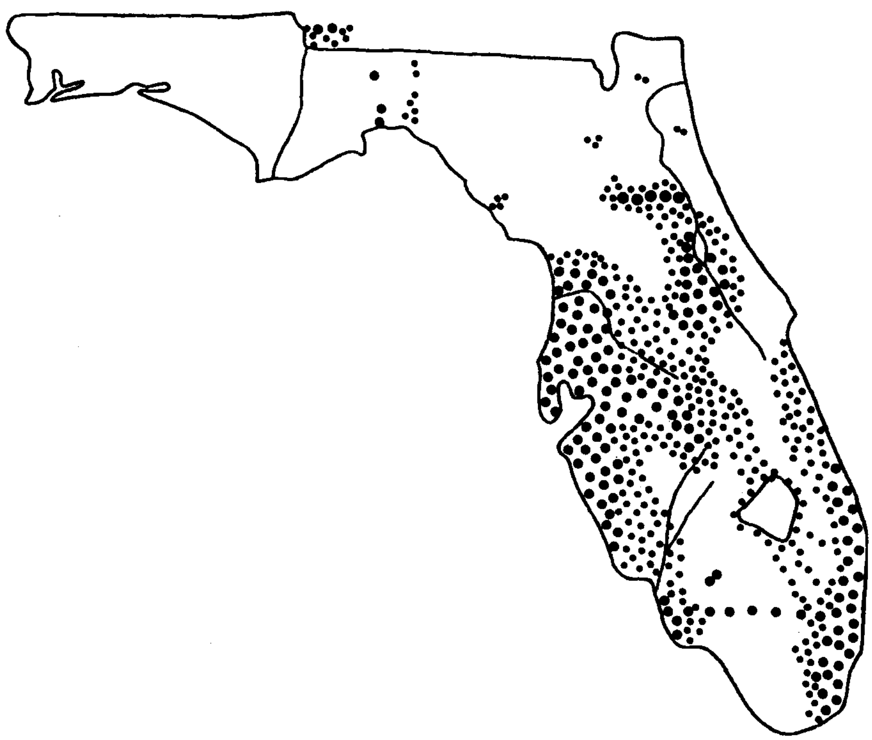

Figure 3. Known distribution of hydrilla in 1978. Larger dots represent dense infestations totaling some 40,000 ha, and smaller dots indicate hydrilla common in the flora of an additional 200,000 ha of Florida's fresh water.

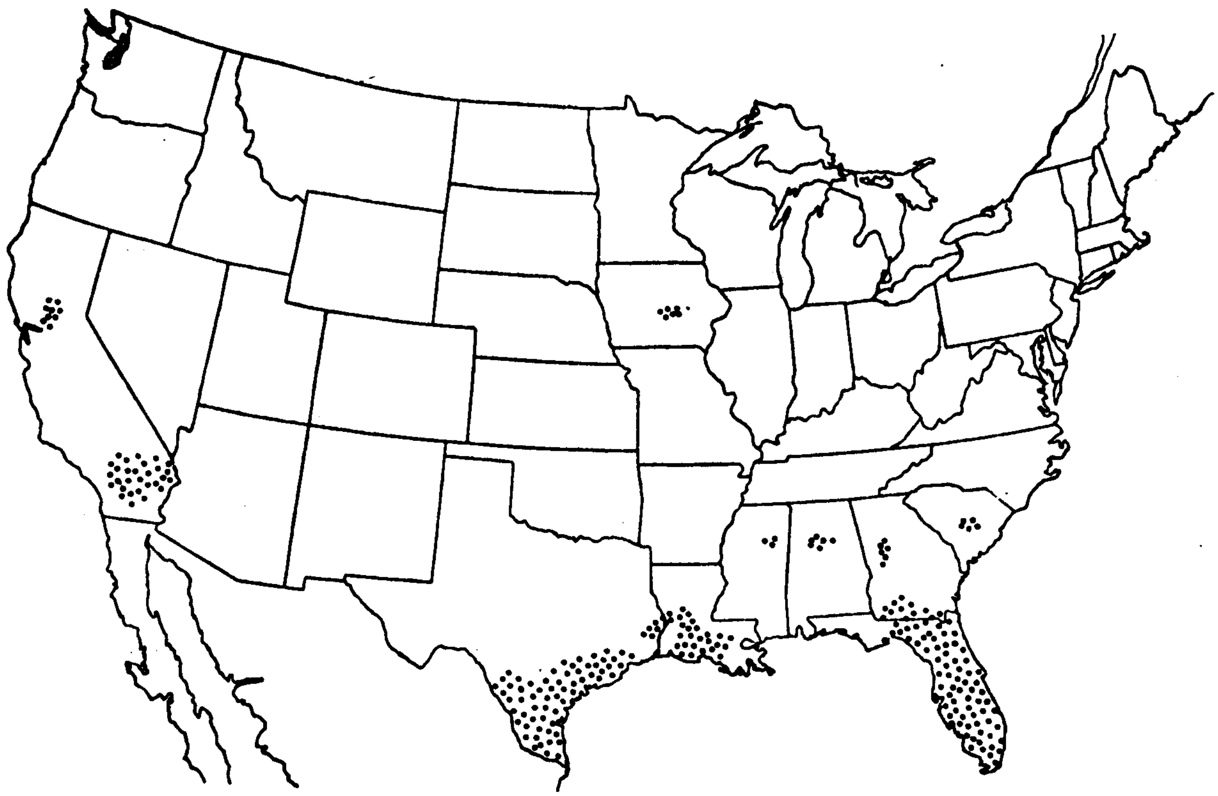

Figure 4. Distribution of hydrilla in the United States, 1978.