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INSECT ENEMIES OF AQUATIC WEEDS

Neal R. Spencer*

INTRODUCTION

Numerous species of aquatic plants attain prime importance as weeds due to luxuriant vegetative growth and vigorous adventive spread. Indeed, since about 1850 almost the only interest in these hydrophytes has been the need to control them (Sculthorpe, 1967).

Many emergent hydrophytes create local problems by forming dense, pure stands in slowly flowing rivers, at lake and reservoir margins, in shallow waters of irrigation channels and drainage furrows, and amongst tropical subaquatic crops. Such extensive growth impedes water flow, increases siltation and flooding, and is a plague to fishing and boating enthusiasts. Alligatorweed (*Alternanthera philoxeroides* (Mart.) Griseb.), *Typha* spp., and *Phragmites* spp. fall into this class of weed.

Submerged and floating-leaved weeds often are of only local importance. Even so, their effects are frequently drastic if controls are not provided. They may restrict the use of lakes and small rivers and impede water flow in drainage canals. *Myriophyllum spicatum* L., *Hydrilla verticillata* Royle, *Ceratophyllum demersum* L., and *Elodea* species are examples of this kind of problem weed.

Many aquatic plants have been classed as weeds because their luxuriant growth has disturbed man's use of the hydrosphere. This problem has been brought about by the adventive spread of the plants and the increased nutrients available. In the tropics and subtropics, waterhyacinth, *Eichhornia crassipes* (Mart.) Solms, is the major aquatic weed problem. Originally described from Brazil in 1823, this free-floating weed has spread to all the major land areas within the tropics. Much of this spread is thought to have occurred in the last one hundred years or less.

The Florida Department of Natural Resources estimates that up to $15 million is being spent each year in attempting to control aquatic weed problems (Dr. Alva Burkhalter, personal communication).

*U. S. Department of Agriculture, Agricultural Research Service, Southern Region, Gainesville, Florida 32602.

In a congressional report of the 85th Congress (Anon, 1957) figures were given for the estimated losses prevented by the elimination of waterhyacinth in Louisiana.

Navigation	$1,875,000
Flood Control	unknown
Drainage	1,584,000
Agriculture	19,557,000
Fish & Wildlife	14,727,000
Public Health	250,000
	$37,993,000

Loss of revenue was reported in 1947 (Anon, 1970-71) to be $65-75 million annually due to aquatic weeds in the State of Louisiana. Mr. Don Lee (pers. comm.), using the average cost of a fishing trip, the average number of times an acre of water is fished a year, and the number of acres available to fishing and also subject to invasion by waterhyacinth or other aquatic weeds, calculated that the control of aquatic weeds resulted in a saving to the state of $425 million annually.

These figures sound impressive; each is a carefully made estimate based on sound facts. It is known that when aquatic weeds are controlled, the cost-benefit ratios are weighed heavily to the plus side.

Biological control is one method that can be used to curb the growth of unwanted aquatic plants. This method is receiving more and more attention by researchers with the U. S. Department of Agriculture, University of Florida, and other groups in the United States.

Alligatorweed

Alligatorweed is thought to be native to South America. It was first found in the Old World in 1875, when it was seen growing near Djakarta, and has since become naturalized in standing and slow-flowing waters throughout much of Western Java (Backer, 1949). It was recorded from Inya Lake in the Rangoon District of Burma in 1932 (Maheshwari, 1965). Since then it has been found in Thailand, India and Australia.

Alligatorweed was reported in the United States in the last decade of the nineteenth century. It is now found throughout the Southeast in rivers, streams, irrigation channels and lakes. In many areas it is very competitive with waterhyacinth. The plant's relatively high tolerance to herbicides and high reproductive capacity makes it difficult to control. For these reasons it was decided to investigate its biological control agents.

George B. Vogt of the Systematic Entomology Laboratory, ARS, USDA, made the initial surveys in South America for insect suppressants of alligatorweed. From his work and the work of D. M. Maddox, USDA, Albany, California, three species of insects were imported into the United States (Maddox *et al.*, 1971).

