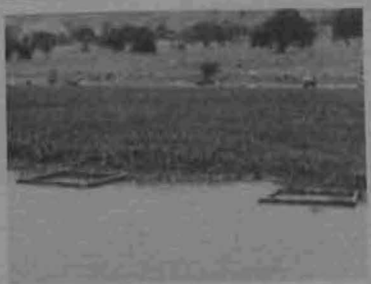
AQUATIC PLANT CONTROL RESEARCH PROGRAM

APCRP



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RECORDING FATHOMETER TECHNIQUES FOR DETERMINING DISTRIBUTION AND BIOMASS OF *HYDRILLA VERTICILLATA* ROYLE

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The primary objective of this study was to investigate the possibility of utilizing a recording fathometer to generate quantitative data by conducting transects of submersed vegetation. Data and techniques were evaluated and assessed for accuracy, advantages, and bias. Five quantitative vegetation parameters are presented for determining the abundance of hydrilla: (1) transect percent cover, (2) total percent cover, (3) percent vertical cross-sectional area infestation, (4) biomass and total standing crop, and (5) mean

(Continued)

20. ABSTRACT (Continued).

hydrilla height and hyrilla-surface distance. Although certain disadvantages and problems were encountered utilizing a recording fathometer for submersed vegetation surveys, valid and accurate quantitative data were generated demonstrating seasonal and/or chemical and biological control fluctuation of hydrilla abundance in Lakes Baldwin and Wales. Conducting vegetation surveys with a recording fathometer proved to be an economical and feasible sampling procedure.

Technological advances improving sensitivity and chart tracing output may be possible in the future. Refinement of the techniques presented could also improve the versatility and possibly increase the amount of information that could be obtained from tracings. The results of this study confirm that a recording fathometer can be a useful sampling device to aquatic botanists and researchers evaluating the impact of various control measures on hydrilla.

White amur were stocked in Lake Baldwin during 1978. The biomass of all fish was estimated at 121 kg/ha for March 1979, and hydrilla biomass for the same month was estimated at approximately 0.6 million kilograms.

PREFACE

The investigation reported herein was performed for the U. S. Army Engineer Waterways Experiment Station (WES) Aquatic Plant Control Research Program (APCRP) by the School of Forest Resources and Conservation, University of Florida, Gainesville, Florida, under Contract No. DACW39-78-C-0044. The study was monitored by the U. S. Army Engineer District, Jacksonville, and the Office, Chief of Engineers.

The principal investigators for the work and the authors of this report were Dr. Jerome V. Shireman and Mr. Michael J. Maceina of the University of Florida. Messrs. Larry E. Nall, Jeffrey D. Schardt, and Chip Swindle of the Florida Department of Natural Resources collected the hydrilla biomass samples.

Mr. Eugene Buglewicz of the WES Waterway Habitat and Monitoring Group (WHMG), Environmental Systems Division (ESD), was the technical monitor.

The work was conducted under the general supervision of Dr. John Harrison, Chief of the Environmental Laboratory, and Mr. Bob O. Benn, Chief of the ESD. The study was under the direct supervision of Dr. Walter B. Gallagher, former chief of the WHMG, and Dr. Thomas D. Wright, current Chief of the WHMG. Manager of the APCRP at WES was Mr. J. Lewis Decell.

The Commander and Director of WES during this period was COL Nelson P. Conover, CE. Technical Director was Mr. F. R. Brown.

CONTENTS

CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
feet	0.3048	metres
horsepower (550 foot-pounds per second)	745.6999	watts
inches	25.4	millimetres
knots (international)	0.5144444	metres per second
miles (U. S. statute)	1.609344	kilometres

RECORDING FATHOMETER TECHNIQUES FOR DETERMINING DISTRIBUTION AND BIOMASS OF *HYDRILLA VERTICILLATA* ROYLE

PART I: INTRODUCTION

Background

1. Aquatic vegetation* is an integral part of aquatic ecosystems and is important to both fish and wildlife species utilizing the habitat (Lantz et al. 1965, Holcomb and Wegener 1972, Teels et al. 1978). Uncontrolled growth of aquatic vegetation, however, can alter both the abundance and well being of fish populations, limit recreational use, create health hazards, and block navigation and irrigation routes (Blackburn 1975). The introduction and spread of exotic aquatic plants and increased nutrient levels, particularly in urban and agricultural areas, have greatly compounded the problem. It becomes necessary, therefore, to control these plants if a water body is to be utilized to its fullest extent. Haller (1977) lists four basic types of control, which include: (1) mechanical harvesting, (2) chemical herbicides, (3) biological control agents, and (4) physical control by water level manipulation.

2. Research efforts continue to examine, formulate, and improve weed control methods, while considering positive and/or adverse impact of these control methods on the entire aquatic system. In order to determine and evaluate control methods, quantitative and qualitative data pertaining to plant communities are needed. This is especially true when evaluating the effectiveness of white amur (*Ctenopharyngodon idella* Val.) for hydrilla control. A reliable estimate of plant biomass is needed to determine stocking rates.

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* See Appendix A for a glossary of terms used in this report.

Purpose

3. The purpose of this research project was to investigate the potential of a recording fathometer for conducting vegetation surveys. The use of this instrument could possibly save time, labor, and capital equipment outlays.

Objectives

4. The objectives of this study were to:

   a. Evaluate the use of a recording fathometer as a means of conducting vegetation surveys.

   b. Develop procedures to estimate plant biomass from fathometer recordings and record vegetation changes that occur during the study period.

   c. Develop quantitative vegetation parameters that describe lake vegetation.

PART II: LITERATURE REVIEW

5. Early aquatic vegetation sampling methods involved various modifications of the line transect method, which was summarized in detail for terrestrial plant ecology by Canfield (1941). Early botanists were primarily concerned with the ecology of macrophytes in aquatic ecosystems and considered plant succession, habitat requirements, growth patterns, and distribution.

6. Pearshall (1917, 1920) examined the distribution of the aquatic plants in the Esthwaite Water of the English lake. In surveying a lake, points were chosen along the shoreline from a map. Starting from one of these corresponding fixed points on shore and rowing towards the other point, a weighted dredge with three hooks was employed by sounding at regular intervals between two points. The dredge was marked for distance so that depth was recorded each time a vegetation sample was brought up from the lake bottom. Bottom type (i.e. sand, mud, or rock) was noted. Aquatic plant communities were illustrated upon a map.

7. Holcomb and Wegener (1972) investigated the effects of lake drawdown on the emergent and submersed vegetation of Lake Tohopekaliga, Florida, utilizing a rod and pointing tool 5.5 ft* long with five steel rods centered along its length. Transects were set at 2-mile intervals, circumventing the shallow portions of the lake basin. The pointing tool was placed every 15 ft along each transect by pacing. Vegetation touching each of the five rods or within 1 in. of the distal tip was recorded. Frequency of occurrence data were generated for each transect and comparisons were made over time.

8. Hestand and Carter (1974) selected five stations in a north Florida shallow water reservoir to study the effects of drawdown on submersed aquatic plants. A 100-ft steel tape was stretched between permanent markers at each station, and at 5-ft intervals a pole was lowered. Plants that touched the pole were recorded. At each 20-ft

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* A table of factors for converting U. S. customary units of measurement to metric (SI) is presented on page 3.

interval, a floating 3.28-ft frame was lowered into the water and the coverage of each species sketched. A color photograph was taken to aid in coverage documentation. Frequency of occurrence and percent cover data were compared to predrawdown and postdrawdown conditions.

9. Arner et al. (1977) utilized a modification of the line intercept method contrasting two marshland ecosystems. All plants directly below a 100-ft tape at points 1 ft apart were recorded and frequency of occurrence determined.

10. Montegut et al. (1976) established 10 permanent line transects in Lake Wales, Florida, to determine hydrilla coverage and biomass. A line marked in metre intervals was stretched between two buoys. At 2-m intervals, a line was lowered and hydrilla height and water depth were noted. At 10-m intervals along two transects, an aluminum square metre frame was lowered into the water employing snorkeling equipment; percent cover and vegetation height were measured. Hydrilla was clipped, removed, and weighed to determine biomass. Percent cover and hydrilla height were positively correlated with hydrilla biomass and predictive regression models were formulated.

11. Macan (1977) installed numbered posts at regular intervals along the edge of a shallow 0.5-ha pond that indicated the start and finishing points of transects. Transects were conducted from a boat that was hauled along a rope marked in metres stretched between two posts. A glass bottom box was used to observe vegetation and the distance from the starting point was recorded for each observation. Numerous transects allowed for thorough coverage of the pond and vegetation maps were drawn. Changes in aquatic macrophyte distribution were monitored for 21 years.

12. Colle et al. (1978a), investigating food selectivity of white amur in 0.81-ha ponds, used three transects the width of the pond to observe vegetation communities. At 1-m intervals, a point estimate of plant species, height of vegetation, and water depth were recorded. Percent coverage by species was determined at 5-m intervals along each transect.

13. Various researchers have devised and utilized a variety of

sampling schemes and methods that involve direct contact and handling of submersed macrophytes, but do not necessarily employ line intercept methodology. Rickett (1921, 1924) established permanent stations by water depth in Lake Mendota and Green Lake, Wisconsin, and examined aquatic plant distribution and biomass at varying water depths. A 0.25-m^2 iron frame was lowered to the hydrosoil and all plants within the frame gathered. Stations located in depths of less than 3 m were reached by ordinary diving, whereas collections at deeper stations were made by employing a diving hood supplied with air by a hand pump in a boat. Plants were separated by species and wet weights obtained. Mean weights per 0.25 m^2 were calculated for each species at the various depth strata. Total area was calculated for each depth strata and multiplied by the corresponding mean biomass for each species and total plant biomass determined. Total standing crop of all submersed macrophytes was reported.

14. Wilson (1935) modified some of Rickett's (1921, 1924) techniques while studying aquatic plant succession in lakes located in Vilas County, Wisconsin. Transects extended from the shoreline towards the center of the lake. Vegetation samples were collected at every successive 0.25-m depth interval from the bottom with a 0.25-m^2 frame. At depths greater than 10 m, a small modified Peterson dredge fitted with a heavy, calibrated rope was lowered and plants were collected from a 0.0625-m^2 area.

15. Edwards and Owens (1960) randomly divided a 132-m-long section of a stream into nine sections. Within each section, a 1.8-m-wide strip across the entire stream was randomly chosen and submersed vegetation clipped and removed. Plants were washed to remove silt, sorted by species, spun for 1 min in a domestic spin dryer to remove excess water, and weighed. Standing crops and percentages by weight of each plant species were determined.

16. Robel (1962) examined changes in submersed vegetation following a change in water level in a freshwater marsh. Forty-two permanent sampling sites, each marked with a 1.2-m steel rod, were chosen from a gridded aerial photograph employing a random numbers table. Maximum

depth at any one station was 6.0 m. A square metal form encompassing an area of 0.093 m^2 was lowered to the top of the hydrosoil and all vegetation removed. At each sampling site, four vegetation samples were collected systematically at a distance of 1.2 m from the marking rod at each of the four points of the compass.

17. Wood (1963) presented a review and evaluated the techniques available to aquatic plant ecologists utilizing SCUBA (self-contained underwater breathing apparatus). Posts driven into the hydrosoil established permanent transects. A line was marked off at regular intervals and secured between the posts. Data were obtained by employing the line intercept method yielding frequency of occurrence data, percent cover utilizing a square frame, and biomass by clipping or gathering plants from an enclosed area.

18. Sheldon and Boylen (1978) also used SCUBA while investigating the ecology of submersed macrophytes in Lake George, New York. Transects were conducted at regular intervals according to water depth with the distance between sampling stations dependent upon water depth. Density (number of shoots per square metre) and biomass (grams dry weight per square metre) were calculated for 40 species of submersed macrophytes. Density and biomass of aquatic plants varied with depth. Increased accuracy in density and biomass values and a higher number of species were collected employing SCUBA techniques compared to conventional sampling gear from a boat. Boylen and Sheldon (1976) reported that SCUBA gear was the only method suitable to study submersed macrophytes under ice cover in Lake George, New York. These authors studied differences in density, biomass, and photosynthetic rates for *Potamogeton* spp., *Najas flexilis*, and *Vallisneria americana*.

19. Various quantitative aquatic vegetation samplers that removed a quantity of vegetation from a known area have been used by past workers (Wilson 1935, Grontved 1957, Nygaard 1958, Forsberg 1959, Martin and Shireman 1976). Grontved (1957) and Nygaard (1958) designed and built cylindrical samplers with sharp cutting blades that cut the plant horizontally at the bottom of the device. Forsberg (1959) constructed a sampler that cut submersed vegetation from a 0.1-m^2 area and pressed

against a plate before the device was brought to the surface. Random samples were taken with Forsberg's (1959) sampler in a 8.8-ha lake entirely covered with coontail (*Ceratophyllum demersum*). The total wet weight standing crop was estimated to be 25,000 kg. Nall and Schardt (1978) utilized a number of different techniques to investigate the submersed macrophytes in a 737-ha central Florida lake. Each month, 18 permanent transects were sampled at 100-m intervals with a cylindrical 0.257-m^2 core vegetation sampler built on a barge. Approximately 200 biomass samples were obtained each month. Plant species were separated and wet and dry weights determined. Twice annually, random biomass samples were collected throughout the lake. A map of the lake was overlaid with a numbered grid system and sites were chosen employing a random numbers table. Nall and Schardt (1978) also established 16 permanent 0.10-ha plots on the lake. A SCUBA diver made 30 random visual observations in the area. Species composition and two measurements of vegetation height were taken. Two random areas within the plot were selected and a 0.25-m^2 area of vegetation was removed by the diver. Upon removal, the number of rooted stems was counted and the internodal and stem lengths were recorded for all species. Quantitative aquatic vegetation data generated from this study included species diversity, mean standing crop by species, frequency of occurrence, and density (number of plant stems per unit area).

20. Osborne and Sassic (1979) randomly sampled hydrilla bimonthly from 20 stations chosen from a map and overlay in a 5.42-ha central Florida lake. Biomass samples of hydrilla were collected utilizing a 110-kg, 0.25-m^2 submersed aquatic plant dredge sampler operated by winch-driven cables on a pontoon boat. Hydrilla abundance was monitored for 2 years following introduction of white amur into the lake. The fish were effective in reducing mean annual hydrilla biomass from 1.70 to 0.96 kg/m^2 fresh weight and caused a decrease in hydrilla production during the study period.

21. Recently, several procedures have been reported on indirect or noncontact techniques to sample and collect aquatic plants. These methods have one outstanding feature in that a time savings can usually

be accomplished to collect vegetation data in a given area versus direct handling, sorting, counting, and weighing of plants. Inspection and onsite submersed vegetation mapping procedures and results have been presented by Hestand et al. (1973) and Southwick and Pine (1975) in a shallow water reservoir and a tidal river. Percent cover by species was determined via motorboat using a detailed map illustrating landmarks and the surrounding topography.

22. Edwards and Brown (1960) first employed an aerial photographic method for studying the distribution of aquatic macrophytes in a clear, shallow stream. A camera equipped with a wide-angle lens was attached to a hydrogen-filled tetrahedral balloon. A 12-volt battery on the ground operated the shutter and automatic rewind mechanism. The camera and balloon were secured at a constant height by three ropes held by observers on the ground. Observers moved downstream along the edges of the streambank and a series of color photographs were taken. Differentiation of various submersed and emerged species was possible with onsite inspection, and percent cover was calculated.

23. Benton and Newnan (1976) utilized both clear and color infrared photography to monitor vegetation in a 36,000-ha Texas reservoir. Waterhyacinth (*Eichhornia crassipes*) produced consistent distinct color images and excellent coverage was documented. The authors found normal color film was more valuable in detecting the presence of various submersed species. Infrared photography did not distinguish color image differences between hydrilla, coontail, and watermilfoil (*Myriophyllum* sp.) when plants were just a few centimetres below the water surface. Surface matting of submersed plants did produce detectable color differences.

24. Co-infrared photography to map the vegetation of a freshwater marsh in Maryland was also used by Shima et al. (1976). Photographs were compared and correlated with data obtained from field surveys. Emerged and floating-leaved plant associations were detectable. Many species, however, clumped into homogeneous vegetation units as individual species could not be differentiated. Submersed macrophytes were not included in any of the vegetation units and

the technique was not evaluated for these plants.

25. Owens et al. (1967) determined the biomass of various submersed plants utilizing photocells at various depths to measure the subsurface light intensity that penetrates stands of macrophytes. Light intensity was correlated with nine species of aquatic macrophytes in rectangular tanks where known quantities of plants were placed. Field conditions were simulated as closely as possible. Vertical depth distribution of biomass by percent was calculated for each plant. An experimental 1.8-ha lake infested with a monoculture stand of *Elodea canadensis* was examined by Owens et al. (1967) to test the applicability of this method to a weed problem lake. Thirty-eight sampling stations were established and optical densities were taken three times before and after herbicide treatment. Mean biomass rose from 0.45 to 1.15 kg wet wt/m^2 the day of spraying. Following 35 days, mean biomass dropped to 0.00 kg wet wt/m^2.

26. Nall and Schardt (1978), utilizing a recording fathometer to construct a bathymetric map of Lake Conway, Florida, noted submersed vegetation growing from the bottom. Construction of a vegetation cover map from the fathometer tracings revealed submersed macrophytes infesting 60.3 percent of the lake. Biomass sampling employing a random grid method, described earlier in the text, estimated total percent cover to be 51.0 percent, underestimating the results calculated from fathometer tracings.

