Waterhyacinth Research In Puerto Rico

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ABSTRACT

Waterhyacinth (*Eichhornia crassipes* (Mart.) Solms) is by far the most troublesome aquatic weed in Puerto Rico. Other weeds exist, but they cause only local problems. In 1972 the Tropical Terrain Research Detachment of the U.S. Army Engineer Waterways Experiment Station conducted a limited study on productivity of waterhyacinth in field situations and on the biological control of some native aquatics with the Brazilian snail (*Pomacea australis* (d'Orbigny)). This paper presents some quantitative data on waterhyacinth productivity in three natural locations on the island. Data are also given on amounts and rates of consumption of aquatics by the snail, whose use as an agent for biological control of aquatic weeds appears promising.

BACKGROUND

The aquatic weed problem in Puerto Rico is limited almost exclusively to waterhyacinth. Alligator weed (*Alternanthera philoxeroides* (Mart.) Griesb.), water lettuce (*Pistia stratioties* L.), chara (*Chara* spp.), and other aquatics are present, but they do not cause serious problems; hydrilla (*Hydrilla verticillata* Royle) has not yet been reported from the island. Problems have occurred with filamentous green algae, especially where lake surfaces are exposed to direct sunlight and have no cover of waterhyacinths.

The problems with waterhyacinth in Puerto Rico are associated primarily with difficulties in the operation of hydroelectric plants and pumping facilities for aqueducts and sewer operations. Hindrance to navigation is very minor, since Puerto Rico's lakes and reservoirs are used by only a few commercial freshwater fishermen and a very small number of pleasure boaters.

Waterhyacinth has clogged portions of almost all the rivers of Puerto Rico, especially within the coastal plain, but is not considered a problem except with respect to sewage treatment pumping facilities. On the other hand, these plants have virtually eliminated a large bird refuge (Laguna Cartagena) in the southwestern part of the island, and are pests in many of the irrigation systems because they seriously reduce the flow capacities of the distribution canals and ditches.

To date, the Puerto Rico Water Resources Authority (Fuentes Fluviales) has kept waterhyacinth under control in the reservoirs where hydroelectric plants are located by extensive spraying with (2,4-dichlorophenoxy)acetic acid (2,4-D) at concentrations of up to several parts per million (ppm) but is being forced to cease using herbicides, due mainly to pressure from environmental groups. The Puerto Rico Aqueduct and Sewer Authority has also used herbicides, but at much lower concentrations, since the water from its lakes is used for the population's water supply. Some mechanical harvesting has also been tried. This operation was abandoned because it was too expensive and ineffective. The latter Authority has come under considerable criticism for using herbicides, and at present controls waterhyacinth by opening spillway gates of reservoirs when the wind is blowing in the proper direction and letting the waterhyacinths go over the dam and down the river. This method provides only a temporary solution and obviously is not very popular with the people downstream. Thus, the local government as a whole is faced with the same problem for controlling waterhyacinths as in Florida, Louisiana, Texas, and other areas in the southeastern United States. Although the problem is serious, very little effort has been directed to waterhyacinth research in Puerto Rico.

PURPOSE AND SCOPE OF THIS STUDY

In August 1972 the U.S. Army Engineer Waterways Experiment Station (WES) Tropical Terrain Research Detachment (TTRD) in Puerto Rico initiated a limited amount of work on waterhyacinths for the Office, Chief of Engineers (OCE). In effect, two separate research programs were conducted. The first involved certain aspects of the basic biology of waterhyacinth, with primary interest centered on determination of productivity in field situations. The need for a basic investigation of waterhyacinth productivity became apparent from a search of the literature on this subject. The paucity of quantitative data on productivity during various phases of the life cycle of waterhyacinth made impossible the assessment of the efficiency of the various control mechanisms being investigated by the Corps of Engineers in the United States. Puerto Rico was considered to be ideal for waterhyacinth research because of its accessibility and abundance of plant material, among other things. Also, its tropical environment is somewhat similar to that in which waterhyacinth is assumed to have originated.

The second program was an investigation of the Brazilian snail as a possible means of controlling waterhyacinth growth. The investigations were made possible by the availability of a quarantined colony of the organisms at a local unit of the U.S. Public Health Service.

PRODUCTIVITY STUDIES

The primary objectives of the Puerto Rico waterhyacinth productivity study were to determine plant numbers and biomass production under field conditions and to determine whether there are significant differences in growth rate as a function of site condition. The experiment was designed for three field locations, each containing four plots.

Field Site Descriptions

The three areas chosen for this study are characterized by widely different conditions. One was a large reservoir lake, one a river, and the third a fresh-water lagoon. Descriptions of the three areas follow.