Federal Permits were granted to introduce the alligatorweed flea beetle, *Agasicles hygrophila* Selman & Vogt, into the U. S. in 1963, the alligatorweed thrips, *Amynothrips andersoni* O'Neill, in 1966, and the alligatorweed stem borer, *Vogtia malloi* Pastrana, a phycitine moth, in 1970. Two hundred and sixty-six alligatorweed flea beetles released on the Ortega River in Jacksonville, Florida increased rapidly and served as a collection point for releases throughout the Southeast. The alligatorweed flea beetle became established throughout all but the most northern perimeter of the weed's distribution in the U. S. It overwinters up to 32° or 33° latitude north but the weed extends northward to approximately 35° latitude. The alligatorweed flea beetle does not diapause during the winter and thus needs some alligatorweed throughout this period as a source of energy. At the more northern latitudes fewer alligatorweed flea beetles survive the winter, and it is not until June that populations begin to flourish. In this area the population will peak in the fall with a resultant defoliation of the alligatorweed. Both larval and adult beetles seem to prefer floating aquatic alligatorweed. Pupation occurs within the hollow stems of these plants. Narrow, spindly stems (caused by insect attack on the plant or the lack of proper nutrients) will not support the alligatorweed flea beetle populations and they will disperse.

The first demonstration of the control of alligatorweed in the U. S. by the alligatorweed flea beetle was at Jacksonville, Florida. Each year since the initial release in 1965 there has been an increase in the alligatorweed flea beetle population and a corresponding decrease in the alligatorweed infestation. Though today the weed is still present, it does not create an obstruction by extending outward into the river. The remaining narrow water-edge band of weed prevents shore erosion and provides a habitat for fish fry and food for some birds and vertebrates.

Observations in Louisiana since the alligatorweed flea beetle's release in 1970 have shown a similar decline in the weed. The attack of the beetle coupled with the side effect of 2,4-D used in the same areas for waterhyacinth control has had striking results within a two-year period (Gangstad *et al.*, 1974). It appears that the stress placed upon alligatorweed by the alligatorweed flea beetle, together with other stress factors such as the use of herbicides or flooding, retards the luxuriant growth of the plant in a relatively short period of time.

The alligatorweed thrips was introduced in the southeastern United States in 1967. Although it became established, its numbers have not increased to the level that results in appreciable control level for the host plant. However, in the summer of 1973 on the Ortega River in Jacksonville, Florida, several acreas of rooted alligatorweed were observed to contain large numbers of the alligatorweed thrips and their feeding was having a noticeable effect. It is expected that these numbers will continue to increase, and over a period of time the alligatorweed thrips will contribute to the control of alligatorweed in the United States.

The alligatorweed stem borer was introduced into the United States in 1971 from Argentina. Releases were made from North Carolina (35° lat. N.) to southern Florida. Checks made on release sites in the spring of 1973 indicated the moth overwintered at least as far as the 32° lat. North (South Carolina). In June of this year alligatorweed stem borer populations of 2.5 larvae per square foot were found in alligatorweed in Columbia, South Carolina. Noticeable plant destruction was caused to the weed by the alligatorweed stem borer in Gardens Corner, South Carolina and just southeast of there at the Savannah National Wildlife Refuge in July. The alligatorweed in the refuge is rooted emersed and occurs in old rice paddies. This site was one of the first release areas of the alligatorweed flea beetle. However, the insect is now known to feed almost exclusively on floating alligatorweed, and its numbers have remained low at this site. The alligatorweed stem borer is found primarily on rooted alligatorweed in South America, and it was a little surprising to find that it preferred the floating weed in the United States. It is probable that the Argentine observations were a result of a decline in floating alligatorweed from biological stresses. The weed was limited to a semiaquatic and terrestrial habitat by these biological stresses. The alligatorweed stem borer was able to move with the weed to this more restricted habitat.

Data have been gathered on the interaction between alligatorweed viability and the occurrence of the alligatorweed flea beetle and alligatorweed stem borer. This information shows that as the weed loses its viability due to insect attack, the insects tend to disperse, and conversely as the weed increases in vigor it becomes more attractive to insects and thus more likely to be attacked (Spencer: unpublished analysis). This information will assist us in understanding the role of insects in holding plants in balance.

Waterhyacinths

This plant would be a worthwhile candidate for a combined effort by the International Organization for Biological Control. It is thought to be a native of South America where it has an extensive range centered in northern Brazil and Venezuela. It is particularly abundant in the Pernambuco region, the Amazon basin and the lower Orinoco. Sculthorpe (1967) presents an excellent account of the spread of waterhyacinth throughout the world.