PART III: MATERIALS AND METHODS

27. A DE-719 Precision Survey Fathometer (Raytheon Marine Co., Manchester, N. Y.) was utilized for all vegetation surveys (Figure 1)

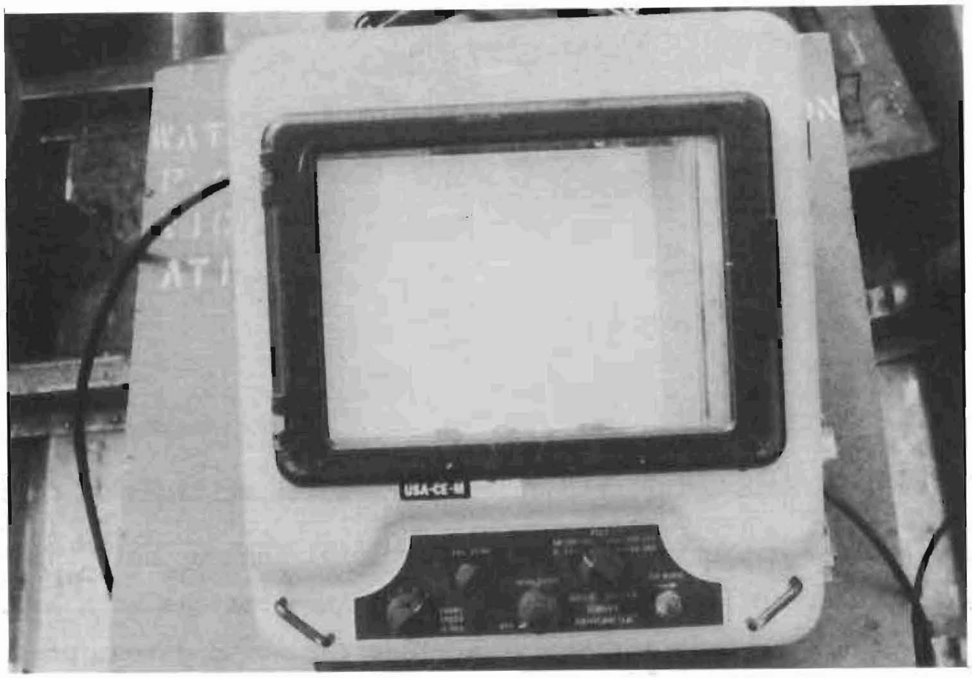


Figure 1. DE-719 recording fathometer

conducted on two central Florida lakes from May 1978 through March 1979. An extendable bracket to house the transducer was permanently mounted on the transom of a 4.9-m aluminum flat-bottomed boat powered by a 20-hp outboard motor (Figure 2). The transducer was mounted at a 14-deg angle above the horizontal to facilitate improved echo depth sounding reception while the boat was moving. The transducer was mounted so that the bottom of the boat was even with the bottom face of the transducer making the apparatus "weedless." A marine 12-volt battery supplied power to the fathometer. Calibration procedures were according to the instructions outlined by the manufacturer (Raytheon Marine Co. 1972).

28. A fathometer works on the principle of echo depth sounding by computing the time interval required for sound waves to travel at a known velocity from a known point to a reflecting surface and return.

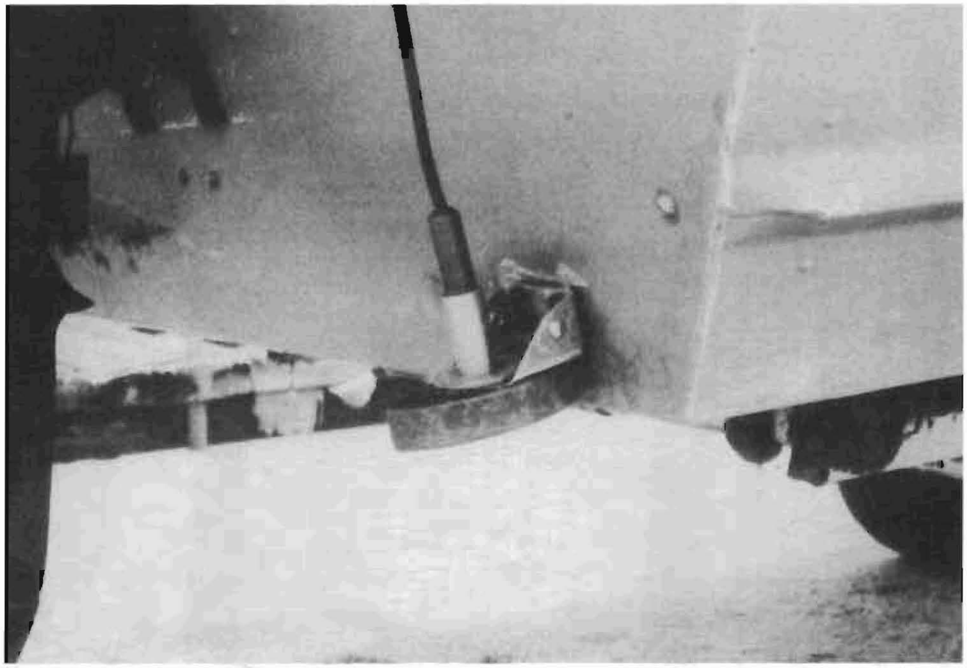


Figure 2. Fathometer transducer and bracket attached to boat

The precise water depth is calculated by multiplying one half the time interval by the velocity of sound in water. Hard bottoms such as sand and rock provide the best reflective surface for sound waves, producing sharp and clear images on chart paper. Aquatic weeds have a lower specific density and generally cause weaker reflections; therefore, tracing patterns are not as clear and defined.

29. A DE-719 is a light-weight (21.3 kg) portable recording fathometer that can be mounted temporarily or permanently. The recorder provides a detailed chart tracing pattern of underwater topography in depths between 0.7 and 125.0 m (Figure 3). Depths are accurate over this range to ± 0.5 percent. The DE-719 is well suited for freshwater vegetation surveys providing high resolution recordings due to the narrow transducer beam width, high sounding rate, rapid chart speed, and high signal frequency. Operating frequency is 200 kHz.

30. Bottom depth readings were consistently accurate to within 0.1 m of the true depth when calibrated with a weighted sounding line. Adjustment to true depth was made by slightly altering the speed of sound control, which is located inside the machine. Highest

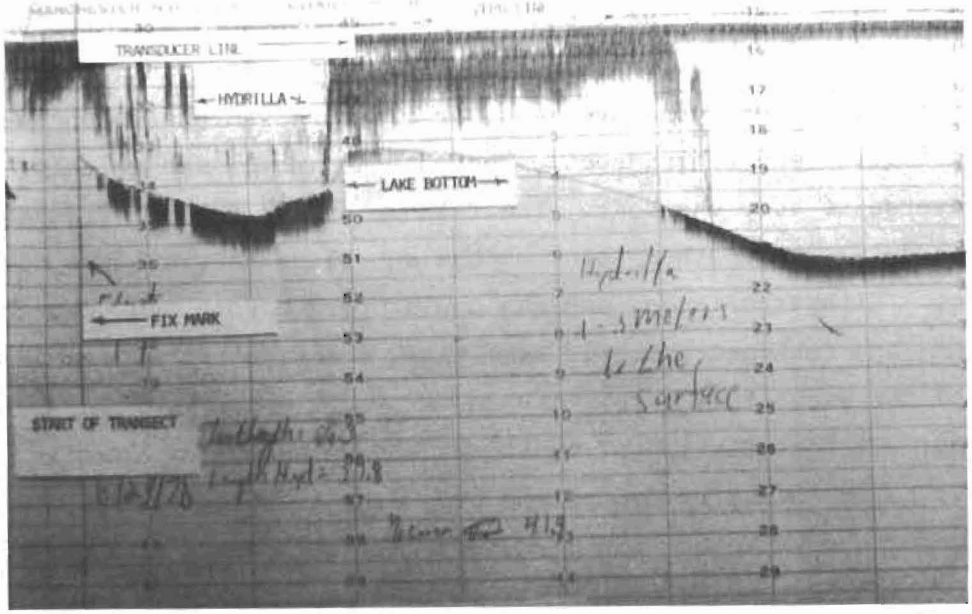


Figure 3. A section of chart tracing recorded from Lake Baldwin, showing start of transect, lake bottom, and hydrilla infestation. Note the tall stand of hydrilla merging with the transducer line

sensitivity was achieved by setting the sensitivity on-off control dial to its highest position and utilizing a chart speed of 10.16 cm per minute. Metric chart paper was used during all surveys.

31. Recent aerial photographs were obtained for each study lake. Permanent landmarks were obtained from these photographs and transects were conducted by traversing the lake from one landmark to another across the lake. Referral to the aerial photographs allowed for exact transect location.

32. To conduct a transect, the following procedure was followed. After calibration, the fathometer was switched on and the on-off sensitivity dial set to the highest sensitivity. The boat was backed slowly to the edge of the lake and aligned between the starting point landmark and the landmark across the lake. The boat was quickly accelerated to a speed of 2 to 3 m/sec (4 to 5 knots). After boat speed was stabilized, a fix mark was placed on the chart paper by engaging the fixmark switch. The boat was driven across the lake towards the chosen landmark maintaining a constant speed by adjusting the speed control on the motor

throttle. During this time, field observations of vegetation conditions, transect number, lake, and date were written directly on the chart paper with pencil. Within 10 m of the opposite bank, emergent vegetation, or other structure, another fix mark was placed on the chart designating the end of transect. The outboard motor was quickly shifted into reverse to stop the boat. The fathometer was turned off and the boat was driven to another point on the shoreline to start the next transect. With experience, one man could operate both the outboard motor and the fathometer at the same time. Bathymetric maps were constructed for each study lake.

33. Differentiation of various submersed macrophytes from tracings was accomplished by dropping a buoy over the side of the boat marking an unknown vegetation community while transects were being conducted. A corresponding fix mark was placed on the chart marking the buoy position. Upon completion of a transect, a weighted dredge was lowered at each buoy and vegetation was collected for identification. Quantitative vegetation data, including total percent cover of submersed vegetation, individual transect percent cover, percent vertical cross-sectional area infestation, mean vegetation height, percent vertical cover, and distance from the top of vegetation to the water surface, were calculated from the graph paper utilizing a 25-cm ruler, planimeter, and drafting tools. Further detail as to the derivation and results of these various vegetation parameters will be described later in the text.

34. Hydrilla biomass was correlated with fathometer tracings to estimate total hydrilla standing crop in Lake Baldwin. While monthly transects were being conducted during August and December 1978 and March 1979, weighted numbered buoys were dropped to mark sampling stations. Simultaneously, corresponding fix marks were placed on the chart paper and the number of the buoy was recorded on the paper. The following day, a circular core biomass vegetation sampler was used to take replicate 0.257-m^2 samples at each buoy (Figure 4). Samples collected with the biomass sampler were washed and shaken in a nylon net to remove excess sand, mud, and water and weighted to the nearest 5 g on a

Figure 4. Corps biomass sampler used to collect biomass samples from Lake Baldwin

platform scale. Wet weights were later converted to kilograms per metre for analysis. A total of 202 samples were collected on these three dates at depths varying from 1.7 to 6.2 m and in different hydrilla densities.

35. Fourteen vegetation transects, totaling 11.32 km in distance, were conducted monthly on Lake Baldwin from May 1978 to March 1979 (Figure 5). Sixteen transects, 13.24 km in distance, were run in Lake Wales, Florida, during May, August, and November 1978 and in February 1979 (Figure 6).

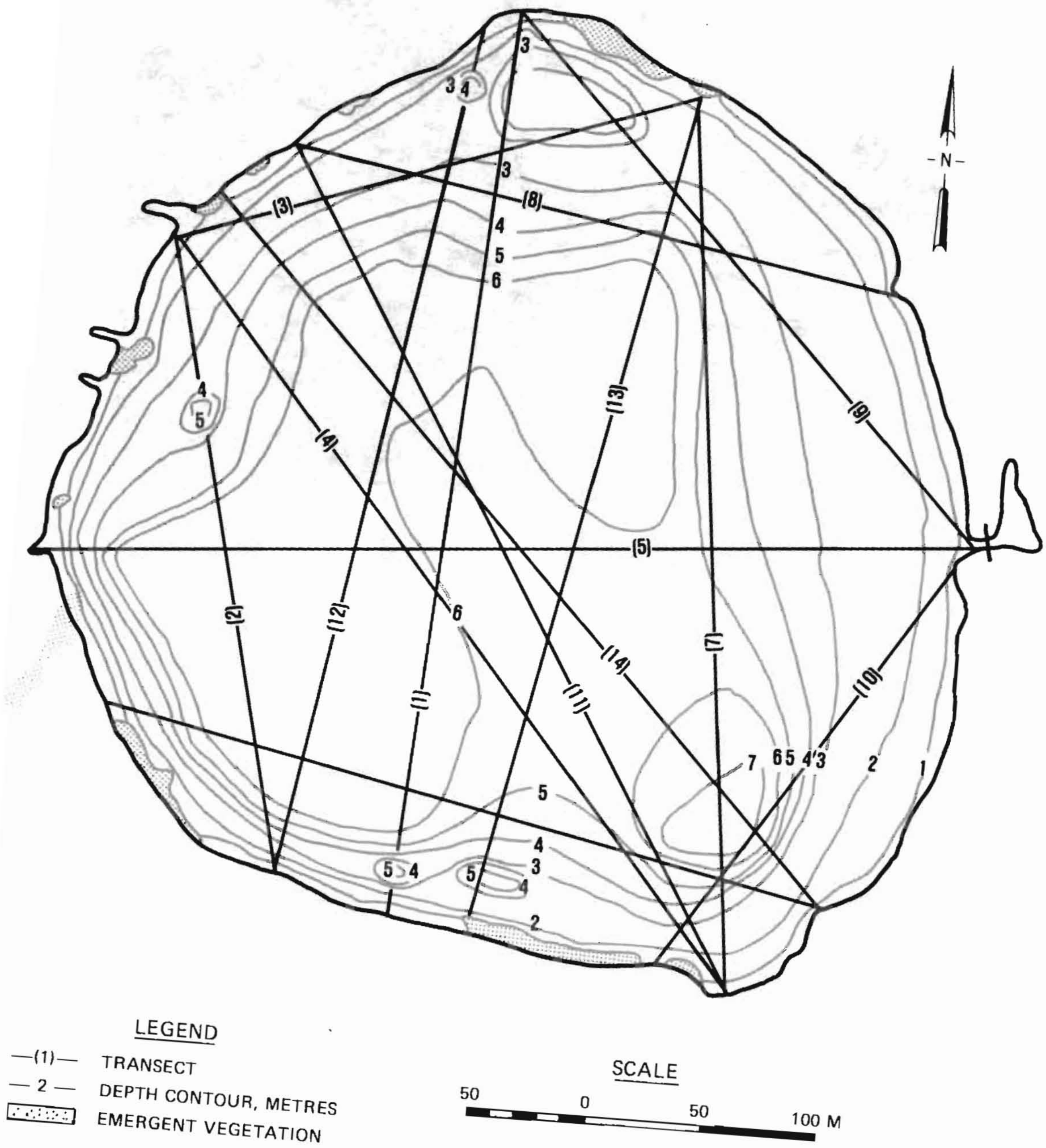


Figure 5. Depth contours and transect lines, Lake Baldwin, Florida

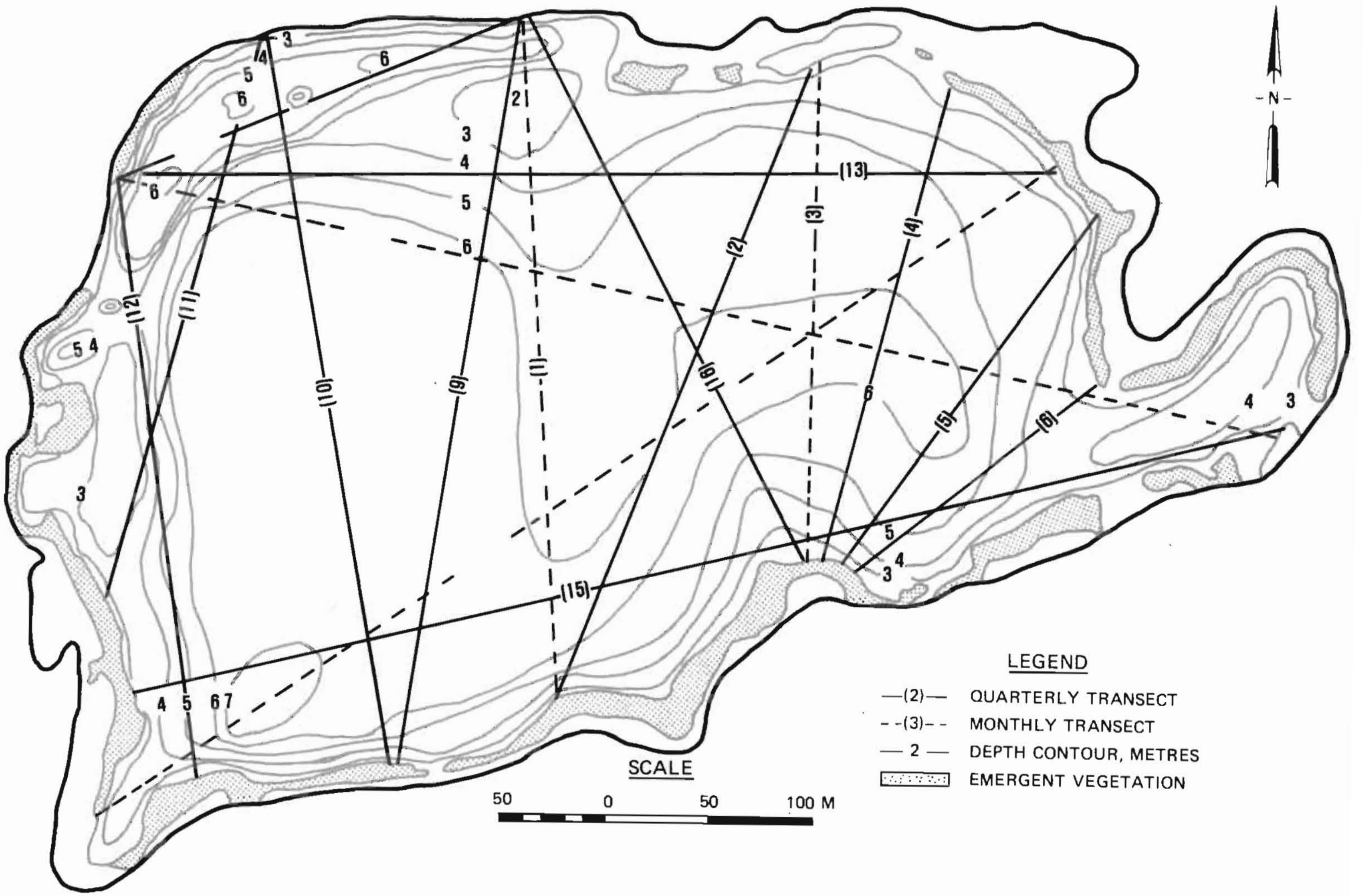


Figure 6. Depth contours and transect lines, Lake Wales, Florida

PART IV: DESCRIPTION OF STUDY AREAS

Lake Baldwin

36. Lake Baldwin, located in Orlando, Florida, adjacent to the U. S. Navy Training Center, is an 80-ha lake with a maximum depth of 7.8 m (Figure 5). The lake bottom consists of 60 percent sand and 40 percent mud (Shireman and Gasaway 1976). Cattail (*Typha latifolia*) and *Panicum* sp. are found along the fringes of the lake shoreline along with waterhyacinths.