Lago Loiza. Lago Loiza is in east-central Puerto Rico, approximately 15 km south-southeast of the center of metropolitan San Juan. The lake averages about 500 m in width, is about 8 km long, and runs in a north-south direction. Its water level is approximately 40 m above sea level. The hills surrounding the lake rise to elevations of up to 200 m. Lago Loiza is impounded by a large dam and serves as the chief water supply for the San Juan area. The lake's spillway empties into the Rio Grande de Loiza, which winds its way northward and eastward to its mouth on the northern coast about 20 km east of San Juan. Waterhyacinth frequently covers much of Lago Loiza; large mats blow back and forth in the main channel. Most of the inlets and fingers are permanently covered, and those fingers that are not completely covered are rimmed with mats 2 to 5 m wide. These mats do not move naturally.

The site for the productivity studies at Lago Loiza was located in the central part of the lake at approximately 18° 18' 00" N latitude and 66° 01' 51" N longitude. The water in this area was about 2 m deep or greater, since the bank of the lake drops off rapidly. The lake bottom was firm, slippery, yellowish red clay. Three sets of plots were set up, one along a north-facing shore at a curve in the lake, another on the northern side of a finger of the lake, and the third on the southern side of a small peninsula. All the sites were within a few hundred meters of each other. The first site, from which the data presented here were taken, had to be abandoned because large mats of waterhyacinths, blown by wind, crushed the plots against the shore. The plots from the second site were eliminated by vandals within 2 weeks after setup, so plots were reestablished at the third site and provisions were made for security.

Rio de La Plata. The Rio de La Plata is one of the longest rivers in Puerto Rico, with headwaters near the town of Cayey in the south-central part of the island and its mouth along the northern coast some 20 km west of San Juan. The specific site chosen for the productivity study was about 1.5 km north of the town of Toa Alta and 500 m south of the point where highway No. 2, the main artery to the west out of San Juan, crosses the river at approximately 18° 24' 17" N latitude and 66° 15' 30" W longitude. This portion of the river is in the north coastal plain, and is about 15 m wide at the test site.

Four plots were located on the northern bank of the river out of the main thrust of the current, but not in backwater. They were protected from the current by a mat of hyacinths and other vegetation, but there was free circulation of water past them at all times. The water depth at the site varied from about 40 cm up to as much as 3 m after heavy rains. The river bottom was covered with sand, and with a few centimeters of silt and dead plant material. Toa Alta has only primary sewage treatment facilities, and not all portions of the town are served by them. Thus, it can be assumed that the water at the site had an abundant supply of those nutrients that are normally a part of human waste. Fringes of healthy waterhyacinth existed in all pools out of the main current and, in some places where suitable, covered the river from bank to bank.

Laguna Cartagena. The Laguna Cartagena is in the southwestern corner of Puerto Rico on the western edge of the Lajas Valley, about 7 km from the western coast and 7 km from the southern coast. The lagoon is about 2 km long in an east-west direction and 800 m wide at its widest point. It is shallow, probably 2 to 3 m at its deepest, and its margins slope very gently on all sides. It is the last remaining lagoon of its type on the island, and the area has been set aside by the Commonwealth Government as a bird refuge. The lagoon surface is covered largely with waterhyacinth with two or three small patches of open water.

The productivity site was located at the western end of the lagoon about 50 m from the outlet structure in a small patch of open water at approximately 18° 00' 52" N latitude and 67° 06' 28" W longitude. This portion of the lagoon was a small dredged channel leading to the outlet. Spoil had been piled along the channel, creating a levee-type embankment jutting into the lagoon from the west. Four plots were located about 20 m south of this levee. The bottom was a very soft, highly organic silt overlying black clay. The channel was surrounded by a fringe of healthy waterhyacinth.

Experimental Procedures

Each field plot consisted of a bamboo frame of approximately 4 m^2 in area. Each side of the frame was two bamboo rungs deep, with each rung having a diameter of approximately 10 cm. The bamboo rungs were laced together with nylon cord and nailed at the joints. The plots were tied together and anchored either to concrete blocks on the water bottom or to small trees on the bank. Sixteen individual waterhyacinth plants without stolons or daughter plants were weighed and placed in each plot. The plants in three of the four plots at each site were lifted out, weighed, and counted at convenient intervals, usually 1 to 2 weeks. For counting purposes a plant was defined as a node on a stolon with both leaves and roots; if no leaves had developed, it was not counted. The plants were kept out of the water only long enough for draining, weighing and counting, and an attempt was made to treat the plants similarly at all plots during each weighing period. The plants in the fourth plot at each site were weighed at the outset of the study but were not touched again until the end. This was done to determine the effect of lifting the plants out of the water at the specific intervals for weighing and counting. It is known that disturbing plants affects productivity, but the magnitude of the effect has not been determined.