Dr. B. D. Perkins (1974) presents information on arthropod enemies of waterhyacinth at this meeting. In Gainesville waterhyacinth has been studied from a physical standpoint in order to understand the effects an insect might have on the plant. It is known that waterhyacinth has a fast growth rate. Dr. Claude Boyd (pers. comm.) at Auburn University, Auburn, Alabama, obtained a whole plant production of 11,880 kg/ha dry weight in three months. These were hyacinths grown in fertilized fish ponds, and this yield includes everything but the roots of the plant. This rate compares with 13,338 kg/ha for corn, dry whole plant weight (Byer & Sturrock, 1965). Considering that waterhyacinth may grow continuously in the tropics, they do appear to be one of our highest yielding plant species.

In order to gain insight into the effects of the physical environment on alligatorweed and waterhyacinth water quality, certain parameters were measured for 114 bodies of water in the southeastern United States. These parameters were pH, alkalinity, total phosphates, total nitrates, hardness, iron, manganese, zinc, calcium, magnesium, copper, potassium, sodium chloride, and fluoride. Samples were taken in still water areas where neither plant was found, where only waterhyacinth was found, and where only alligatorweed was found. Analysis of these data, using an IBM 365 computer, differentiated some of the physical parameters of the "niche" of waterhyacinth and alligatorweed. Alligatorweed was found in the most eutrophic situations, waterhyacinth in slightly less eutrophic waters, and the control sites were the least fertile. The control group represented "medium" calcium richness (10-25 ppm ca) while the sites with the two weed species were calcium "rich" ($>$25 ppm ca).

It has been difficult to measure the effect of insect or mite feeding on waterhyacinth because the effect in the field is compounded by the invasion of plant pathogens. *Cephalosporium zonatum* Sawada, a zonal leaf spot of waterhyacinth (Rintz, 1973), is a major invader of waterhyacinth infested with the waterhyacinth weevil in south Florida (R. Charudattan, Dept. of Plant Path., U. of Fla., pers. comm.). An experiment set up in the laboratory eliminating such pathogens would tell the investigator very little about what he might experience in the field.

It has been found by Mr. Ted Center, a graduate student in our laboratory, that the noctuid, *Arzama densa* (Walker), can cause a decline in waterhyacinth when the moth larvae increase to more than ten per squate meter. Parasites and pathogens of *A. densa* restrict the effectiveness of this insect in the United States. Study of a colony of the waterhyacinth weevil, *N. eichhorniae*, in our greenhouse also shows that this insect can also have an effect on waterhyacinth, especially when associated with plant pathogens. With a population of about one larva per plant, diseases became evident in all the plants, and during the summer months the plants began to decline.

Eurasian Watermilfoil

During the 1960's *Myriophyllum spicatum* invaded over 81,000 hectares in the Chesapeake Bay, 2,023 hectares in Tennessee Valley Authority reservoirs, and upwards of 32,000 hectares in Currituck Sound, North Carolina, U.S.A. The State of Florida is experiencing trouble with the weed as well as the State of Washington. Complaints have also come from South Africa and India.

In Yugoslavia and Pakistan, entomologists working on a PL-480 grant found some 25 insect species feeding on eurasian watermilfoil. Some of these species are potentially useful for the biological control of the weed. The question has been raised: are insects capable of providing control of a submersed aquatic weed?

Aquatic moths (Pyralidae, Nymphulinae) found living in conjunction with eurasian watermilfoil differ greatly from the terrestrial forms. In one species, *Parapoynx stratiotata* (L.), the pupa may be attached to the stem of the aquatic plant where oxygen is obtained from the aerenchyma tissue (Lekić, 1970). This species is recorded from all of Europe and probably extends into Eurasia. The larvae are found feeding on aquatic plants under the surface of still or slowly flowing, fresh water. Lekić (1970) reported that adult *P. stratiotata* are nocturnal and fly over the surface of the water and along the edge of the shore. Eggs are laid on the underside of foliage projecting above the surface of the water. The larvae are found moving over the underwater portion of the host plant in tubular plant shelters constructed of plant fragments. They obtain oxygen through tracheal gills. *P. stratiotata* is a multivoltine species, whose duration of life cycle is dependent on water temperatures. Larvae diapause in the III to V instar in the second generation in Yugoslavia (Lekić, 1970) and complete development in the spring. Lekić found that a larva in its protective tube could spend four months frozen in a block of ice without apparent harm. Pupation occurs in off-white cocoons that are attached to the portion of the host beneath the water. A connection between the interior of the cocoon and the aerenchyma tissue of the plant stem provides oxygen.