37. In the past, hydrilla dominated the submersed aquatic flora, but following chemical herbicide treatment with Hydout TM (Endothall Technical) in 1975, filamentous blue-green algae, southern naiad (*Najas quadalupensis*), *Chara*, and *Nitella* appeared. On 15 April 1975, 4,999 white amur fingerlings were stocked and the combined effects of chemical and biological control were monitored for 3 years. By 1978, hydrilla again became a serious and nuisance weed problem, surfacing in many parts of the lake and forcing the closure of the lake to waterskiing. During the summer of 1978, an additional 2,100 yearling white amur were stocked in the lake and chemical herbicide was applied to 19 ha of the lake.

Lake Wales

38. Lake Wales, a 134-ha lake, is located within the city of Lake Wales, Polk County, Florida (Figure 6). Maximum depth is 7.2 m. The lake bottom consists primarily of sand with a mud layer found only in the deeper regions of the lake. Hydrilla is the dominant submersed plant in the lake. Eelgrass (*Vallisneria americana*) is found inhabiting some shallow shoreline areas and flats. Cattails form a fringe around the lake.

39. In October 1974 and January 1977, 11,053 and 50,000 white amur fingerlings, respectively, were introduced into the lake for hydrilla control. During the summers of 1975 to 1976, surface matting of hydrilla

occurred over 80 percent of the lake (Shireman 1977). During 1977 and 1978, hydrilla did not surface mat, but was present in most parts of the lake.

PART V: TECHNIQUES AND RESULTS

Differentiation of Submersed Macrophytes

40. During the study, hydrilla was the only submersed macrophyte found growing in Lake Baldwin. Separation of vegetation communities by species did not occur. In Lake Wales, eelgrass beds were found growing at depths to 3.0 m and did not reach a height greater than 0.7 m from the hydrosoil. During the late spring, summer, and fall, hydrilla could be differentiated from eelgrass simply by examining differences in vegetation height on the chart tracing (Figure 7). Typically, hydrilla was found growing taller than eelgrass. In some cases, examination of fathometer tracings revealed that hydrilla patterns were denser near the top of the plant, whereas eelgrass patterns were less dense and more evenly distributed. According to Haller and Sutton (1975), the major portion of the biomass production in hydrilla is located in the upper

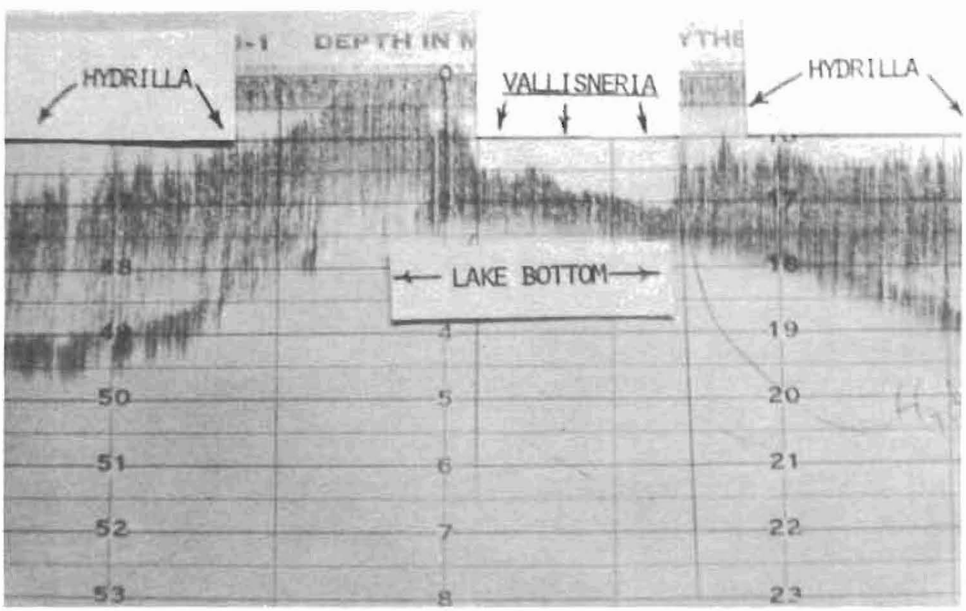


Figure 7. Transect section as recorded by the fathometer, Lake Wales, Florida, illustrating stands of *Vallisneria* and hydrilla

portion of the plant, whereas in eelgrass biomass is more evenly distributed. This accounts for the differences in tracing patterns. Evenly mixed stands of hydrilla and eelgrass appeared as pure stands of hydrilla on the tracing. When eelgrass dominated, tracing patterns were characteristic of pure stands of this plant.

41. A lake adjacent to Lake Baldwin, Lake Susannah, was utilized to further test the detection of submersed macrophyte species by characteristic and distinctive tracing patterns. Filamentous blue-green algae (*Lyngbya* sp.) characteristically grows 0.1 to 0.2 m in height above the hydrosoil and was recorded as a low flat mound. The tracing is similar in pattern density to the hydrosoil (Figure 8). During the summer and fall months, this pattern was distinguishable from all other types of submersed macrophytes in the lake. Hydrilla, southern naiad, *Nitella*, and *Chara* were sampled in different areas; however, differences in tracing patterns could not be detected. During the winter when submersed vegetation was near the bottom, *Lyngbya* also could not be

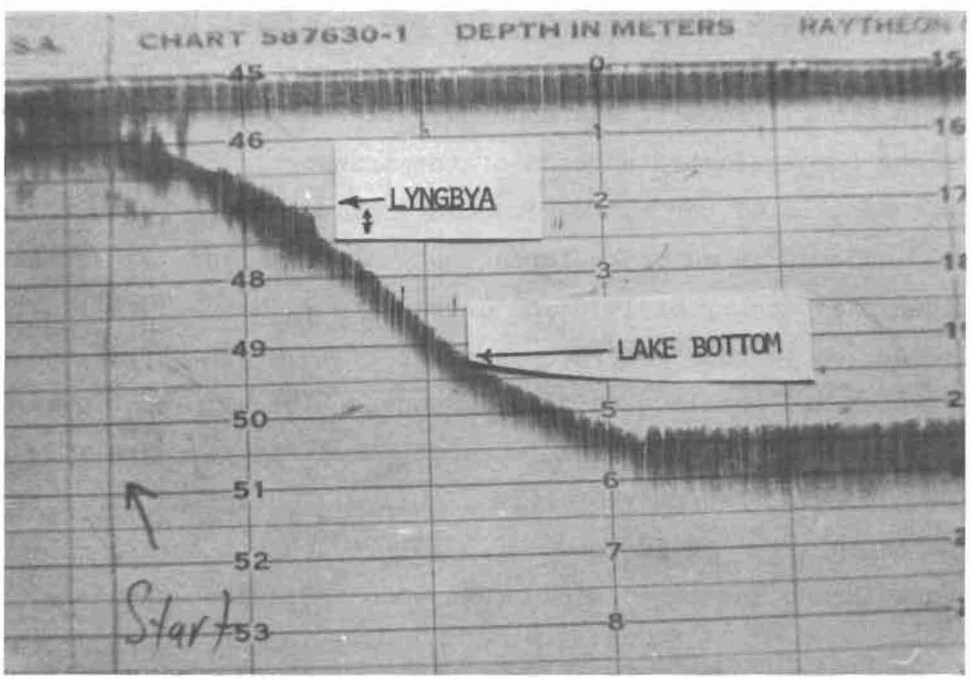


Figure 8. Transect section recording in Lake Susannah, Florida, illustrating filamentous blue-green algae (*Lyngbya* sp.)

differentiated from the other macrophytes by tracing patterns.

Transect Percent Cover

42. In order to calculate the percent vegetation cover for a transect, the linear measurement of hydrilla on the chart paper was divided by the total chart paper length of the transect. These distances were measured along a horizontal plane parallel to the 0-m depth mark (surface of the water) and not along the bottom contour. The maximum slope gradient for Lakes Baldwin and Wales for any one transect was 1:30; therefore, measurement biases were considered negligible. Measurements were made in consistent fashion each month so that percent cover values among dates could be compared accurately.

43. In Lake Baldwin, surface matting of hydrilla along the edges of the lake in June and August of 1978 prevented access to shallow water start and finishing points. Transects were run from the edge of the mat in line with the start and finishing points and were run as far as possible before the boat was slowed by hydrilla on the opposite shoreline. Total chart transect distances were derived by estimating the true start and finishing points on the chart paper. Calculation of percent cover of hydrilla along transects was made assuming complete hydrilla infestation along the estimated portion of the transect.

44. Results of percent cover of hydrilla in Lake Baldwin showed a general increase in coverage throughout the summer of 1978, peaking in November and January of 1979 and decreasing in March 1979 (Table 1). The decrease in hydrilla coverage in March of 1979 was attributed to winter dieback and possible white amur consumption.

45. Hydrilla coverage increased in Lake Wales through 1978 peaking in November and February of 1979 (Table 2). Eelgrass correspondingly decreased with the increase of hydrilla, except during February 1979 when eelgrass increased along transects throughout the lake.

Total Percent Cover

46. Vegetation maps depicting hydrilla infestation were drawn for Lakes Baldwin and Wales (Appendix B). For each transect, the map

length of the transect was divided by the corresponding transect chart length to derive conversion factors. From the starting point on the chart tracing, the distance of hydrilla infestation or extent of open water was measured following the same procedures described for determination of transect percent cover. This value was multiplied by the conversion factor and the distance marked from the corresponding transect starting point on the map. By repeating this procedure where the last vegetation type ended along the transect (i.e. hydrilla, eelgrass, open water), vegetation coverage was determined for the entire transect. Comparison of water depths on the chart tracing and contour lines on the bathymetric maps was used to verify and adjust distances.

47. Generally, maximum hydrilla infestation in Lakes Baldwin and Wales extended to the 5.0- to 6.2-m contour. Eelgrass was always found inhabiting shallow waters. Lines connecting various vegetation types were drawn among transects. Entire vegetation communities were then imposed upon the map, and the total area of the lakes containing vegetation was determined by planimetry. Areas of emergent vegetation and areas inaccessible for conducting transects were not included in the determination of total area covered and total percent vegetation cover.

48. When surface matting of hydrilla occurred along the edge of Lake Baldwin, transects were started at the outer edge of the mat. From chart tracings along a transect, the depth at which surface matting ended was determined. On a bathymetric map the distance of hydrilla matting was marked off along the transect. Lines were drawn connecting matted portions of transects and adjustments were made according to field observations. In this manner, the area of surface matting was determined.

49. In Lake Baldwin, hydrilla total percent cover increased from 58 percent in May 1978 to 78 percent in January 1979 and decreased to 71 percent by March of 1979 (Table 3). Hydrilla matting occurred during the summer and fall months. In August 1978, hydrilla mats covered 23 percent of the lake surface, but disappeared by winter. These data were similar to trends indicated by transect percent cover data.

50. In Lake Wales, similar results were obtained as hydrilla cover increased from 49 to 65 percent throughout the study period (Table 4). A decline was not observed between November 1978 and February of 1979. Hydrilla surface matted in a few areas but was not a serious problem. Eelgrass communities decreased in the summer and fall but increased in cover during February 1979.

Percent Vertical Cross-Sectional Area Infestation

51. A vegetation transect conducted with a recording fathometer produces a cross-sectional vertical profile of the water column and submersed vegetation (Figure 9). Monthly transects indicate that hydrilla grows towards the surface of the water before expanding horizontally. Percent cover data for transects do not describe hydrilla expansion in the water column; therefore, the percent vertical cross-sectional area infestation was determined.

52. Since transects were usually started and finished in water depths greater than 1.5 m, areas less than this depth were not sampled nor included in the determinations. For each transect, a planimeter was used to determine the cross-sectional area. The area of vegetation was also determined by planimetry. The percentage of the water column

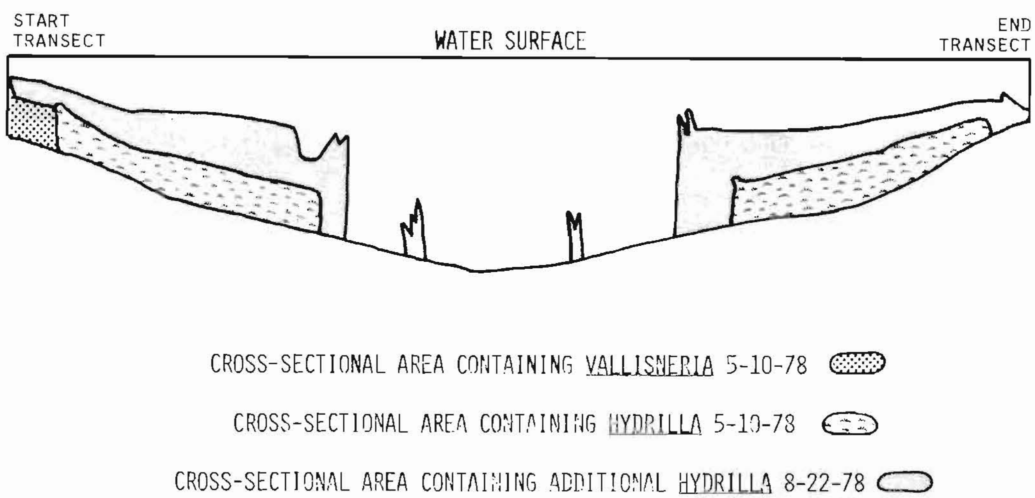


Figure 9. Diagrammatic representation of transect 3 chart tracing, Lake Wales, May and August 1979

infested with hydrilla was determined by dividing the vegetation area by the total water area. A diagrammatic representation, Lake Wales transect 3, was drawn for May and August 1978 as an example (Figure 9). Percent cover data for this transect indicated hydrilla increased from 49 to 64 percent during this time period, whereas percent cross-sectional area infestation increased from 10 to 34 percent during the same time interval.

53. A transect percent cover value of 100 percent may not necessarily indicate a weed problem along a particular transect if the vegetation height is not great. However, a 100 percent vertical cross-sectional area infestation infers total vegetation inhabitation from the water surface to the hydrosoil and complete coverage along the length of the transect.

54. Percent vertical cross-sectional area infestation showed a twofold to fourfold increase along transects conducted in Lake Wales from May to August 1978 (Table 5). Cross-sectional infestation peaked in November. From November 1978 to February 1979 hydrilla decreased in the lake causing a marked reduction in cross-sectional area infestation. Transect percent cover and total percent cover data revealed no marked decreases in hydrilla abundance from November 1978 to February 1979. Percent vertical cross-sectional values probably represented a more accurate description of hydrilla abundance throughout the year.

Correlation and Prediction of Hydrilla Biomass Utilizing Chart Tracings

55. Biomass data collected from August and December 1978 and March 1979 were used for analysis and model building. Two models correlating hydrilla biomass with fathometer tracings were based on tracing pattern characteristics. The first model, thick hydrilla, was indicated by sampling stations where dense and thick hydrilla did not permit a clear reading of the lake bottom (Figure 10a). The high hydrilla density prevented sound waves from penetrating and/or reflecting back to

the transducer through the plants. A second model, sparse hydrilla, permitted a clear reading of the lake bottom due to sparse and/or shallow hydrilla stands (Figure 10b).

56. For thick hydrilla, the multiple regression equation found to be the best fitting ($R^2 = 0.796$) is:

$$Y = 1.977 + 1.029X_1 - 1.341(\ln X_2) \quad (1)$$

where

Y = wet weight of hydrilla, kg/m^2

X_1 = height of hydrilla from the hydrosoil to the top of the plant along the fix mark, m

X_2 = distance from the top of the hydrilla plant to the surface of the water along the fix mark

This was the highest probable model ($P < 0.01$) relating thick hydrilla biomass with tracing characteristics. A positive relationship between hydrilla height and biomass ($m = +1.029$) existed. As height of hydrilla increased, biomass increased. A negative relationship between the distance from the top of the hydrilla plant to the water surface and biomass ($m = -1.341$) occurred. As hydrilla approached the water surface, biomass increased. As the distance from the top of the hydrilla plant to the surface of the water increased, biomass decreased.

