Hydrilla in Three North Carolina Lakes

STEVE M. HARLAN[1], GRAHAM J. DAVIS[1], AND GEORGE J. PESACRETA[2]

ABSTRACT

Hydrilla did not overwinter in lakes in Wake County, North Carolina in 1982 to 1983. Most biomass was produced at water depths between 0.0 and 2.0 m with little growth at depths greater than 3.0 m. Tuber formation began in late June, while regrowth from tubers and turions began from late March to mid April. Laboratory experiments indicated no seasonality in tuber germination, but this was not true for turion germination. Both male and female flowers were produced, but reproduction was solely vegetative.

Key words: biomass, tubers, turions, flowers, phenology.

INTRODUCTION

Hydrilla (*Hydrilla verticillata* (L.f.) Royle) is a noxious submersed aquatic weed which was introduced into the United States in Florida about 1960 (Haller 1978). Since its introduction hydrilla has spread as far north as Delaware (Joe Joyce, personal communication 1982) and as far west as California (Yeo and McHenry 1977). Based on its distribution in Europe (Cook and Luond 1982), the range of hydrilla could potentially extend into Canada.

Certain reproductive and physiological characteristics are associated with the ability of hydrilla to invade an aquatic system. One of these characteristics is the formation of tubers which are vegetative propagules formed at the ends of positively geotropic rhizomes (Van et al. 1978). Tubers develop in the hydrosoil and thus are very resistant to most control methods. Another adaptation in hydrilla is photosynthetic efficiency at low light intensities that is probably unequaled by any other submersed aquatic macrophyte (Van et al. 1976).

Hydrilla growing in lakes in Umstead State Park, Wake County, North Carolina was first identified in 1981 and had apparently been established in the area for several years. Since its initial identification, hydrilla has been found in 11 other water bodies, all in Wake County. Hydrilla has the potential to become a very serious problem as there are presently no economically efficient means of halting its spread or eradicating it after infestation occurs.

Since the hydrilla in North Carolina represented one of the most northerly major infestations in the United States, we decided to investigate its growth characteristics. The objectives were to study growth, biomass, and phenology in three of the infested North Carolina lakes.

[1]Research Associate and Professor, Department of Biology, East Carolina University, Greenville, North Carolina 27834-4353.

[2]Research Assistant, Department of Zoology, North Carolina State University, Raleigh, North Carolina 27695-7617.

MATERIALS AND METHODS

Annual Biomass Sampling

Standing crop biomass during July and August (1982 and 1983) was surveyed in three study lakes (Lake Anne (5.9 ha), Big Lake (23.7 ha), and Lake Wheeler (200.1 ha)). Biomass estimates were determined for areas representative of all reaches of a given lake. Depending on the size and homogeneity of the area being sampled, random samples were taken either from a predetermined area at an intermediate depth parallel to the shoreline or along transects perpendicular to the shoreline. Biomass samples were removed from 0.1 m^2 or 0.5 m^2 quadrat frames, washed in the field, sealed in plastic bags, stored in the shade, and returned to the laboratory for processing the same day. In the laboratory the samples were sorted by species, rewashed, and spun to no runoff in a commercial clothes washer. Wet weights were determined, aliquots of each sample were dried in a forced-draft oven for 24 h at 85 C, allowed to cool to room temperature in a desiccator, and weighed to calculate percent dry weight. Biomass values are reported as g dry weight m^{-2} ± standard error of the mean.

Ten transects perpendicular to the shoreline in Lake Wheeler were used to study species composition and biomass distribution along a depth gradient. These transects were randomized in an area of high plant density where hydrilla extended from 25 to 115 m from the shoreline. Sampling began at a random starting point within 10 m of the shoreline and continued at 5 or 10 m intervals depending on the length of the transect and the species diversity encountered. Biomass samples were collected from 0.1 m^2 areas in dense plant growth and 0.5 m^2 areas as plant density decreased. Sampling continued to the point where standing crop biomass fell to less than 1.0 g dry weight m^{-2}. Measurements included: biomass for each species present, water depth, and the distance from shore that each sample was taken.

Monthly Biomass Sampling

Begining in September 1982 seasonal variations in biomass were determined in a study plot established in each lake. The surface areas for each study plot were: Big Lake, 350 m^2; Lake Anne, 100 m^2; and Lake Wheeler, 120 m^2. Each study plot was within the 1.0 ± 0.2 m depth contour in an area of dense plant growth. Five replicate 0.1 m^2 samples were randomized and collected from each study plot. Processing of the plants in the laboratory was the same as for the annual biomass samples.