Supplementary Data

In addition to the number and weight data, some other data were collected during each visit to a site. Temperatures were measured at 1 m above the water surface (ambient air) and at 0.5 and 50 cm below the surface. Water samples were collected at the surface and at the 50-cm depth for determination of pH.

Results And Discussion

Field studies. The measurement schedule and the growth (or productivity) data accumulated through 25 October 1972 for the three field sites are shown in Table 1. The numbers are averages for three of the plots at each site at each weighing. Since the fourth plot at each site was the control plot, it was not intended to be disturbed until the end of the experiment; however, for various reasons including vandalism and elimination by floodwaters, these control plots were lost and no definitive information was obtained. Quantitative observation showed that disturbing the plants for counting and weighing did affect their growth, but they recovered in a few days. It is felt, however, that over a long period, the undisturbed plants would have had a higher productivity than the ones disturbed periodically. Just how much difference is still uncertain.

Waterhyacinth reproduction rate based on arithmetic averages was greatest at Rio de La Plata, with a rate of 8.7 plants and 587.4 g per day, medium at Laguna Cartagena with a rate of 1.3 plants and 89.1 g per day, and slowest at Lago Loiza with a rate of 0.9 plants and 48.3 g per day. Daily increment factors[1] based on the assumption of geometric growth rate followed the same trends for the three sites, i. e., 1.03 for Lago Loiza and Laguna Cartagena and 1.08 for Rio de La Plata. Productivity was expected to be highest at Rio de La Plata because of the abundance of nutrients that were surely present because of the location of the site immediately downstream from a small town without adequate sewage facilities. Although no data are available, the Rio de La Plata at this point was assumed to have an abundant supply of nitrogen and phosphorus.

The slow productivity of waterhyacinths at Lago Loiza may have been caused by disturbance of the plots when they were frequently buffeted by large mats of waterhyacinth drifting before the wind; some of the plants in the field plots could have been lost. The waterhyacinths were expected to produce slowest at Cartagena, at least at the time of the study. The water in the lagoon was low and appeared rather stagnant at the plots. Water circulation was minimal. Possibly, if the water level in the lagoon rises during the rainy months, the situation may change drastically.

The rate of production of daughter plants in the field sites is given in Figure 1. The daily rate of production of daughter plants was calculated by the following equation:

$$P = \frac{N_{i+1} - N_i}{N_i (D_{i+1} - D_i)}$$

where:

P=number of daughter plants produced per day per parent plant

N_i=number of plants on $_i$th day

D_i=number of days since initiation of experiment

The point of interest is that, at all three sites, the rate of production of daughter plants rose to a maximum during a period of from about 15 to 40 days, and then declined. Some time within the 15 to 40 days, plant material at all sites had covered the water surface within each plot, thus producing crowded situations. This suggests that the production of daughter plants is inhibited as soon as crowding occurs. This interpretation is supported by the observation that the number of days required to reach maximum productivity is shortest for the site exhibiting greatest productivity (Rio de La Plata) and longer for the sites ex-

[1]J. H. Bock. 1970. An ecological study of *Eichhornia crassipes* with special emphasis on its reproductive biology. Doctoral Dissertation, University of California, Berkeley.

TABLE 1. PRODUCTIVITY OF WATERHYACINTHS IN PUERTO RICO.

Date of observation during 1972	Lago Loiza		Rio de La Plata		Laguna Cartagena	
	Number[a]	Weight (g)	Number	Weight (g)	Number	Weight (g)
10 Aug	—	—	—	—	16	995
16 Aug	16	1059	—	—	—	—
18 Aug	—	—	—	—	17	1420
23 Aug	20	1169	—	—	—	—
1 Sep	—	—	—	—	27	2383
5 Sep	37	2017	—	—	—	—
11 Sep	—	—	16	767	—	—
15 Sep	—	—	38	1149	—	—
16 Sep	—	—	—	—	55	3730
27 Sep	54	3086	—	—	—	—
29 Sep	—	—	112	4677	—	—
2 Oct	—	—	—	—	83	5718
11 Oct	—	—	352	17140	—	—
25 Oct	—	—	397	26611	—	—

[a]Each value represents the mean of three plots.

TABLE 2 ENVIRONMENTAL FIELD DATA FOR PRODUCTIVITY STUDIES OF WATERHYACINTH.

Observation	Site name: Lago Loiza	Rio de La Plata	Laguna Cartagena
Air temperature (C)	30	29	29
Water temperature (C)			
Surface	29.4	29.4	29.1
0.5-mm Depth	28.8	28.9	28.8
pH	6.4	6.5	7.7

hibiting much lower overall productivity (Lago Loiza and Laguna Cartagena). In this context, it should be noted that the Lago Loiza plants were artificially crowded by the press of wind-driven waterhyacinth mats early in the experimental period. This may explain the fact that peak production of daughter plants occurred within the same general time period as at the site at Rio de La Plata, despite the fact that overall productivity suggests that the site should have performed more nearly like the Laguna Cartagena site.