57. For sparse hydrilla, the multiple regression equation found to be the best fitting ($R^2 = 0.807$) is:

$$\ln Y = -5.099 + 0.982(\ln X_1) + 1.301(\ln X_2) - 0.281(\ln X_3) \quad (2)$$

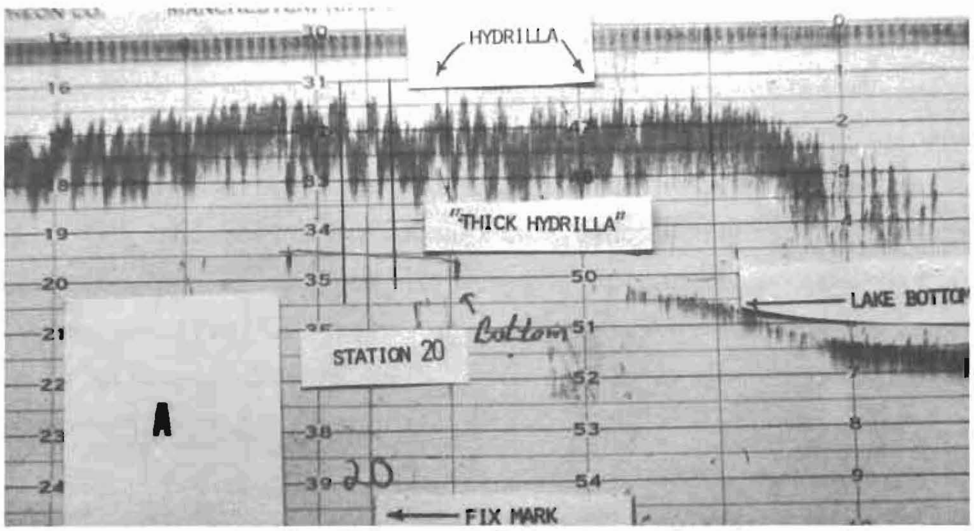
where

Y = wet weight of hydrilla, kg/m^2

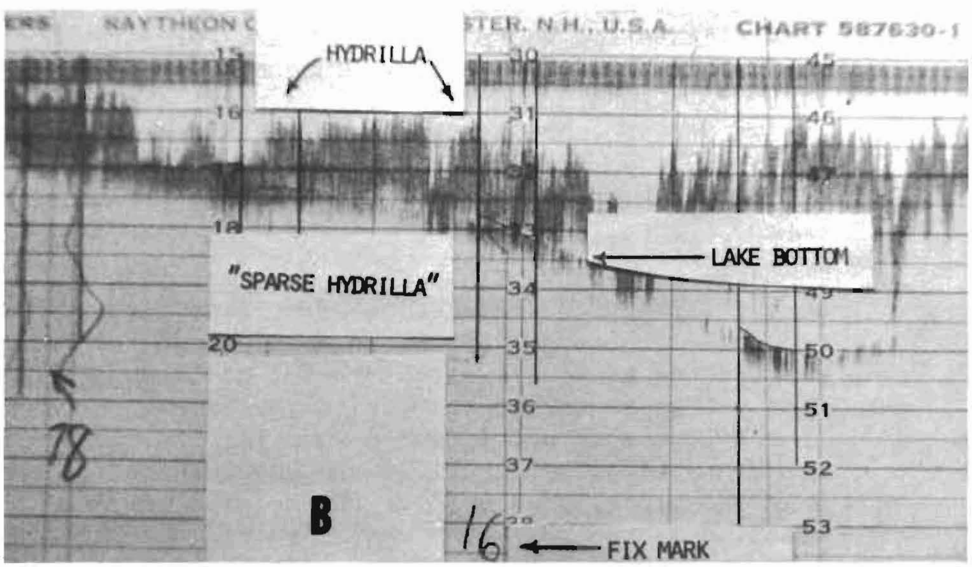
X_1 = hydrilla height from the hydrosoil to the top of the plant along the fix mark, m

X_2 = percent vertical cover of hydrilla on the tracing

X_3 = distance from the top of the hydrilla plant to the surface of the water along the fix mark, m



a. Thick hydrilla



b. Sparse hydrilla

Figure 10. Chart tracings from Lake Baldwin displaying biomass sampling stations

This was the highest probable model ($P < 0.01$) relating sparse hydrilla biomass with tracing characteristics. Similar relationships existed between biomass and hydrilla height and the top of hydrilla to the surface of the water for sparse hydrilla. A positive ($m = +1.301$) linear relationship existed between ln(biomass) and ln(percent vertical cover). A vegetative area on the chart covered by an increased number of tracing lines caused a dense, dark pattern corresponding to higher hydrilla biomass. Examination of multiple regression analysis utilizing Type IV sum of squares revealed that the ln(percent vertical cover) proved to be the strongest of the three independent variables ($F = 131.74$; 1,147 d.f.), explaining the variation due to the ln(biomass) of sparse hydrilla.

58. The calculation of percent vertical cover yields a quantitative ocular estimate or index of the percent of hydrilla infesting a particular section of the water column. The procedure utilized to determine this relationship is described below:

<u>a</u>. A 5-mm distance on each side of the fix mark designating a sample station was marked and lines were drawn parallel to the fix mark (Figure 11). This corresponded to a lake distance of 6 m. Hydrilla biomass samples obtained with the vegetation core sampler were taken within 6 m of the weighted buoy marking a sample station. Therefore, the biomass samples corresponded to the area marked on the chart paper.

<u>b</u>. The area within the lines drawn parallel to the fix mark were utilized for calculation of percent vertical cover. Each 0.5-m interval within the area around the fix mark was treated as a separate block for cover determination. Blocks that contained the top of the hydrilla and the lake bottom were not included when percent vertical cover was computed. When hydrilla and the lake bottom occupied only one block, then a cover estimate was made in that fraction of the box above the hydrosoil.

<u>c</u>. A dissecting microscope (10 to 15 power) was used to estimate the percentage of a particular block that was covered by tracing lines. Each individual block was treated in the same manner.

<u>d</u>. Individual blocks were summed and divided by the total number of blocks to derive average values. These values were determined as the percent vertical cover for the sampling station.

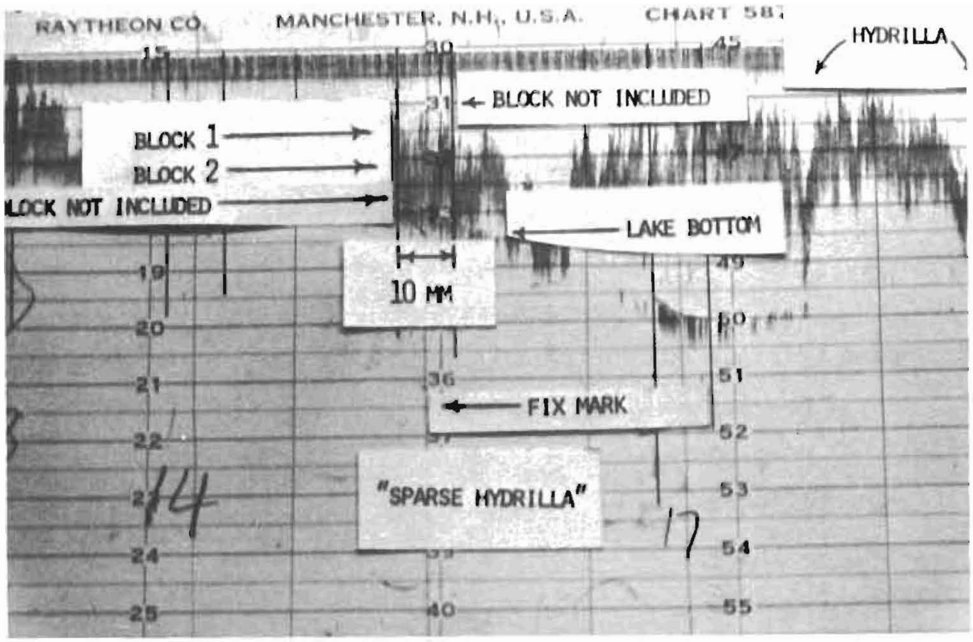


Figure 11. Illustration of the derivation of percent vertical cover

59. When the top of a hydrilla plant reached 0.7 m or closer to the surface of the water, vegetation tracing patterns and water surface patterns became mixed and could not be differentiated (Figure 3). In order to determine actual hydrilla height and the distance from the top of the plant to the surface of the water, measurements of the distance from the water surface to the top of the plant were made at marked buoys where hydrilla was approaching the surface. These measurements were used for biomass correlations.

60. Biomass regression models were used to estimate total biomass in Lake Baldwin from monthly transects. A systematic random design was formulated to accomplish this goal. On metric chart paper, vertical lines transversed the chart paper at 25.4-mm intervals. Starting with the first transect, the first vertical line on the transect became the first prediction station for that month. The vertical line was treated equivalently to the fix mark line that was utilized to calculate the independent model variables. Hydrilla height, percent vertical cover, and distance from the top of hydrilla to the surface of the water were

determined for these stations utilizing the same procedures employed for determining actual biomass. Each vertical line on the chart paper that crossed hydrilla on all 14 transects was utilized as a prediction station. When the vertical line intercepted areas on the chart paper that indicated open water, no measurements were made. Approximately 150 to 200 prediction stations were used per monthly sample.

61. For sparse and thick hydrilla prediction stations, mean values for hydrilla height, percent vertical cover, and distance from the top of the hydrilla plant to the surface of the water were calculated for six depth intervals: 1.0 to 1.9, 2.0 to 2.9, 3.0 to 3.9, 4.0 to 4.9, 5.0 to 5.9, and 6.0 to 6.9 m. Stratification by depth intervals reduced variation about the mean. The majority of stations used to calculate thick hydrilla were between 4 and 6 m in depth.

62. The total area of each depth interval of the lake was determined by planimetry for Lake Baldwin (Table 6), and the total area of hydrilla infestation was determined from vegetation maps for each depth interval. Each depth interval was assigned a percentage of the area in hectares according to the proportion of the entire area in which sparse and thick hydrilla vegetation type stations were observed. For example, if the 5.0- to 5.9-m depth interval contained 10 ha of hydrilla and 20 prediction stations, then the ratio of thick and sparse stations was determined. If 15, or 75 percent, of these stations were sparse hydrilla and 5, or 25 percent, were thick hydrilla stations, then 7.5 ha of the 10.0 ha would be designated as containing sparse hydrilla and 2.5 ha as thick hydrilla.

63. Mean vegetation values (hydrilla height, percent vertical cover, and surface distance) for each depth interval and for both thick and sparse hydrilla vegetation types were entered into their respective multiple regression models. The mean weight of hydrilla, in kilograms per square metre (95 percent confidence interval), was generated for each depth interval and for the two hydrilla types. At each depth interval, the total vegetation area in hectares was converted to square metres and multiplied by the mean weight of hydrilla per square metre for both vegetation types. For each depth interval where sparse and

thick hydrilla occurred, the total weight of hydrilla and the upper and lower confidence intervals were derived by summation. Weight of hydrilla and confidence intervals were summed for all depth intervals to determine total hydrilla standing crop (Tables 7-11).

64. As stated previously, the depth interval 0 to 0.9 m was not sampled due to limitations of the recording fathometer. Standing crop of hydrilla in this depth interval was estimated by dividing the mean biomass (kg/m^2) of the 1.0- to 1.9-m depth interval by 2 and multiplying this value by 2.7 ha (Table 6). It was assumed that this area contained 100 percent hydrilla coverage throughout the year. Confidence intervals were calculated from a percentage of the values determined in the 1.0- to 1.9-m depth interval. The 0- to 0.9-m depth interval contributed 1.4 to 2.8 percent of the total standing crop for any one estimate.

65. Total hydrilla standing crop rose from 1.5 million kilograms in June 1978 to 2.0 million kilograms by August 1978 (Tables 7-11), and decreased in November 1978 and January 1979. By March 1979 hydrilla had declined to approximately 0.6 million kilograms. Winter dieback and probable white amur consumption accounted for this rapid decline during the winter months.

Comparison of Fathometer and Direct Biomass Sampling Methods

66. In order to evaluate the total hydrilla standing crop estimate generated by utilizing fathometer tracings, hydrilla standing crop was also determined by the method reported by Nall and Schardt (1978). On 8 March 1979, following collection of replicate hydrilla biomass samples to correlate biomass with chart tracings, 100 random biomass samples were taken utilizing the core vegetation sampler. A map of Lake Baldwin was constructed and a grid pattern overlaid with two hundred 0.4-ha (1-acre) blocks. One hundred blocks were randomly selected for sampling from a random numbers table. At each sampling site, water depth was measured and recorded. Hydrilla samples were washed and shaken to remove excess sand, mud, and water and weighed to the nearest

5 g. Weights were converted to kilograms per square metre for analysis.

67. Analysis of the direct random biomass sampling method determined a mean value of 1.21 $\pm$ 0.23 kg wet hydrilla/m^2 ($\pm$ 0.05 percent) (Table 12). Total standing crop was calculated and found to be 0.95 $\pm$ 0.18 million kilograms hydrilla for the entire lake. The estimated mean biomass calculated from fathometer tracings was slightly lower, 1.04 kg hydrilla/m^2. These two means were not statistically tested due to the different collection methods utilized and derivation of variances, but the occurrence of overlapping confidence intervals exhibited by each mean might indicate that the mean values were not significantly different. However, the fathometer biomass estimate was generated from those areas containing only hydrilla or for 70.5 percent of the area of the lake. The biomass estimate generated from direct random sampling was claculated for the entire area of the lake including those areas with and without stands of hydrilla. Of the 100 biomass samples collected, only 14 samples contained no hydrilla. These observations were calculated into the mean and confidence interval values, which reduced the estimate. However, total standing crop estimates were observed to be much larger for the direct random biomass sampling (946,640 kg) than the estimate calculated from fathometer tracings (576,800 kg). Because the confidence intervals did not overlap, it is likely that these values are significantly different.

68. Inspection of the data revealed reasons for this discrepancy. Data from the direct random biomass sampling method indicated that hydrilla was inhabiting 86 percent of the lake. Fathometer tracings revealed only 71 percent of the lake area contained hydrilla. It is felt that the 71 percent coverage figure calculated for the lake is more accurate due to the high number of transects conducted (14) and the total distance covered by these transects (11.32 km). Therefore, calculation of mean hydrilla biomass and total hydrilla standing crop values from the direct random biomass sampling data overestimated the amount of hydrilla in the lake due to the number of samples taken in hydrilla.

69. Closer inspection of the data reveals this source of error.

Of the 100 samples collected by the direct random sampling method, only 4 percent were taken in water depths greater than 6.1 m. However, depth interval area values for Lake Baldwin demonstrate that 28.0 percent of the lake area is greater than 6 m in depth (Table 6). The random sampling method underestimated the amount of sampling required in this portion of the lake. This method, though, placed the remaining 96 percent of the sampling effort in water depths less than 6 m, while actually 72 percent of the lake area is less than 6 m. A vegetation map of Lake Baldwin for March 1979 (Appendix B) and the area of hydrilla infestation for water depth greater than 6 m (Table 11) revealed that only 3 percent of the lake area greater than 6 m contains hydrilla. Therefore, it appears a disproportionate amount of sampling effort was placed in hydrilla-infested waters by the direct random biomass sampling method causing an overestimation of the total hydrilla standing crop.

Hydrilla Height

70. Another parameter that was used to estimate hydrilla abundance was to examine the height of hydrilla and the distance from the top of the hydrilla plant to the surface of the water. A decrease in hydrilla height was associated with a decline of hydrilla in a lake.

71. The data generated from stations used to predict biomass in Lake Baldwin were utilized in this analysis. A systematic sampling procedure was used to derive vegetation values for hydrilla height, percent vertical cover, and the distance from the top of the hydrilla plant to the surface of the water (hydrilla-surface) at different depth intervals. Sparse and thick hydrilla stations were combined and mean values generated for hydrilla height and hydrilla-surface distance.

72. Analysis of variance and Duncan's (1955) multiple range test were used to determine if water depth fluctuated at each 1-m depth interval over the five sampling dates. Observed variation in water depth at each depth interval might have occurred in two ways:

- a. A rise or fall in the lake water level would alter the water depth over which transects were conducted. Water level fluctuated 0.2 m in Lake Baldwin during the study period accounting for some of the variation.

b. Initially, stations were chosen for hydrilla height and hydrilla-surface distance measurement which contained hydrilla. Expansion of the plant into deeper depth stratas caused an increase in the mean water depth within the station sampled.

Differences in the water depth sampled altered the hydrilla-surface distance values for a depth interval. If differences in station water depth were not observed, analysis of variance and Duncan's (1955) multiple range test were utilized to test differences between mean values for hydrilla height and hydrilla-surface distance among sampling dates.

73. Differences in the mean water depth samples were determined among sampling dates for the following depth strata: 1.0 to 1.9, 5.0 to 5.9, and 6.0 to 6.9 m. Increased expansion of hydrilla into deeper waters throughout the study period accounted for the increase in water depth at the deeper depth stratas (see Appendix B). In order to remove the interaction of variable water depth and its influence on hydrilla height and hydrilla-surface distance, water depth was treated as a co-variable in the analysis. By removing this influence, the mean values (hydrilla height and hydrilla-surface distance) obtained at each depth strata could be tested among sample dates in order to determine if these values changed significantly.

74. Results of this analysis showed a general increase in hydrilla height which peaked in August 1978 and decreased significantly ($P < 0.05$) to a low in March of 1979 for all depth strata. The hydrilla-surface distance also increased significantly during the study period (Table 13).

PART VI: WHITE AMUR

75. In April 1975, 4,999 fingerling white amur were stocked in Lake Baldwin to evaluate their effectiveness for long-term hydrilla control. The lake was chemically treated during September 1975, causing a considerable reduction in the amount of hydrilla during the next year. The weed, however, continued to grow and reached nuisance proportions during 1977 when the lake was closed to swimming and waterskiing. The explanation was that the number of white amur remaining in the lake was not sufficient to control hydrilla. In order to determine the number of white amur remaining, a selective rotenone treatment was conducted (Colle et al. 1978b). The population was estimated to be 264 white amur averaging 943 mm in total length (TL) and 12.23 kg. Because this stocking rate was not adequate, additional white amur over 305 mm were stocked into the lake during 1978 (Table 14). Previous studies indicated that white amur over 305 mm should escape predation (Shireman et al. 1978). Fifteen percent of the stocked fish were fin clipped and 10 percent of these were tagged with numbered tags (Table 15). To date none of the tagged fish have been recaptured.