Areas of plant growth were determined either by measuring the dimensions on site or by planimetry based on field measurements of the areas sketched on a USGS map of the lake. Total surface areas of each study lake were determined by planimetric measurements of USGS maps and aerial photographs obtained from the North Carolina Department of Transportation.

Tuber and Turion Studies

Samples of tubers were taken monthly along the margins of each study plot. Samples were collected with a corer constructed from metal electrical conduit pipe (10.2 cm diameter) with a serrated cutting edge and a push rod for extruding the cores (modified from Sutton 1982). Ten samples (20 cm deep in the hydrosoil) were taken from each lake at equal intervals beginning at a random starting point. Samples were washed in the field in lake water in 0.75 mm mesh bags, and the tubers were counted and stored in lake water. Five of the ten samples were sliced into four subsections of 0 to 8 cm, 8 to 12 cm, 12 to 16 cm, and 16 to 20 cm to determine tuber density distribution within each core. Tuber density estimates are reported as the number of tubers m^{-2} within the study plots. Turion samples were taken from the same cores during tuber sampling. The method of handling and the reporting of turion density estimates is the same as for tubers.

Tubers and turions were transported to East Carolina University within 36 h, incubated in deionized water for 14 days at 26 C in the dark, and the average percent germination determined. Tuber germination was determined for each subsection separately with no less than three replicates of 20 tubers each for each lake. The number of replicates and the number of turions used for turion germination studies was determined by availability.

RESULTS AND DISCUSSION

Biomass: Annual

Virtually all biomass production occurred in 2.0 to 3.0 m of water depth or less. In clear waters hydrilla can grow to depths of as great as 7.0 m (Cook and Luond 1982). Secchi depths were mostly 1.3 to 1.7 m for Lake Wheeler and 1.0 to 1.3 m for Big Lake and Lake Anne. Generally plants grew in Lake Wheeler 0.5 m deeper than either Big Lake or Lake Anne. Thus the depth of significant biomass production in these North Carolina lakes is probably limited over the long term (years) by light penetration. Biomass distribution patterns would be expected to adjust to changes in seasonal light penetration patterns or water depth fluctuations with respect to the maximum depth of encroachment. Standing crop biomass estimates for Big Lake are compared to some of those reported for Florida in Table 1. These estimates are presented for Big Lake only as the Lake Anne estimates were affected by hebicide studies being conducted by North Carolina State University in 1983 and the Lake Wheeler estimates were affected by a drawdown of the lake in 1983.

Hydrilla occurred in dense monospecific stands in both Big Lake and Lake Anne; however, during 1982 in Lake Wheeler dwarf spikerush (*Eleocharis acicularis* (L.) R. & S.) and bushy pondweed (*Najas minor* All.) grew in association with hydrilla. Dwarf spikerush grew to a depth of 1.0 m and bushy pondweed grew to a depth of 1.5 m in 1982. However, due to a drawdown in 1983 plant stands from the shoreline to a depth of 1.5 m were killed. This essentially eliminated both bushy pondweed and dwarf spikerush form the plant community in 1983.

Biomass: Study Plots

Growth of hydrilla began from tubers and turions in late March to mid April and reached peak standing crop biomass in September. Plant stands began breaking up in October, and by late December standing crop and fragmented biomass were negligible (Table 2). Belowground biomass during late December to late March was due to tubers. The lower biomass for the Lake Anne study plot in 1983 was an artifact of the herbicide studies being conducted by North Carolina State University. Biomass sampling of the Lake Wheeler study plot was terminated in March 1983 because of the lake drawdown.

Phenology

Propagation of hydrilla in North Carolina occurred by four means: tubers, turions, plant fragments, and stolons. In addition, both male and female flowers were produced. All plants observed were monoecious. These phenological characteristics for North Carolina are compared to those reported for Florida (Haller 1978) in Figure 1.

In these North Carolina lakes, tuber germination began in late March to mid April and continued through August, and tuber formation began in late June and continued through October. Tuber formation below 12 cm was infrequent (Table 3). Tuber germination in North Carolina appeared to be initiated by increasing temperature and occurrred when the temperature of the hydrosoil was 11 to 13 C. Only mature tubers were found to germinate.