Supplementary data. Averages for the supplementary data collected at the three sites are presented in Table 2. Virtually identical water temperatures at all three sites was surprising. The only parameter that appears to have varied significantly is pH; pH values for Laguna Cartagena are substantially higher than those measured at the other two sites. This was because the lagoon is located in the most arid portion of the island, and the adjacent soils are alkaline.

BIOLOGICAL CONTROL STUDIES

The Brazilian snail has been reported to feed rather voraciously on aquatic weeds. The U.S. Public Health Service Tropical Disease Laboratory (TDL) in San Juan has a colony of the organisms which it maintains for its own studies. This species of snail has not been reported in Puerto Rico, so the colony is under quarantine by the Department of Agriculture. Workers at TDL noticed that when they played a few waterhyacinths in the tank with the snails, the plants disappeared rapidly. Knowing the interest of the TTRD in the control of waterhyacinth in Puerto Rico, TDL invited TTRD to use its snail colony to investigate the snail as a possible biological control agent.

Experiments

Three preliminary experiments were conducted from April to July 1972. In the first experiment, two shallow rectangular concrete tanks, approximately 3 m by 5 m by 30 cm deep and situated side by side, were used. Rain water had accumulated in the tanks, and the walls and bottoms were coated with algae. A known quantity of waterhyacinth was placed in one tank, and waterhyacinth plus snails were placed in the other. At the end of 30 days, the waterhyacinths in both tanks were weighed. In the second experiment, the tanks were cleaned, painted, and filled with fresh tap water. Waterhyacinths were placed in the control tank and waterhyacinths plus snails in the other. The tanks were observed periodically. The waterhyacinths and snails were weighed at the beginning and the end of the experiment. The third experiment was designed to obtain some preliminary data on the snails' preference for one aquatic weed over another. Four tanks were cleaned, painted, and filled with fresh water, weeds, and Brazilian snails as follows:

a. Tank 1 — Waterhyacinth and water lettuce.
b. Tank 2 — Waterhyacinth, water lettuce, and Brazilian snails.
c. Tank 3 — Water lettuce and Brazilian snails.
d. Tank 4 — Waterhyacinth and Brazilian snails.

This experiment ran for 44 days; all plants and all snails were weighed and counted at the beginning of the experiment and on the 29th and 44th days.

Results And Discussion

In experiment 1, the waterhyacinths in the control tank grew 2546 g in 30 days. In the tank with 36 snails, the plants weighed about 200 g less than the initial weight after 30 days. In the second experiment, which ran for 43 days, waterhyacinths in the control tank increased 12,334 g. In the tank with Brazilian snails, the waterhyacinths decreased 4740 g with only a few fragments of plants remaining. In experiment 2 the Brazilian snails initially weighed 7.3 g each and increased in number from 93 to 106 within 43 days weighing 7.2 g each at the end of this test.

Table 3 shows that in the third experiment the snails eliminated water lettuce somewhat faster than waterhyacinth. In the tank with both plants (tank 2), the snails eliminated the water lettuce in 25 days, while about 1600 of the original 2500 g of waterhyacinth remained. However, after the water lettuce was gone, the waterhyacinths decreased rapidly. It is not obvious at this point why the snails prefer the water lettuce; perhaps the plants are easier to hang on to or they are more tender. It is also im-

TABLE 3 BIOLOGICAL CONTROL STUDIES TO DETERMINE PLANTS PREFERENCED BY BRAZILIAN SNAILS.

Tank Number	Date of sampling during 1972	Waterhyacinth (g)	Water lettuce (g)	Snails (Number)	Snails (g)
1	21 Aug	2500	2500		—
	19 Sep	5253	6296		—
	4 Oct	5635	6300		—
2	21 Aug	2500	2500	152	371
	19 Sep	1583	0[a]	164	676
	4 Oct	476	0	146	572[b]
3	21 Aug	—	2500	95	185
	19 Sep	—	1406	87	380[b]
	4 Oct	—	0	106	399
4	21 Aug	2500	—	104	185
	19 Sep	1161	—	72	226[b]
	4 Oct	939	—	89	237

[a]A few grams (15 to 20) of water lettuce were noticed in tank 2 on 15 September. The snails eliminated them sometime between 16 and 19 September.
[b]Some snail shells (dead organism) were found in each of the tanks: thus the decrease in number of snails.

portant that the snails eat a variety of green plant material, such as tree leaves, etc. It is obvious that snails are not specific to waterhyacinths, and just what they would do in nature is not clear at this point. However, it does seem that their use as a biological control mechanism is worth a closer look. This is especially true for areas such as Puerto Rico where in many places the most abundant aquatic weed is waterhyacinth.