76. Visual and fathometer samples indicated that white amur were consuming hydrilla. Definite eat-out areas were noticeable in the 2- to 3-m contour. During April 1979, 6 white amur were collected from these areas and an additional 21 escaped capture. Captured fish ranged in weight from 2.15 to 6.25 kg indicating that all were from the summer stocking. Until marked fish are recaptured, the actual growth rate for individual fish cannot be determined.

77. Biomass estimates can be approximated from growth curves established for Lake Wales fish. Lake Wales is very similar in habitat and latitude. Weights of Lake Baldwin white amur can be extrapolated from this curve (Figure 12) and total biomass estimated. Utilizing the Lake Wales growth line and considering the length of time the fish were in the lake, total biomass of all white amur in the lake for March 1979 was estimated at 121 kg white amur/ha. At

the same time, hydrilla biomass was estimated at 0.6 million kilograms. A reduction in hydrilla biomass this summer is anticipated due to white amur feeding.

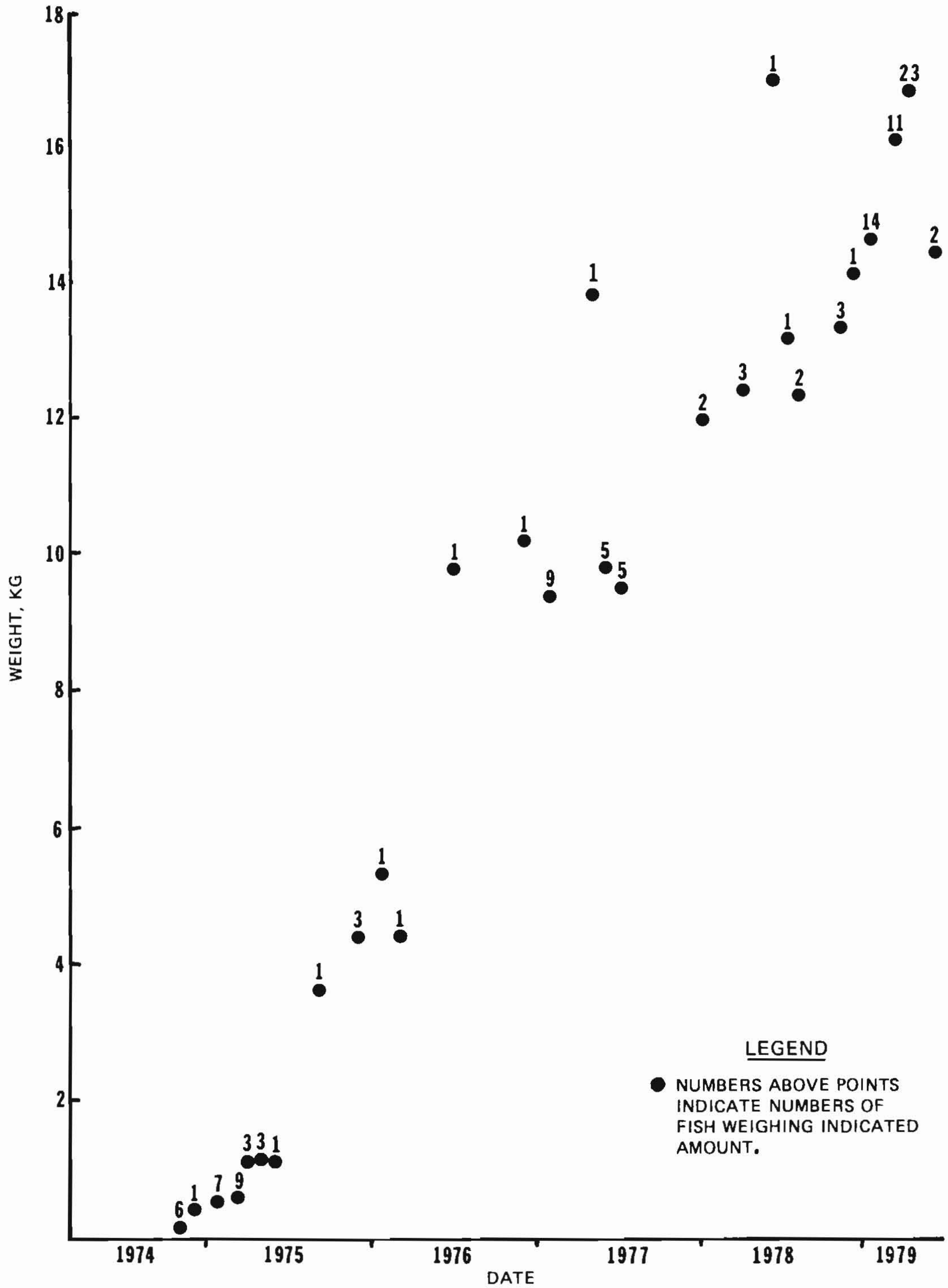


Figure 12. White amur weights 1974-1979, Lake Wales, Florida

PART VII: DISCUSSION

78. A general increase in hydrilla infestation was noted during the summer and fall months of 1978, followed by a decline in the latter part of the winter in 1979 in Lake Baldwin. Transect percent cover and total percent cover data indicated hydrilla abundance peaked in November 1978 and January 1979. Results of total hydrilla standing crop and hydrilla height and hydrilla-surface and percent cross-sectional area data implied peak hydrilla abundance occurred in August of 1978. Discrepancies in the data were caused by a decline in hydrilla height and a reduction and later elimination of surface matted hydrilla starting in November 1978. Therefore, total hydrilla standing crop was reduced. The principal reason for increases in percent cover and total percent cover was the expansion of sparse hydrilla into the 6.0- to 6.9-m depth interval from August 1978 to January 1979. However, hydrilla infestation at this depth contributed less than 5 percent to the total standing crop for November 1978 and January 1979. Herbicide treatment of hydrilla in Lake Baldwin in August 1978 did not eliminate the plant from shoreline areas where the application was made.

79. In Lake Wales, similar results were obtained. Transect percent cover and total percent cover of hydrilla increased from May 1978 through February 1979. A reduction in hydrilla height caused percent vertical cross-sectional area infestation values to decline nearly 50 percent from November 1978 to February 1979. This indicated an actual decrease in hydrilla abundance.

80. In analyzing results and changes in hydrilla abundance in a lake, presentation of quantitative vegetation parameters is recommended. As a result, accurate and more reliable conclusions will be made concerning hydrilla abundance and the effect of any control measure.

81. The principal advantage of utilizing a recording fathometer for vegetation surveys is that savings in time and manpower are accomplished. In Lake Baldwin, 14 transects covering a total distance of 11.32 km were completed in 3 hr. In Lake Wales, 16 transects covering

13.24 km can be run in 3.5 hr. From previous experience, the completion of a 100-m (0.1-km) conventional line intercept transect with points at 2-m intervals requires 0.5 to 1.0 hr for completion and two surveyors. With experience, one person can operate the motor boat and fathometer simultaneously and sample a greater portion of the lake.

82. Compared to other indirect or noncontact vegetation survey techniques that sample submersed macrophytes including onsite mapping (Hestand et al. 1973), color photography (Edwards and Brown 1960), and color infrared photography (Benton and Newnan 1976), a recording fathometer is advantageous since vegetation is monitored in two planes in the water column, vertical and horizontal. The other methods examine only the water surface or horizontal plane of the water column.

83. The results of this study indicated that a recording fathometer is best suited for aquatic vegetation surveys in lakes where the problem plant exists as a monoculture. Small beds of eelgrass, though, were distinguishable from hydrilla. Gross morphological differences in plant structure appear to account for variation in recording chart tracing patterns. Future testing may prove that other submersed macrophytes can be differentiated from hydrilla by examination of chart tracing patterns. Previous tests indicated that differentiation between hydrilla and other submersed macrophytes of similar morphological structure (*Ceratophyllum*, *Myriophyllum*, *Utricularia*, *Cabomba*, and *Egeria*) cannot be accomplished by examination of tracing patterns.

84. Direct sampling of submersed macrophytes, including the line intercept transect techniques, offers the advantage of monitoring species composition. Hestand et al. (1973) present a noncontact technique, onsite mapping, that differentiates between submersed vegetation species by presenting percent cover data.

85. If projects require that different submersed macrophyte species be treated as a group, a recording fathometer could be utilized to generate quantitative data for the entire submersed aquatic plant community. Random direct contact sampling or line intercept transects could be employed to monitor species abundance and diversity. Results of this study demonstrated that fathometer tracing patterns could be

correlated with actual hydrilla biomass and that the total standing crops of hydrilla in Lake Baldwin could be estimated throughout the year. In March 1979, separate biomass and total standing crop values were derived and compared between two methods: fathometer tracings and direct random biomass sampling. As described earlier, deep water areas (> 6 m) not containing hydrilla were disproportionately sampled by the direct random biomass sampler. This caused an overestimation of mean hydrilla biomass in the lake, resulting in an inflated total standing crop value.

86. The utilization of fathometer tracings for estimation of biomass eliminated the chance of error that occurs when employing a random numbers table for selection of sampling stations. A systematic random approach of selecting biomass prediction stations on chart tracings allowed all water depths to be adequately sampled. Choosing biomass prediction stations containing only hydrilla reduced variation about the mean. By determining predictive independent vegetation variables, which were utilized to calculate mean biomass values at 1-m intervals, variation was further reduced in the models. A greater number of hydrilla biomass prediction stations, 152 versus 86 for the biomass samples, were used in the analysis utilizing the fathometer method as compared to direct random biomass sampling method in March 1979 in Lake Baldwin.

87. One major limitation of the fathometer for estimation of hydrilla biomass and total standing crop was the inability to conduct transects in water depths less than 1 m; therefore, direct estimation of biomass in these water depths was prevented. Also, when formulating predictive regression models correlating fathometer tracing patterns with actual biomass, only two observations in water depths less than 2 m were utilized in the analysis. Therefore, because of limited sampling, biomass estimates from these shallow water areas may be biased. In Lake Baldwin, 9.2 percent of the lake area was less than 2 m in depth. This area contained a small percentage of the total hydrilla standing crop in the lake. Due to these sampling errors, total standing crop estimates possibly were slightly inaccurate.

88. On some sampling dates, an overall increase in transect percent cover occurred, but some individual transect values indicated decreases in hydrilla in Lakes Baldwin and Wales. Discrepancies and inconsistent transect percent cover values were probably due to boat drift. Transects were conducted at a slow boat speed (2 to 3 m/sec), and a fairly strong wind blowing perpendicular to the direction of boat movement could cause the boat to deviate from the assigned course resulting in a longer and slightly different transect. Fathometer transects should be conducted on calm, windless days. However, previous experience has shown that conventional line intercept transects also cannot be conducted during windy conditions.

89. The primary limitation of conducting vegetation surveys with a recording fathometer was incurred when submersed vegetation approached the surface of the water. Three disadvantages were then encountered: (1) Hydrilla tracing patterns merged with the transducer line when hydrilla was 0.7 m or closer to the water surface, preventing the top of the hydrilla plant from being distinguishable on the chart paper. (2) Hydrilla growth within 0.5 m of the surface impeded boat movement in these areas and occasionally caused complete stops while conducting transects. A boat slow down caused higher proportions of the total transect length to be recorded over hydrilla, which caused an overestimation of hydrilla in the lake. Determination of quantitative data from monthly transects in Lake Baldwin for September and October 1978 proved to be difficult, unreliable, and inconsistent due to extensive surface matting throughout the center of the lake. Surface matting along the edge of Lake Baldwin was accurately compensated for as described earlier in the text. (3) Thick and dense stands of hydrilla, especially approaching the surface of the water, prevented bottom sounding. Water depth determination is an important component when calculating quantitative results. Referral to corresponding chart paper transects conducted when hydrilla was less dense, however, allowed for bottom readings to be determined for those tracings where the bottom was not detected on chart tracings.

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Table 1. Percent cover of hydrilla along individual transects in Lake Baldwin.

Transect Number	Date 5-11-78	6-14-78	8-2-78	11-4-78	1-6-79	3-5-79
1	33.1	29.3	35.9	69.5	55.5	64.0
2	39.6	35.0	48.5	71.2	61.9	45.7
3	100.0	100.0	100.0	100.0	100.0	95.1
4	54.2	59.5	63.0	76.7	N.A.	71.9
5	49.2	49.6	71.2	67.3	65.3	64.8
6	54.4	N.A.	53.6	63.2	N.A.	53.1
7	76.5	80.7	69.3	82.5	79.0	77.3
8	96.7	99.6	100.0	91.3	94.9	90.8
9	95.7	99.3	100.0	100.0	100.0	100.0
10	96.8	96.1	100.0	100.0	100.0	94.5
11	N.A.	52.2	58.8	68.7	69.5	65.3
12	N.A.	22.1	25.7	35.2	36.2	27.0
13	N.A.	56.4	N.A.	74.1	72.0	69.4
14	N.A.	48.6	N.A.	64.6	61.5	58.4

N.A. = Not available.

Table 2. Submersed vegetation transect data for Lake Wales.

Date	Transect Number	% Cover *Hydrilla*	% Cover *Vallisneria**	% Bare Hydrosoil
5-10-78	1	18.2	15.9	65.9
8-22-78	1	43.6	10.0	46.4
11-15-78	1	67.9	5.7	26.4
2-20-79	1	65.5	8.8	25.7
5-10-78	2	45.3	2.1	52.6
8-22-78	2	63.2	0.0	36.8
11-15-78	2	73.4	0.0	20.6
2-20-79	2	72.1	2.8	25.1
5-10-78	3	49.2	2.5	48.3
8-22-78	3	63.8	0.0	36.2
11-15-78	3	79.4	0.0	20.6
2-20-79	3	80.6	7.4	22.1
5-10-78	4	66.6	2.5	30.9
8-22-78	4	74.9	2.0	23.1
11-15-78	4	79.3	3.0	17.7
2-20-79	4	79.5	4.5	24.3
5-10-78	5	61.6	4.4	34.0
8-22-78	5	82.1	0.0	17.9
11-15-78	5	77.4	0.0	22.6
2-20-79	5	87.9	0.0	23.8
5-10-78	6	85.2	8.8	6.0
8-22-78	6	100.0	0.0	0.0
11-15-78	6	100.0	0.0	0.0
2-20-78	6	84.9	10.6	4.8
5-10-78	7	31.9	4.3	63.8
8-22-78	7	43.7	3.3	53.0
11-15-78	7	50.3	1.1	48.6
2-20-79	7	63.6	4.8	31.6
5-10-78	9	22.9	7.8	69.3
8-22-78	9	24.5	8.9	66.6
11-15-78	9	27.4	8.7	63.9
2-20-79	9	22.8	11.4	65.8
5-10-78	10	26.7	0.0	73.3
8-22-78	10	26.7	0.0	73.3
11-15-78	10	35.2	0.0	64.8
2-20-79	10	27.2	0.0	72.8

(Continued)

* Some beds of *Vallisneria americana* contained sparse *Hydrilla* infestation.

Table 2. Continued.

Date	Transect Number	% Cover *Hydrilla*	% Cover *Vallisneria**	% Bare Hydrosoil
5-10-78	11	47.8	12.7	39.5
8-22-78	11	59.2	14.1	21.7
11-15-78	11	N.A.	N.A.	N.A.
2-20-79	11	63.9	13.3	22.8
5-10-78	12	55.2	37.5	7.3
8-22-78	12	55.3	38.2	6.5
11-15-78	12	63.5	36.5	0.0
2-20-79	12	62.1	32.9	5.0
5-10-78	13	67.0	1.6	31.4
8-22-78	13	85.9	0.0	14.1
11-15-78	13	100.0	0.0	0.0
2-20-79	13	86.8	2.8	10.4
5-10-78	14	47.1	0.0	52.9
8-22-78	14	42.2	0.0	55.8
11-15-78	14	48.0	0.0	52.0
2-20-79	14	N.A.	N.A.	N.A.
5-10-78	15	N.A.	N.A.	N.A.
8-22-78	15	63.5	0.0	36.5
11-15-78	15	65.2	0.0	34.8
2-20-79	15	61.7	0.0	38.3
5-10-78	16	N.A.	N.A.	N.A.
8-22-78	16	76.4	2.8	20.8
11-15-78	16	84.6	1.0	14.4
2-20-79	16	88.1	112.	0.2

N.A. = Not available.

Table 3. Submersed vegetation cover data from Lake Baldwin.

Date	*Hydrilla* investation area (ha)	*Hydrilla* investation % cover*	*Hydrilla* mats area (ha)	*Hydrilla* mats % cover*
5-11-78	45.4	57.9	0.0	0.0
6-14-78	48.4	61.7	4.2	5.4
8-2-78	52.4	66.8	17.8	22.7
11-14-78	61.2	78.1	0.6	0.8
1-6-79	61.3	78.2	0.0	0.0
3-5-79	55.3	70.5	0.0	0.0

* Fringe of cattail and *Panicum* allowed for sampling of submersed aquatic vegetation in 78.4 of 79.8 ha of Lake Baldwin.

Table 4. Submersed vegetation cover data from Lake Wales.

Date	*Hydrilla* infestation area (ha)	*Hydrilla* infestation % cover*	*Hydrilla* mats area (ha)	*Hydrilla* mats % cover*	*Vallisneria*** area (ha)	*Vallisneria*** % cover*
5-10-78	54.7	48.9	0.0	0.0	7.3	6.5
8-22-78	65.6	58.7	0.4	0.4	5.2	4.7
11-15-78	72.2	64.6	1.4	1.3	2.4	2.1
2-20-78	72.7	65.0	0.0	0.0	5.5	4.9

* Extensive fringe of cattail allowed for sampling of submersed aquatic vegetation in 111.8 of 133.5 ha of Lake Wales.