Tuber germination experiments indicated little seasonality because greater than 85 percent and frequently 95 to 100 percent germination occurred in the laboratory. Tubers did not germinate in the plant stands in late August when the water temperature was 26 C—well above the minimum temperature for germination found in this study and also that reported for Florida (Haller et al. 1976).

Given the phenology of tuber formation and germination and the observation that few tubers germinated in the lakes until the spring after formation, significant numbers of tubers should be available for regrowth the following spring even if all plants were killed following tuber germination and prior to tuber formation (Table 4, March to July). Also, tubers can remain viable for up to 10 years in the hydrosoil (Haller, personal communication in Nall and Schardt 1978); this could be an additional management problem.

Turion formation occurred in October through December in the leaf axils or at the apices of axillary branches in proximity to the apical meristem of floating plant fragments. Three to four weeks after formation begins they abscise and fall to the surface of the hydrosoil. In the late fall plant fragments were usually rafted near the shore

Table 1. Some maximal seasonal biomasses for hydrilla in Florida compared to North Carolina.[1]

Water Body	Month	Year	Biomass (g m^{-2})	Citation
Southern canals	—	1964	242	Blackburn et al. (1968)
Lake Jackson (northern)	November	1977	240	Bowes et al. (1979)
Orange Lake (central)	November	1977	240	Bowes et al. (1979)
Lake Trafford (southern)	August	1977	890	Bowes et al. (1979)
Little Lake Burton	October	1976	300	Osborn and Sassic (1981)
Lake Baldwin	August	1978	622	Maceina and Shireman (1980)
Lake Conway (west pool)	July	1977	155[2]	Nall and Shardt (1978)
Big Lake (whole lake)	September	1982	52	This Study
Big Lake (whole lake)	September	1983	64	This Study

[1]Dry weights for this study are based on 7.0 percent of wet weight. Also, in this study, ash free dry weights were found to be 82 percent of the oven dryed weight. Otherwise, except for the study of Bowes et al. (1979), dry weights were calculated as 10 percent of wet weight. This figure varies from 5 percent or less (Haller 1978) to 13.5 percent (Boyd and Blackburn 1970). Dry weight as percent of wet weight of hydrilla in Lake Conway is only for quadrats with hydrilla. For all studies except for that of Bowes et al. (1979), biomass is actually standing crop. Below ground biomass of hydrilla is relatively small. Root to shoot ratios in the experiments of Barko and Smart (1980) were around 0.05; ratios of plants growing in earthern ponds were 0.14 (Haller and Sutton 1975).
[2]Lake Conway had mixed communities at the time of the study and hydrilla was not a serious problem.

Table 2. Biomass estimates[1] for the study plots in Big Lake, Lake Anne, and Lake Wheeler from September 1982 to September 1983 within the 1.0 ± 0.2 m depth range.

Month	Big Lake	Lake Anne	Lake Wheeler
Sep.	181.5 ± 20.0	178.2 ± 20.2	179.8 ± 30.8
Oct.	152.4 ± 14.2	45.2 ± 11.7	152.4 ± 11.7
Nov.	4.4 ± 1.7	—	10.1 ± 2.4
Dec.	0.0	0.0	0.0
Jan.	0.0	0.0	0.0
Feb.	0.0	0.0	0.0
Mar.	0.0	0.0[2]	0.0
Apr.	0.0	1.0[3]	—
May	1.5 ± 0.2	11.3 ± 1.9	—
June	37.0 ± 6.8	64.1 ± 5.7	—
July	201.6 ± 11.9	87.5 ± 24.0	—
Aug.	235.8 ± 13.2	102.9 ± 69.4	—
Sep.	374.0 ± 20.7	73.1 ± 23.5	—

[1]g dry weight m^{-2} ± standard error.
[2]Subterranean regrowth was evident from tuber samples taken at this time.
[3]1 sample.