Hosts of *P. stratiotata* have been listed as *Stratiotes aloides* L. (Hydrocharitaceae), *Trapa natans* L. (Trapaceae), *Alisma plantago-aquatica* L. (Alismataceae), and the genera *Potamogeton* L. (Potamogetonaceae), *Callitriche* L. (Callitrichaceae), and *Ceratophyllum* L. (*Ceratophyllaceae*). Field observations in Yugoslavia by Lekic (1970) indicated the following host preferences: eurasian watermilfoil, 90%; *Myriophyllum verticillatum* L., 8%; *S. aloides*, 1.5%; and *C. demersum*, 0.5%. Under experimental conditions, the caterpillars also fed on *Potamogeton lucens* L. and *T. natans* (Lekic, 1970).

In North America *Parapoynx allionealis* (Walker) is recorded from Nova Scotia to Florida, but the host plants are poorly understood. It was first found feeding on eurasian watermilfoil by the author in concrete plant rearing tanks in the summer of 1970 at the USDA-ARS, University of Florida Agricultural Experiment Station at Ft. Lauderdale, Florida. However, the larvae feeding on watermilfoil caused such damage as to make evaluation of herbicides that were being studied difficult. Dr. D. H. Habeck (1974) of the Entomology Department, University of Florida, has recently reared *P. allionealis* from *Eleocharis vivipara* Link, *Hydrochloa caro-*

linensis Beauv., *Salvinia rotundifolia* Wild., *Utricularia inflata* Walt., *Myriophyllum heterophyllum* Michx; and *Potamogeton pusillus* L.

The work currently underway in Florida (University of Florida) on the biology and host relationships of *P. allionealis* and other aquatic insects that attack aquatic plants will assist us in evaluating the control to be expected from the introduced species.

Litodactylus leucogaster Marsh (*myriophylli* Gyll.) inhabits standing and slow-moving waters of England, Scandinavia, Spain, Italy, Balkans, Hungary, and all of central Europe. The adults and larvae are found in conjunction with the flowers of eurasian watermilfoil. The adults live on the emersed part of the stem and most frequently among the flowers above the surface; they lay eggs in the buds. When the adults are in water, their bodies are surrounded by an air bubble that serves as a reservoir of oxygen. According to Lekić and Mihajlovic (1970), the larvae feed mainly on the flowers of the host and so hinder the sexual reproduction of the plant. The importance of sexual reproduction of eurasian watermilfoil in spreading the plant is unknown. Data indicate that *L. leucogaster* is a monophagous insect.

Control of the eurasian watermilfoil in the U. S. is presently accomplished by the use of herbicides and by water management. However, the search for insects, and subsequent studies noted, suggest that biological control may be within the realm of possibility. Further testing in U. S. quarantine will be needed to determine whether *P. stratiotata* and *L. leucogaster* could be imported for release in North America. Also, additional surveys are needed to determine other potential biological control agents for eurasian watermilfoil.

Hydrilla

The submersed aquatic weed, *Hydrilla verticillata* (Hydrocharitaceae), was first found in Florida in 1960 (Weldon, *et al.*, 1969). Since then it has increased to the point that it is now considered the second most important aquatic weed problem in Florida and is established in the states of Georgia, Alabama, Louisiana, Texas, and Iowa. It may grow rooted to the bottom in water 3 meters deep, where it forms a dense underwater mat of vegetation extending to the surface. Lakes, rivers, ponds, and irrigation canals are affected. Researchers working at the University of Florida under Dr. George Allen are attempting to find the geographical place of origin of *Hydrilla*.

A PL-480 project in Pakistan under Dr. M. A. Ghani and Mr. G. M. Baloch has resulted in the discovery of a number of species of Coleoptera and Lepidoptera feeding upon the plant. A dipteran, *Hydrellia* sp. (designated no. 4), appears to show specificity for *Hydrilla* according to reports received from the investigators.

The lack of specificity in the other insects may result from the fact that in Pakistan *Hydrilla* is nonendemic. It would be interesting to study the ecology of *Hydrilla* in its known native area in an attempt to discover the checks and balances placed upon it by nature.

CONCLUSION

The biological control of alligatorweed has shown the feasibility of using insects to control an aquatic weed. Present lines of research on a similiar program for waterhyacinth tend to indicate that we may expect similiar results with this weed.

Research on submersed aquatic weeds such as eurasian watermilfoil and *Hydrilla* is just beginning. It is hoped that insects will contribute to the control of these weeds. As in all biocontrol programs of weeds and insects, it is important that we find and search the area of origin of the host.

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