** Sparse *Hydrilla* was growing in beds of *Vallisneria*.

Table 5. Percent vertical cross-sectional area vegetation transect data for Lake Wales.

Date	Transect number	% vertical cross-sectional area containing *Hydrilla*	% vertical cross-sectional area containing *Vallisneria**
5-10-78	1	5.7	2.9
8-22-78	1	19.1	2.0
11-15-78	1	29.0	1.3
2-20-79	1	21.6	2.3
5-10-78	2	10.6	0.2
8-22-78	2	34.3	0.0
11-15-78	2	45.3	0.0
2-20-79	2	34.2	0.3
5-10-78	3	9.8	0.5
8-22-78	3	34.1	0.0
11-15-78	3	41.4	0.0
2-20-79	3	32.8	1.0
5-10-78	4	18.2	0.4
8-22-78	4	42.2	1.2
11-15-78	4	51.4	0.2
2-20-79	4	32.1	0.6
5-10-78	5	16.0	0.4
8-22-78	5	52.9	0.0
11-15-78	5	53.0	0.0
2-20-79	5	26.2	0.0
5-10-78	6	27.8	0.2
8-22-78	6	72.0	0.0
11-15-78	6	73.7	0.0
2-20-79	6	39.2	2.2
5-10-78	7	8.5	0.2
8-22-78	7	34.0	0.0
11-15-78	7	23.0	0.3
2-20-79	7	29.7	0.5
5-10-78	9	5.6	1.2
8-22-78	9	14.0	0.2
11-15-78	9	14.7	0.2
2-20-79	9	6.8	1.8
5-10-78	10	5.8	0.0
8-22-78	10	13.6	0.0
11-15-78	10	14.9	0.0
2-20-79	10	7.7	0.0

(Continued)

* Some beds of *Vallisneria americana* contained sparse *Hydrilla*.

Table 5. Continued.

Date	Transect number	% vertical cross-sectional area containing *Hydrilla*	% vertical cross-sectional area containing *Vallisneria**
5-10-78	11	18.9	8.6
8-22-78	11	62.0	1.9
11-15-78	11	N.A.	N.A.
2-20-79	11	26.5	1.7
5-10-78	12	31.0	13.1
8-22-78	12	62.9	6.6
11-15-78	12	48.0	6.5
2-20-79	12	31.0	9.7
5-10-78	13	13.0	0.6
8-22-78	13	57.5	0.0
11-15-78	13	66.6	0.0
2-20-79	13	33.5	0.3
5-10-78	14	9.4	0.0
8-22-78	14	27.9	0.2
11-15-78	14	24.1	0.0
2-20-79	14	N.A.	N.A.
5-10-78	15	N.A.	N.A.
8-22-78	15	35.0	0.0
11-15-78	15	33.4	0.0
2-20-79	15	17.9	0.0
5-10-78	16	N.A.	N.A.
8-22-78	16	44.6	0.2
11-15-78	16	52.3	0.2
2-20-79	16	33.2	1.5

N.A. = Not available.

Table 6. Depth interval area values for Lake Baldwin.

Depth interval (m)	Area (ha)	% Area*	Emergent Vegetation area (ha)	% Area
0 - 0.9	2.7	3.4	0.9	1.1
1.0 - 1.9	4.6	5.8	0.3	0.4
2.0 - 2.9	15.8	19.8	—	—
3.0 - 3.9	9.9	12.4	—	—
4.0 - 4.9	8.5	10.7	—	—
5.0 - 5.9	14.6	18.3	—	—
6.0 - 6.9	21.6	27.1	—	—
7.0 - 7.9	0.7	0.9	—	—
Total	78.4**	98.4	1.2	1.5

* Total area excluding cove = 79.6 ha.

** Total area available to sampling with recording fathometer.

Table 7. Hydrilla biomass and standing crop determinations for Lake Baldwin, 14 June 1978.

Depth interval (m)	Area infested (ha)	kg hydrilla/meter^2 $\bar{X}$	L.B.	U.B.	Total hydrilla (kg) $\bar{X}$	L.B.	U.B.
0 - 0.9	2.7	1.82*	1.43*	2.32*	49,140	38,610	62,640
1.0 - 1.9	4.6	3.64	2.85	4.64	167,440	131,100	213,440
2.0 - 2.9	15.8	2.88	2.46	3.36	454,960	388,080	530,600
3.0 - 3.9	9.6	4.26	3.71	4.84	408,600	351,180	464,350
4.0 - 4.9	8.5	6.08	5.40	6.77	516,740	458,800	575,590
5.0 - 5.9	7.2	1.98	1.61	2.43	142,430	115,560	174,610
	48.4	3.59	3.08	4.18	1,739,310	1,483,330	2,021,230

All weights are wet weights.

* Estimated.

L.B. = 95% lower bound confidence value.

U.B. = 95% upper bound confidence value.

Table 8. Hydrilla biomass and standing crop determinations for Lake Baldwin, 2 August 1978.

Depth interval (m)	Area infested (ha)	kg hydrilla/meter^2 $\overline{X}$	L.B.	U.B.	Total hydrilla (kg) $\overline{X}$	L.B.	U.B.
0 - 0.9	2.7	2.07*	1.26*	2.88*	55,890	34,020	77,760
1.0 - 1.9	4.6	4.14	3.54	5.69	190,440	115,920	264,960
2.0 - 2.9	15.8	2.89	2.39	3.42	456,360	376,920	541,060
3.0 - 3.9	9.9	5.31	4.75	5.88	525,360	470,400	581,720
4.0 - 4.9	8.5	6.22	5.78	7.19	529,040	491,150	610,750
5.0 - 5.9	10.6	2.16	1.80	2.55	229,400	191,060	270,260
6.0 - 6.9	0.3	0.13	0.08	0.21	390	240	630
	52.4	3.79	3.21	4.48	1,986,880	1,679,710	2,347,140

All weights are wet weights.

* Estimated.

L.B. = 95% lower bound confidence value.

U.B. = 95% upper bound confidence value.

Table 9. Hydrilla biomass and standing crop determinations for Lake Baldwin, 4 November 1978.

Depth interval (m)	Area infested (ha)	kg hydrilla/meter^2			Total hydrilla (kg)		
		$\bar{X}$	L.B.	U.B.	$\bar{X}$	L.B.	U.B.
0 - 0.9	2.7	0.87*	0.68*	1.15*	23,490	18,360	31,050
1.0 - 1.9	4.5	1.73	1.35	2.21	77,850	60,750	99,450
2.0 - 2.9	15.5	2.57	2.21	3.00	398,410	342,170	465,140
3.0 - 3.9	9.9	2.79	2.32	3.28	276,330	229,650	324,930
4.0 - 4.9	8.5	3.45	2.99	3.90	292,840	254,440	331,800
5.0 - 5.9	13.6	4.57	3.76	5.41	621,500	511,480	735,600
6.0 - 6.9	6.5	0.69	0.52	0.89	44,840	33,600	57,850
	61.2	2.84	2.37	3.34	1,735,260	1,450,450	2,045,820

All weights are wet weights.

* Estimated.

L.B. = 95% lower bound confidence value.

U.B. = 95% upper bound confidence value.

Table 10. Hydrilla biomass and standing crop determinations for Lake Baldwin, 6 January 1979.

Depth interval (m)	Area infested (ha)	kg hydrilla/meter^2 $\bar{X}$	L.B.	U.B.	Total hydrilla (kg) $\bar{X}$	L.B.	U.B.
0 - 0.9	2.7	1.29*	1.06*	1.57*	32,400	28,620	42,390
1.0 - 1.9	4.6	2.57	2.11	3.13	118,220	97,060	143,980
2.0 - 2.9	15.8	2.28	1.97	2.64	360,240	311,260	417,120
3.0 - 3.9	9.9	2.44	2.09	2.85	241,560	206,910	282,150
4.0 - 4.9	8.5	2.96	2.51	3.47	251,650	213,600	294,650
5.0 - 5.9	14.2	3.27	2.65	3.93	464,660	375,630	558,090
6.0 - 6.9	5.6	0.27	0.20	0.35	15,120	11,200	19,600
	61.3	2.42	2.03	2.87	1,483,850	1,244,280	1,757,980

All weights are wet weights.

* Estimated.

L.B. = 95% lower bound confidence value.

U.B. = 95% upper bound confidence value.

Table 11. Hydrilla biomass and standing crop determinations for Lake Baldwin, 5 March 1979.

Depth interval (m)	Area infested (ha)	kg hydrilla/meter^2			Total hydrilla (kg)		
		$\overline{X}$	L.B.	U.B.	$\overline{X}$	L.B.	U.B.
0 - 0.9	2.7	0.29*	0.22*	0.39*	7,830	5,940	10,530
1.0 - 1.9	4.6	0.58	0.43	0.77	26,680	19,780	35,420
2.0 - 2.9	14.3	0.38	0.29	0.50	54,340	41,470	71,500
3.0 - 3.9	9.8	0.86	0.72	1.01	84,280	70,560	98,980
4.0 - 4.9	8.4	2.03	1.60	2.49	170,590	134,450	209,450
5.0 - 5.9	13.6	1.69	1.23	2.17	229,470	166,760	295,020
6.0 - 6.9	1.9	0.19	0.14	0.26	3,610	2,660	4,940
	55.3	1.04	0.80	1.31	576,800	441,620	725,840

All weights are wet weights.

* Estimated.

L.B. = 95% lower bound confidence value.

U.B. = 95% upper bound confidence value.

Table 12. Comparison of fathometer and direct random biomass sampling methods for hydrilla biomass and total hydrilla standing crop for Lake Baldwin, March 1979.

Method	Calculated Area Infested (ha)	Calculated Percent Cover (%)	kg hydrilla/meter^2 $\bar{X}$	kg hydrilla/meter^2 L.B.	kg hydrilla/meter^2 U.B.	Total hydrilla (kg) $\bar{X}$	Total hydrilla (kg) L.B.	Total hydrilla (kg) U.B.
Fathometer tracings	55.3	70.5	1.04	0.80	1.31	576,800	441,620	725,890
Direct biomass sampling	67.4 (78.4)*	86 (100)*	1.21	0.98	1.44	946,640	768,320	1,128,960

* Kilograms of hydrilla per square metre and total hydrilla (kg) were calculated from the total area of the lake.

L.B. = 95% lower bound confidence value.

U.B. = 95% upper bound confidence value.

Table 13. Mean values (metres) for water depth, hydrilla height, and the distance from the top of the hydrilla plant to the surface of the water (hydrilla surface) by varying depth strata in Lake Baldwin.

Depth Strata (m)	Variable	Date 6-14-78	8-2-78	11-4-78	1-6-78	3-5-78
1.0 - 1.9	$\overline{X}$ water depth of strata sampled	1.8^{a}	1.7^{ab}	1.5^{ab}	1.8^{ab}	1.7^{b}
	$\overline{X}$ hydrilla height	1.3^{a}	1.2^{ab}	0.8^{b}	1.1^{ab}	0.5^{c}
	$\overline{X}$ distance hydrilla surface	0.5^{a}	0.5^{a}	0.7^{a}	0.7^{a}	1.3^{b}
2.0 - 2.9	$\overline{X}$ water depth of strata sampled	2.5^{a}	2.6^{a}	2.5^{a}	2.5^{a}	2.5^{a}
	$\overline{X}$ hydrilla height	1.5^{ab}	1.7^{a}	1.4^{b}	1.3^{b}	0.5^{c}
	$\overline{X}$ distance hydrilla surface	1.0^{a}	0.9^{a}	1.1^{ab}	1.2^{b}	2.0^{c}
3.0 - 3.9	$\overline{X}$ water depth of strata sampled	3.4^{a}	3.4^{a}	3.5^{a}	3.4^{a}	3.4^{a}
	$\overline{X}$ hydrilla height	2.4^{b}	2.8^{a}	1.9^{b}	1.8^{b}	1.0^{c}
	$\overline{X}$ distance hydrilla surface	0.9^{a}	0.7^{a}	1.6^{b}	1.5^{b}	2.4^{c}
4.0 - 4.9	$\overline{X}$ water depth of strata sampled	4.4^{a}	4.4^{a}	4.4^{a}	4.4^{a}	4.5^{a}
	$\overline{X}$ hydrilla height	3.6^{a}	3.9^{a}	2.5^{b}	2.5^{b}	1.9^{c}
	$\overline{X}$ distance hydrilla surface	0.8^{a}	0.5^{a}	2.0^{b}	1.9^{b}	2.6^{c}
5.0 - 5.9	$\overline{X}$ water depth of strata sampled	5.3^{b}	5.4^{ab}	5.3^{b}	5.4^{a}	5.4^{a}
	$\overline{X}$ hydrilla height	2.9^{b}	3.8^{a}	3.8^{a}	3.2^{b}	2.4^{c}
	$\overline{X}$ distance hydrilla surface	2.3^{a}	1.6^{b}	1.5^{b}	2.3^{a}	3.0^{c}
6.0 - 6.9*	$\overline{X}$ water depth of strata sampled	N.A.	6.1^{a}	6.2^{a}	6.4^{b}	6.4^{b}
	$\overline{X}$ hydrilla height	N.A.	4.3^{a}	3.2^{a}	2.8^{a}	2.6^{a}
	$\overline{X}$ distance hydrilla surface	N.A.	1.8^{a}	3.0^{a}	3.5^{b}	3.6^{b}

Values followed by the same letter are not statistically different ($P < 0.05$) over time.
N.A. = hydrilla was not found growing in water depths greater than 6 m.
* Co-variant analysis employed to test differences in hydrilla height and hydrilla-surface distance with water depth as co-variable.

Table 14. Stocking rates of white amur in Lake Baldwin.

Date	Number of fish stocked	Mean weight (kg)	Mean length (mm TL)	Number with identity tags	Number with fin clip
10/17/77	190*	12.23	943	0	0
10/17/77	88*	0.65	390	0	88
4/5/78	54	2.49	604	54	54
6/26/78	290	0.63	382	0	0
7/17/78	232	0.78	423	51	51
7/25/78	234	0.72	408	63	63
8/25/78	67	0.66	395	0	0
9/7/78	262	0.80	410	0	0
9/14/78	124	0.80	410	0	0
9/28/78	195	0.81	410	12	12
11/1/78	190	0.83	412	0	0
Total	1926			180	268

* Fish remaining in lake after population estimate, 10/17/77.

Table 15. White amur recapture data collected with electrofishing gear.

Date	Number captured	Number with marks	Length (mm TL)	Weight (kg)	Hours electrofished
8/2/78	0				8
12/18/78	4	0	615	3.78	8
			456	1.47	
			472	1.42	
			610	3.96	
2/12/79	4	0	475	1.95	3
			492	1.87	
			500	2.02	
			518	2.28	
2/13/79	1	0	659	4.05	3
4/11/79	0	0			4
4/12/78	6	0	644	4.30	4
			565	2.15	
			653	4.60	
			758	6.25	
			598	3.45	
			727	5.90	
Total	15	0			30

APPENDIX A: GLOSSARY OF TERMS

Aquatic vegetation/macrophyte - Macroscopic plants inhabiting permanent or temporary stands of water.

Exotic aquatic plant - A nonnative or nonindigenous aquatic plant.

Biomass - Weight per unit area.

Emergent aquatic plant - An aquatic plant generally rooted in shallow water and having most of its vegetative growth above water.

Frequency of occurrence - Number of samples in which a species occurred divided by the total number of samples taken.

Hydrosoil - The submersed bottom soil (i.e. sand, mud, detritus) of a lake or river.

Internodal length - The distance along the stem of a plant between two nodes.

Lake drawdown - Lowering of the water level in a reservoir or lake.

Macrophyte/plant density - Number of plant stems per unit area.

Macrophyte/plant distribution - The spatial position or arrangement of a plant species in a defined ecosystem.

Macrophyte/plant succession - The change in the flora following seasonal and annual cycles or to modifications in the environment.

Mean annual biomass - The statistical average weight per unit area taken over a 1-year (12-month) period.

Open water - Water without aquatic macrophytes.

Percent cover - The percentage of a given area in which a particular plant species is found.

Percent vertical cover - An ocular quantitative estimate of the density of hydrilla occupying the water column from the hydrosoil to the top of the plant.

Profundal mud - The deepest portion of a lake bottom, free of vegetation and composed of dead organic material.

Rooted stem - The base of a particular plant stem having roots.

Standing crop - The total weight of vegetation in a given area or defined ecosystem at a point in time.

Stem length - The distance from the base of a stem to its apex.

Stocking rate - The number and/or weight of fish introduced into a particular ecosystem over time.

Submersed vegetation - A heterogeneous group of aquatic macrophytes including (1) filamentous algae, (2) macroalgae (Charales), and (3) vascular flowering plants that attach to the hydrosoil and grow towards the surface of the water.

Surface mat - A growth characteristic of large stands of submersed vegetation that occurs when plants reach the surface of the water.

Total percent cover - The percentage of a given area covered by a plant species.

Transect percent cover - The length of a plant community along a transect divided by the total length of the transect.

Vegetation height - The distance from the top of the hydrosoil to the apex of a plant or stand of plants.

Vertical cross-sectional area infestation - The percentage of the water column along a transect infested with a submersed macrophyte determined from fathometer tracings.

Wet weight - Fresh or undried submersed vegetation weight.

Winter dieback - A decrease in standing crop or abundance of a plant species caused by colder seasonal temperatures and/or a decrease in photoperiod.