Table 3. Vertical tuber density distribution in the study plots.[1]

Month	Vertical Depth in the Hydrosoil (cm)			
	0.0-0.8	0.8-12.0	12.0-16.0	16.0-20.0
Sep.	—	—	—	—
Oct.	75.0	23.0	2.0	0.0
Nov.	73.7	26.3	0.0	0.0
Dec.	44.6	52.4	3.0	0.0
Jan.	96.2	3.8	0.0	0.0
Feb.	54.0	36.8	7.2	2.0
Mar.	98.5	0.0	1.5	0.0
Apr.	84.7	15.3	0.0	0.0
May	63.0	27.0	0.0	0.0
June	98.0	2.0	0.0	0.0
July	100.0	0.0	0.0	0.0
Aug.	86.3	9.7	4.0	0.0
Sep.	96.0	4.0	0.0	0.0

[1]Tuber density estimates are expressed as the relative percent of all tubers collected from all study plots within each specified vertical depth range within the 1.0 ± 0.2 m depth range of the study plots.

which resulted in the greatest observed density of germinating turions during the spring in depths less than 0.5 m.

Turion densities were low compared to tuber densities (Table 5). Turion germination appeared to begin before tuber germination, but this varied among lakes. Also, no differences in turion germination were noted between laboratory studies and field observations; thus, turion germination is seasonal.

Plant fragments are the most likely means of spread of hydrilla to other water bodies. Adventitious root formation in floating plant fragments resulted in anchorage of the plants in shallow water at times. These roots grew to approximately 1.0 m and such root growth may play a part

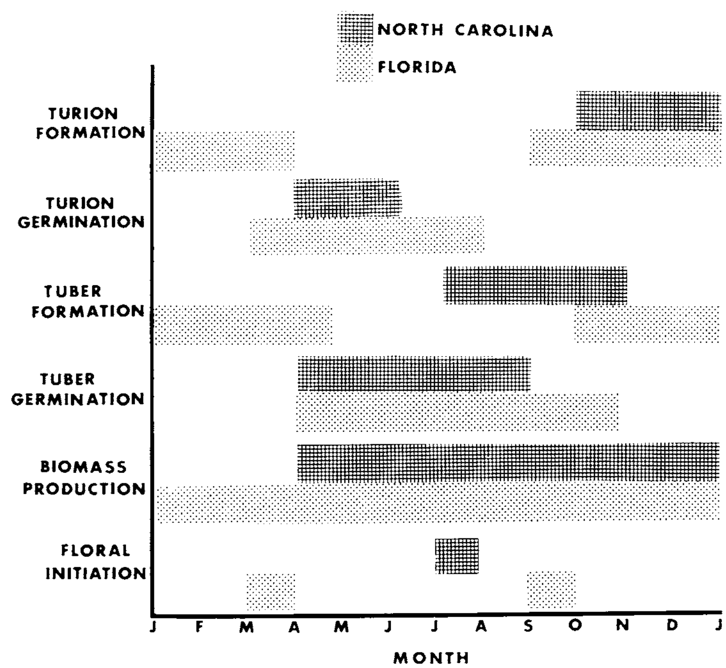

Figure 1. The patterns in the growth and phenology of hydrilla in North Carolina compared to that in Florida.

TABLE 4. TUBER DENSITY[1] ESTIMATES FOR THE STUDY PLOTS IN BIG LAKE, LAKE ANNE, AND LAKE WHEELER FROM SEPTEMBER 1982 TO SEPTEMBER 1983 WITHIN THE 1.0 ± 0.2 m DEPTH RANGE.

Month	Big Lake	Lake Anne	Lake Wheeler
Sep.	434 ± 69	665 ± 70	301 ± 87
Oct.	875 ± 83	971 ± 126	525 ± 110
Nov.	473 ± 85	1181 ± 107	598 ± 164
Dec.	357 ± 79	1233 ± 72	588 ± 133
Jan.	798 ± 99	987 ± 178	630 ± 174
Feb.	378 ± 104	1228 ± 215	357 ± 100
Mar.	703 ± 156	1312 ± 275	819 ± 84
Apr.	472 ± 96	977 ± 183	315 ± 75
May	525 ± 78	829 ± 129	556 ± 134
June	725 ± 128	735 ± 153	462 ± 94
July	200 ± 40	537 ± 153	189 ± 88
Aug.	399 ± 94	609 ± 115	357 ± 79
Sep.	599 ± 77	410 ± 86	389 ± 70

[1]Tuber m^{-2} ± standard error.

TABLE 5. TURION DENSITY ESTIMATES[1] FOR THE STUDY PLOTS IN BIG LAKE, LAKE ANNE, AND LAKE WHEELER FROM SEPTEMBER 1982 TO SEPTEMBER 1983 WITHIN THE 1.0 ± 0.2 m DEPTH RANGE.