APPENDIX B: VEGETATION MAPS

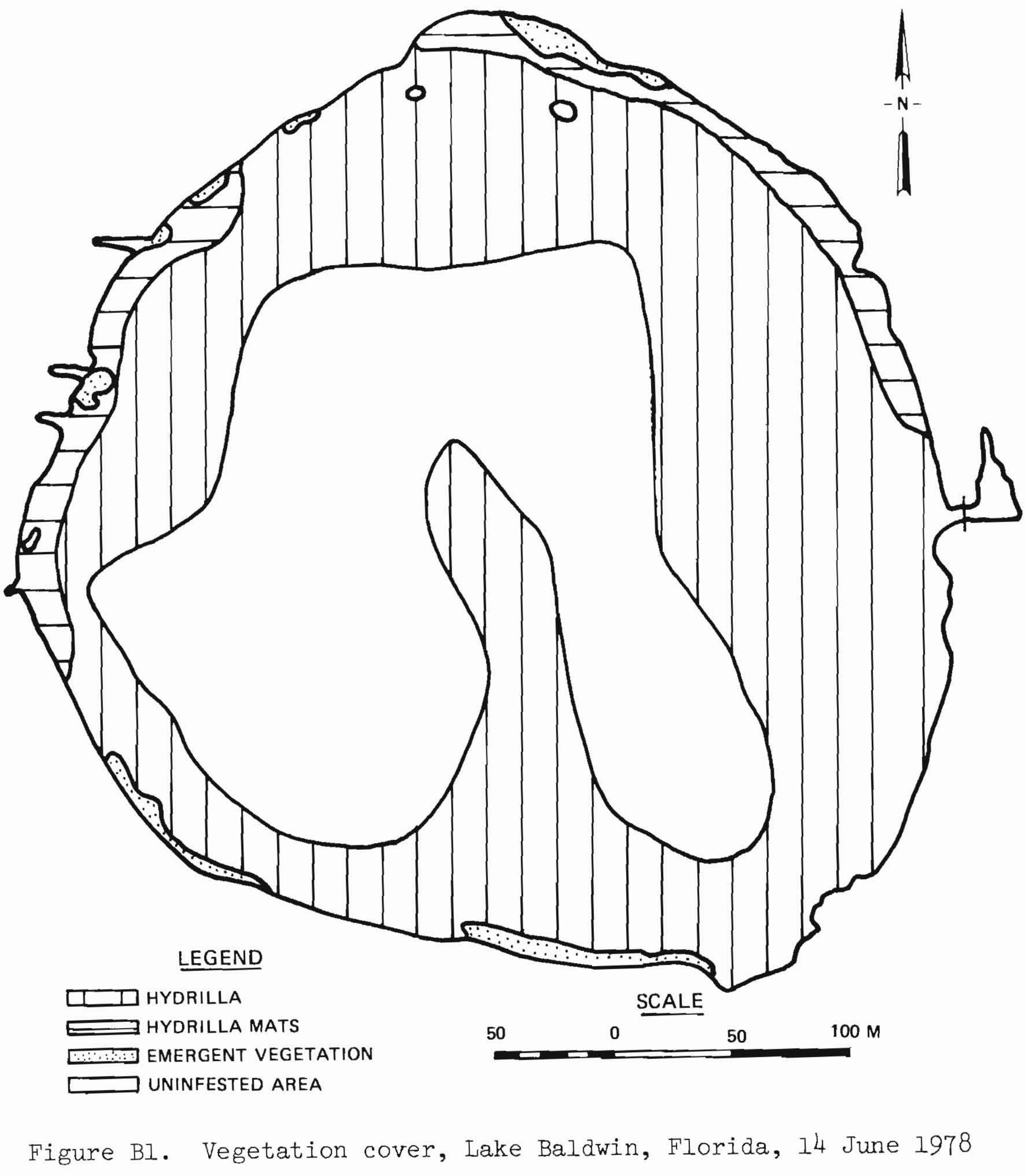

Figure B1. Vegetation cover, Lake Baldwin, Florida, 14 June 1978

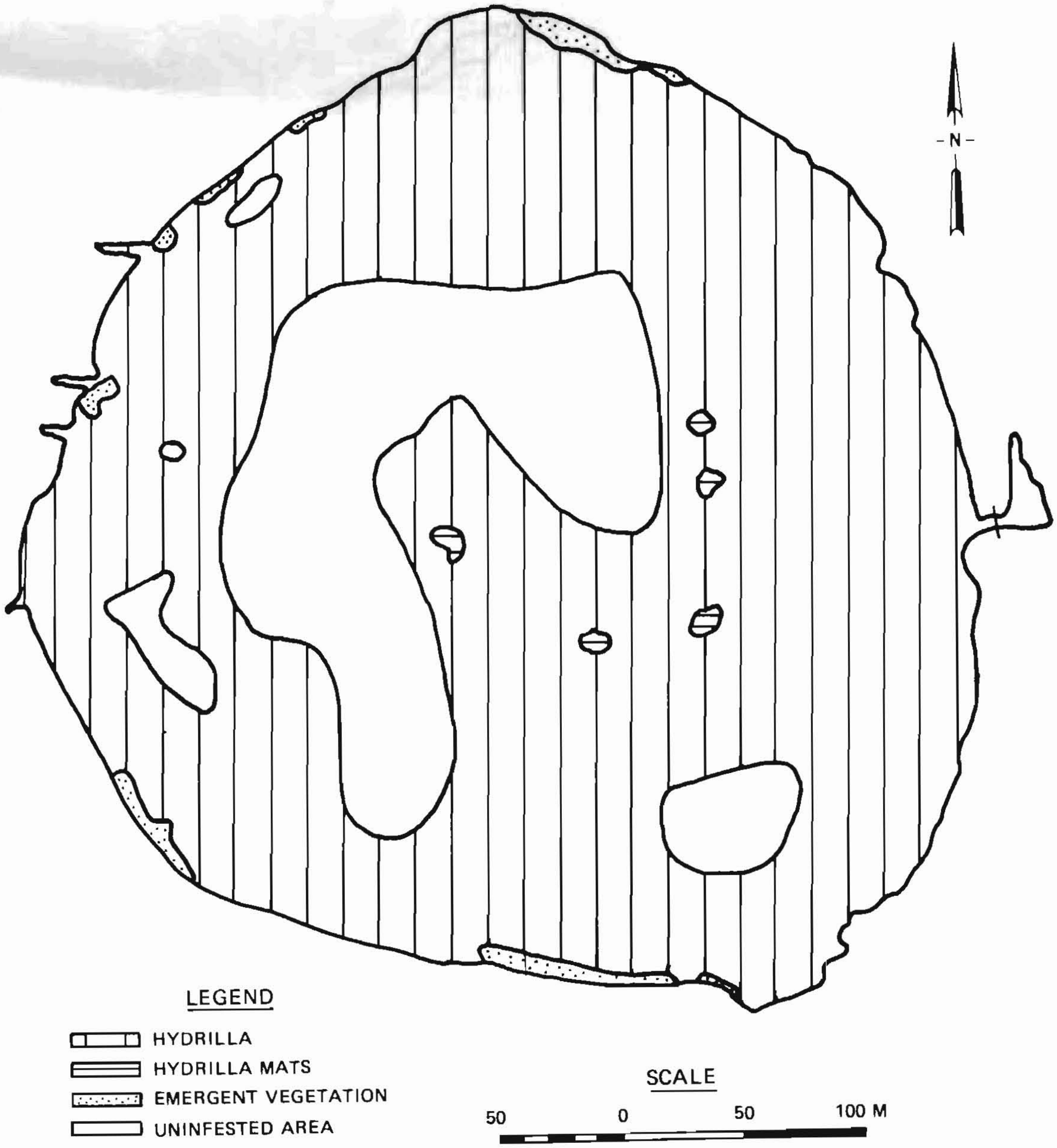

Figure B2. Vegetation cover, Lake Baldwin, Florida, 4 November 1978

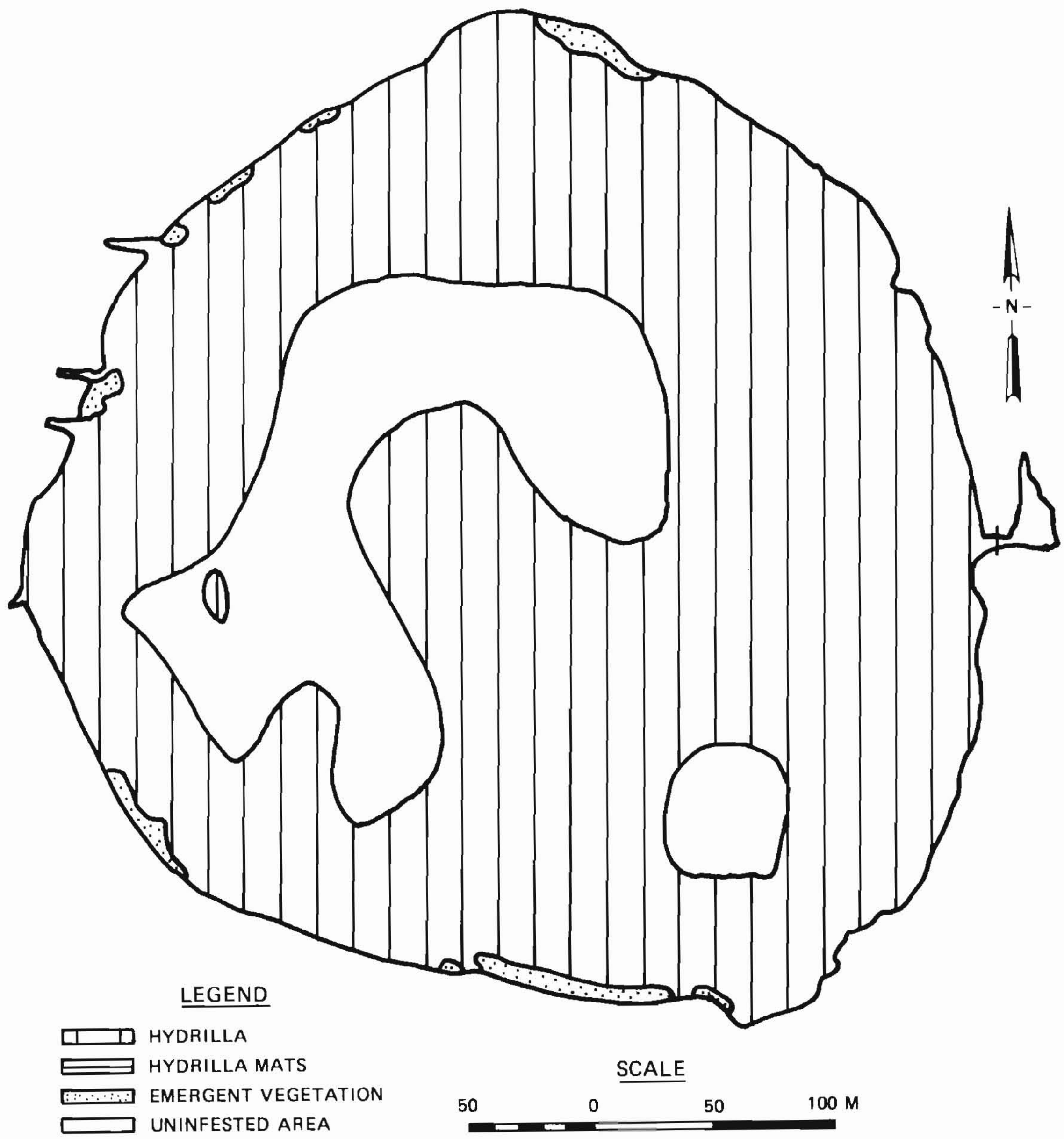

Figure B3. Vegetation cover, Lake Baldwin, Florida, 6 January 1979

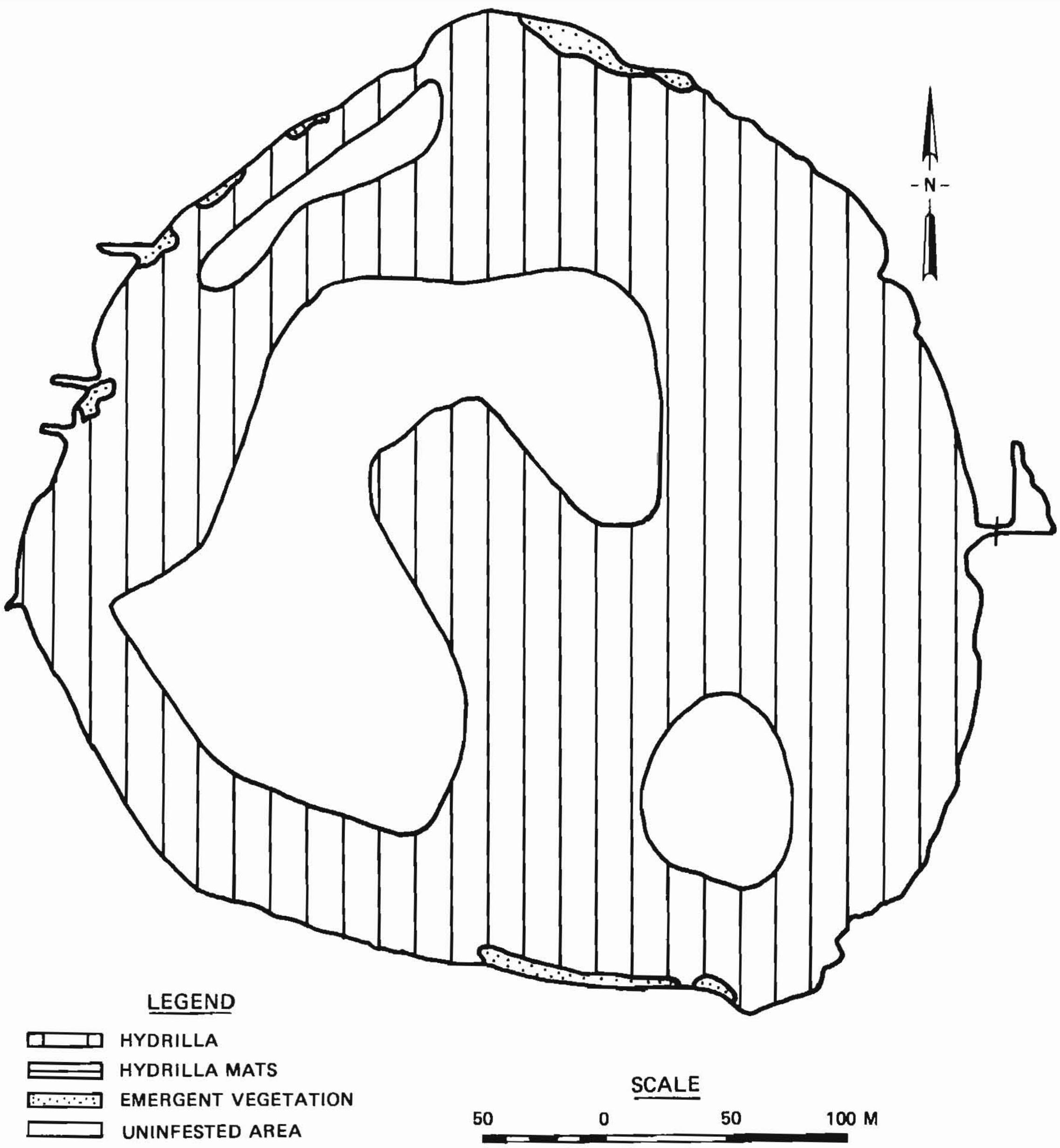

Figure B4. Vegetation cover, Lake Baldwin, Florida, 5 March 1979

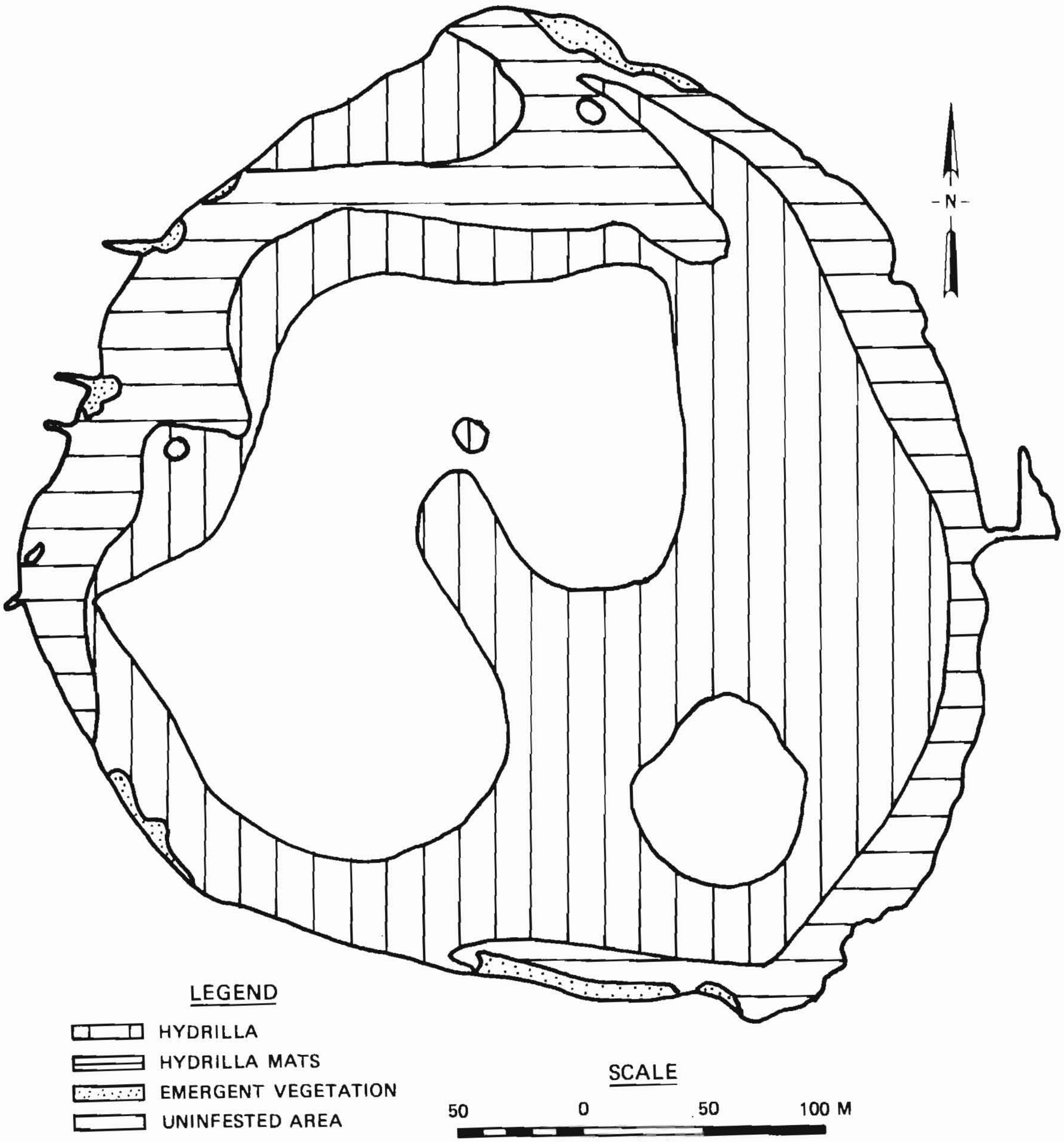

Figure B5. Vegetation cover, Lake Baldwin, Florida, 2 August 1979

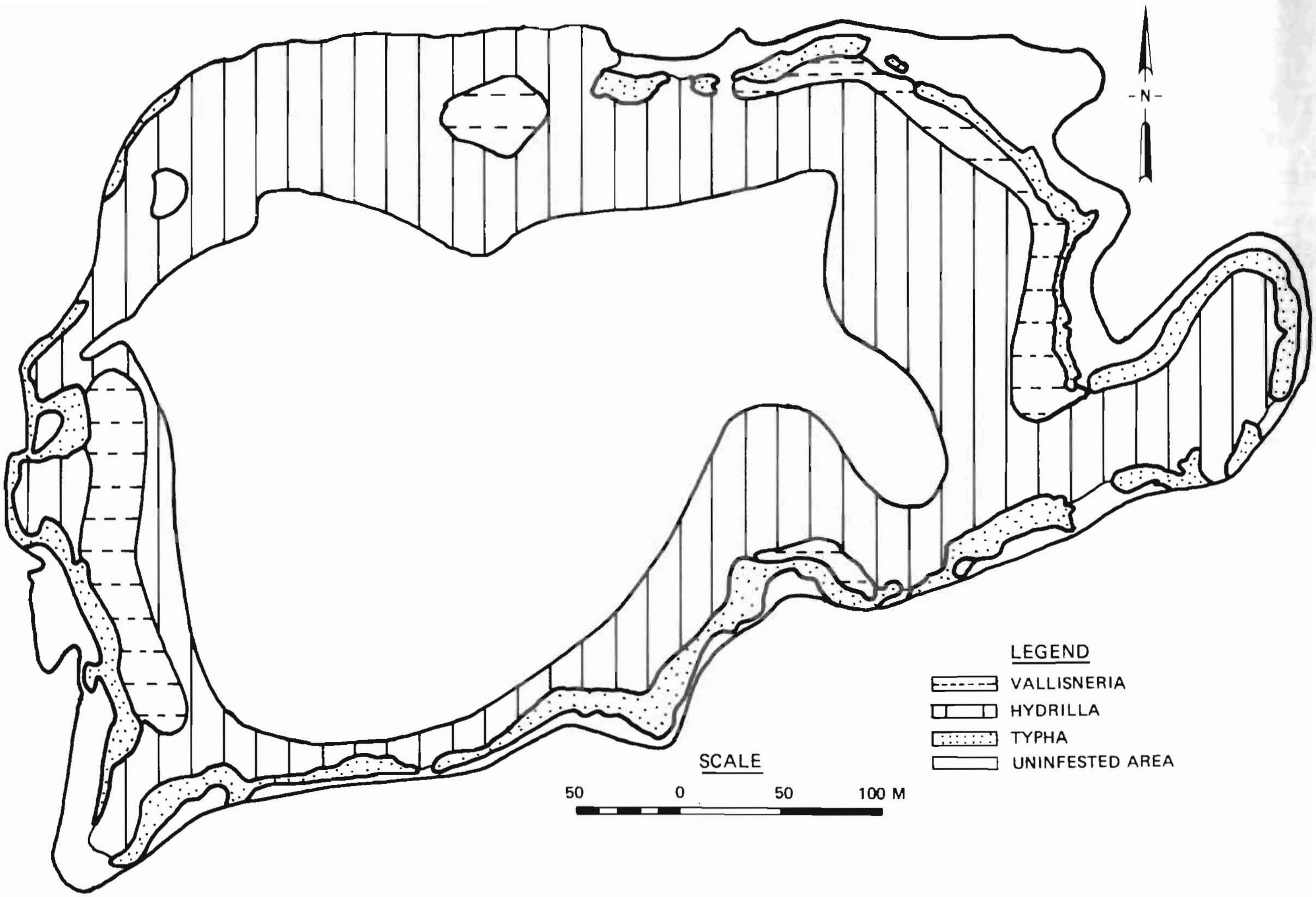

Figure B6. Vegetation cover, Lake Wales, Florida, 10 May 1978

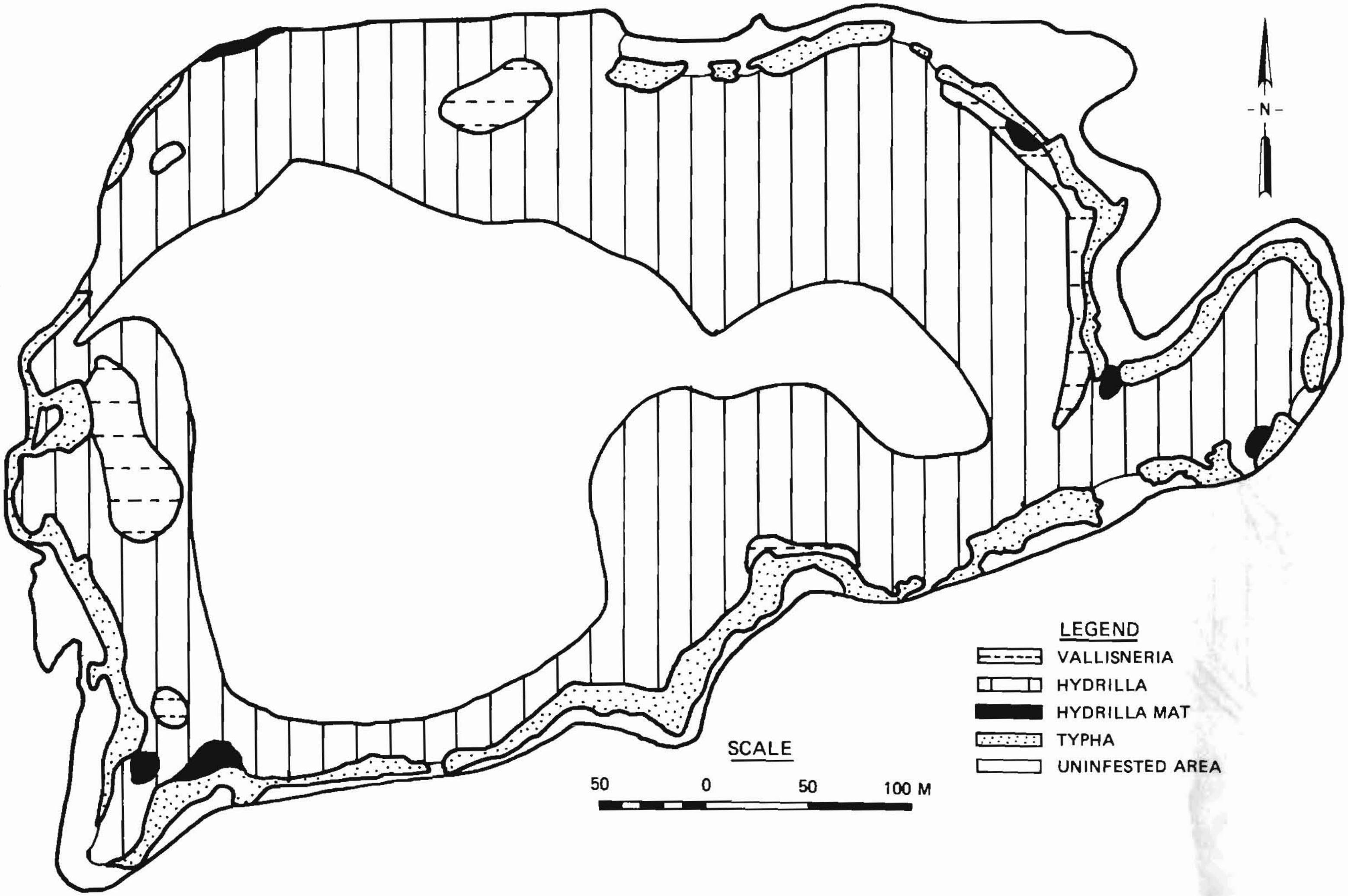

Figure B7. Vegetation cover, Lake Wales, Florida, 22 August 1978

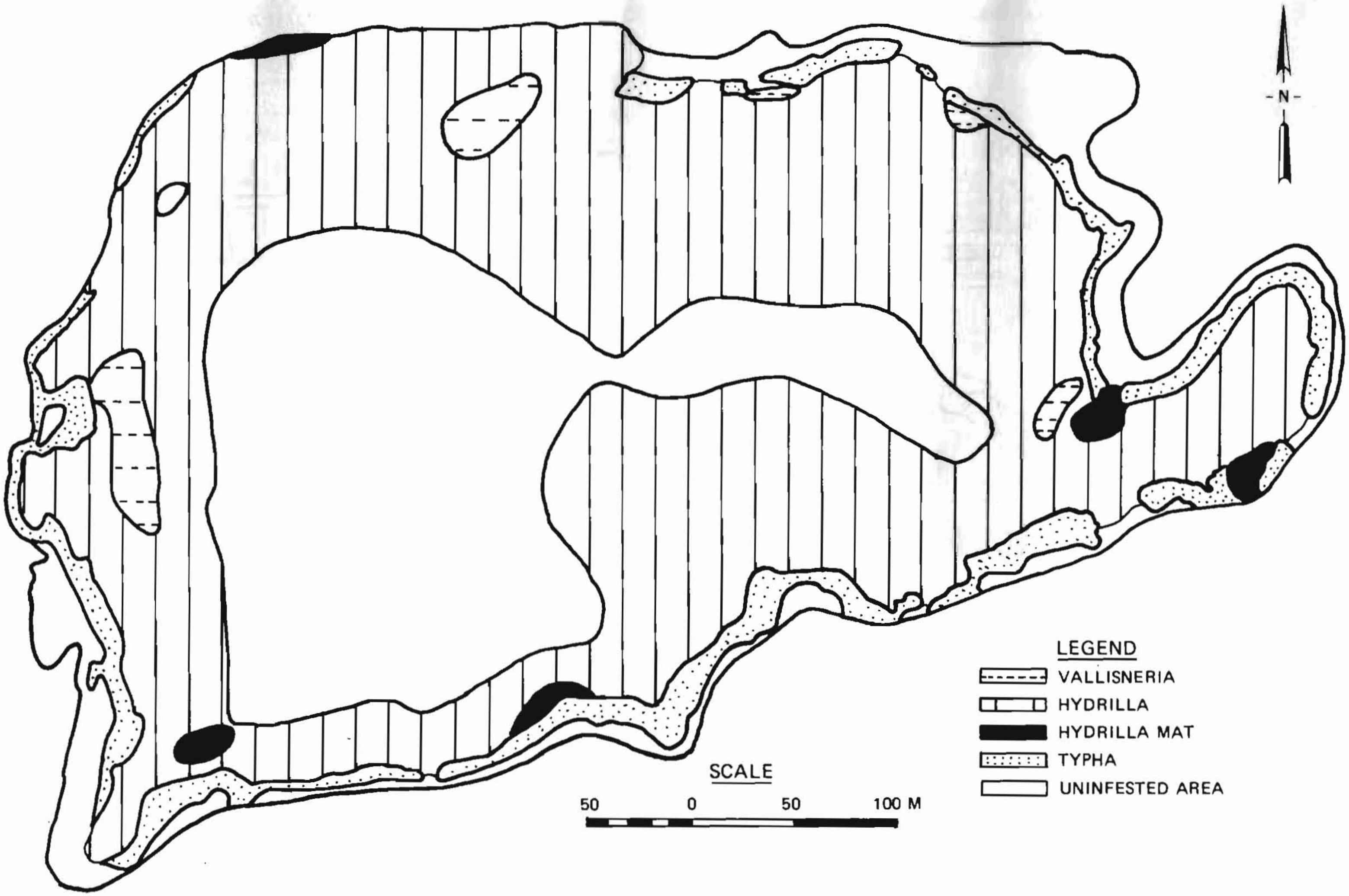

Figure B8. Vegetation cover, Lake Wales, Florida, 15 November 1978

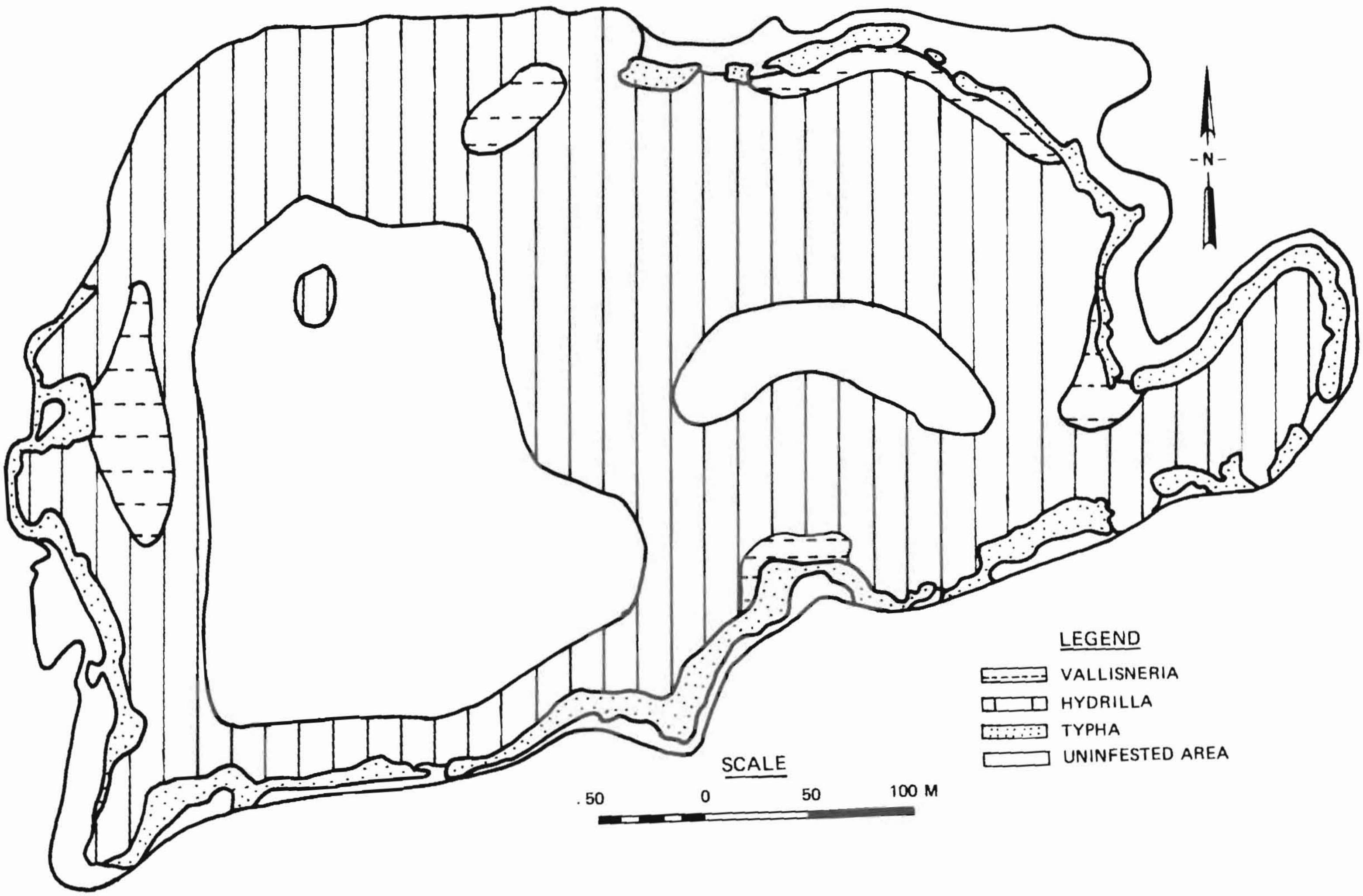

Figure B9. Vegetation cover, Lake Wales, Florida, 20 February 1979

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Macêina, Michael J
Recording fathometer techniques for determining distribution and biomass of Hydrilla Verticillata Royle / by Michael J. Macêina, Jerome V. Shireman, University of Florida, Gainesville, Fla. Vicksburg, Miss. : U. S. Waterways Experiment Station ; Springfield, Va. : available from National Technical Information Service, 1980.
46, [16], 13 p. : ill. ; 27 cm. (Miscellaneous paper - U. S. Army Engineer Waterways Experiment Station ; A-80-5)
Prepared for Office, Chief of Engineers, U. S. Army, Washington, D. C., and U. S. Army Engineer District, Jacksonville, Jacksonville, Fla., under Contract No. DACW39-78-C-0044.
References: p. 44-45.
1. Aquatic plants. 2. Biomass. 3. Fathometers. 4. Hydrilla. 5. White amur. I. Shireman, Jerome V., joint author. II. Florida. University of Florida, Gainesville. III. United States. Army. Corps of Engineers. IV. United States. Army. Corps of Engineers. Jacksonville District. V. Series: United States. Waterways Experiment Station, Vicksburg, Miss. Miscellaneous paper ; A-80-5.
TA7.W34m no.A-80-5