Month	Big Lake	Lake Anne	Lake Wheeler
Sep.	0.0	0.0	0.0
Oct.	21.0 ± 1.9	0.0	0.0
Nov.	10.5 ± 1.7	—	21.0 ± 1.7
Dec.	31.5 ± 2.6	0.0	10.5 ± 1.3
Jan.	21.0 ± 1.7	0.0	10.5 ± 1.3
Feb.	31.5 ± 4.3	0.0	0.0
Mar.	42.0 ± 5.1	10.5 ± 1.4	0.0
Apr.	0.0	0.0	—
May	0.0	0.0	—
June	0.0	0.0	—
July	0.0	0.0	—
Aug.	0.0	0.0	—
Sep.	0.0	0.0	—

[1]Turions m^{-2} ± standard error.

in plant establishment. Propagation from plant fragments is only possible during the growing season because neither plant stands nor plant fragments overwintered in North Carolina lakes. For this same reason stoloniferous growth would only be a problem during the growing season.

Regrowth of hydrilla in these North Carolina lakes is dependent on tuber and turion germination in the spring. In a previously infested system, tuber germination is the primary means for reestablishment of the plant stands, but in other nearby uninfested systems turions formed in the late fall on floating plant fragments could be of significance.

ACKNOWLEDGEMENTS

This research was supported in part by the U.S. Department of the Interior through the Water Resources Research Institute of the University of North Carolina. Additional funding was provided by the City of Raleigh, North Carolina.

LITERATURE CITED

Barko, J. W. and R. M. Smart. 1980. Mobilization of sediment phosphorus by submersed freshwater macrophytes. Freshwater Biol. 10:229-238.

Blackburn, R. D., P. F. White, and L. W. Weldon. 1968. Ecology of submersed aquatic weeds in South Florida canals. Weed Sci. 16:261-265.

Bowes, G., A. S. Holaday, and W. T. Haller. 1979. Seasonal variation in the biomass, tuber density, and photosynthetic metabolism of hydrilla in three Florida lakes. J. Aquat. Plant Manage. 17:61-65.

Boyd, C. E. and R. D. Blackburn. 1970. Changes in the proximate composition of some common aquatic weeds. Hyacinth Contr. 8:42-44.

Cook, C. D. K. and R. Luond. 1982. A revision of the genus *Hydrilla* (Hydrocharitaceae). Aquat. Bot. 13:485-504.

Haller, W. T. and D. L. Sutton. 1975. Community structure and competition between hydrilla and vallisneria. Hyacinth Contr. J. 13:48-50.

Haller, W. T., J. L. Miller, and L. A. Garrard. 1976. Seasonal production and germination of hydrilla vegetative propagules. J. Aquat. Plant Manage. 14:26-29.

Haller, W. T. 1978. Hydrilla: A new and rapidly spreading aquatic weed problem. Agricultural Experiment Stations, Institute of Food and Agricultural Sciences, University of Florida, Gainesville.

Maceina, M. J. and J. V. Shireman. 1980. Recording fathometer techniques for determining distribution and biomass of *Hydrilla verticillata* Royle. Misc. Paper A-80-5. US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Nall, L. E. and J. D. Schardt. 1978. The aquatic macrophytes of Lake Conway, Florida. Vol. 1 of large-scale operations management test of use of the white amur for control of problem aquatic plants. Rept. No. 1, Baseline Studies. Tech. Rept. A-78-2. US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Osborne, J. A. and N. M. Sassic. 1981. The size of grass carp as a factor in the control of hydrilla. Aquat. Bot. 11:129-136.

Sutton, D. L. 1982. A core sampler for collecting hydrilla propagules. J. Aquat. Plant Manage. 20:57-59.

Van, T. K., W. T. Haller, and G. Bowes. 1976. Comparison of the photosynthetic characteristics of three submersed aquatic plants. Plant Physiol. 58:761-768.

Van, T. K., W. T. Haller, and L. A. Garrard. 1978. The effect of daylength and temperature on hydrilla growth and tuber production. J. Aquat. Plant Manage. 16:57-59.

Yeo, R. R. and W. B. McHenry. 1977. *Hydrilla*, a new noxious aquatic weed in California. California Agriculture 31:4-5.