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Prediction of Submersed Plant Biomass by use of a Recording Fathometer[1]

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ABSTRACT

A recording fathometer was used to estimate the biomass of submersed macrophytes in Florida lakes. Prediction equations were generated from fathometer tracing characteristics and compared to data collected from an earlier study on Lake Baldwin. Coefficients of determination (R^2) for these equations ranged from 0.15 to 0.65 indicating that the fathometer biomass estimation technique is not equally reliable for all water bodies. Significantly different coefficients between best-fit equations indicate equations developed for one water body cannot be used indiscriminately in others. Recording fathometer data, however, can be used to accurately determine submersed plant coverage and volume. Accurate biomass determinations can be obtained if fathometer tracings are calibrated with actual biomass data.

Key words: regression models, hydrilla, coefficient of determination, fathometer tracings.

INTRODUCTION

Submersed macrophytes are an integral component of freshwater ecosystems, but in excessive amounts they can hinder recreation, cause health hazards, and block irrigation and navigation systems. To assess the extent of an aquatic weed problem and the effectiveness of various management techniques, quantitative data is often needed pertaining to plant coverage, distribution and biomass. Several methods including line intercept-transects, aerial photography, and direct biomass sampling have been used to estimate submersed macrophyte abundance. Direct methods like biomass sampling, however, are costly, labor intensive, and generally inadequate in large water bodies. Remote sensing techniques utilizing color and infrared aerial photography have been used successfully for emergent and floating aquatic macrophytes (1, 10) but have not been extremely successful for determining the abundance of submersed vegetation (2, 11).

Recently, Maceina and Shireman (6) demonstrated that a recording fathometer could be used to rapidly determine subsurface hydrilla (*Hydrilla verticillata* Royle) coverage and distribution in the water column at Lake Baldwin, Florida. These measurements were also used as predictive variables in regression equations to estimate hydrilla biomass. Although the recording fathometer proved to be an economical and effective technique for estimating hydrilla abundance in Lake Baldwin, the technique has not been tested sufficiently to determine if the biomass of hydrilla or other plant species can be estimated in other water bodies. In this paper, the use of a recording fathometer to estimate submersed macrophyte biomass in a number of freshwater systems is discussed and results are compared to the original work conducted at Lake Baldwin.

MATERIALS AND METHODS

Between January 1980 and September 1981, the abundance of submersed vegetation was measured in nine different Florida water bodies (Table 1). A DE-719 Precision Survey Fathometer (Raytheon Marine Co., Manchester, NH) was used to determine basin morphometry, plant coverage and distribution of submersed macrophytes in the water column. Procedures for conducting fathometer transects and determining quantitative vegetation parameters have been described previously (6). Submersed plant biomass was determined with a circular core vegetation sampler (7) which was used to take 0.257 m^2 samples. At King's Bay, a total of 199 samples were taken from water depths ranging from 0.5 to 3.5 m. Fifty biomass samples were collected at Lake Pearl from water depths ranging from 1.8 to 2.9 m. In Orange Lake and Lake Stella, 32 and 42 samples were collected, respectively. Water depths at Orange Lake ranged from 1.7 to 2.7 m, whereas depths at Lake Stella ranged from 0.8 m to 5.2 m. At Compass Lake, Dunford Pond, Gap Pond, Lake McKenzie and Mirrow Lake (oligotrophic lakes with no hydrilla) plants were collected by SCUBA divers from 0.25 m^2 quadrats. Plants were washed, dominant species recorded, and oven-dried at 60°C to a constant weight. Because plant coverage was sparse, only 37 samples were taken from all these lakes. Samples were taken in water depths ranging from 1.8 to 7.7 m.

RESULTS AND DISCUSSION

Maceina and Shireman (6) developed two logarithmic regression models (thick and sparse hydrilla) for predicting hydrilla biomass in Lake Baldwin. The thick hydrilla model was developed for areas when dense vegetation prevented a clear reading of the lake bottom. This model was:

$$Y = 1.997 + 1.029X_1 - 1.34\ (\ln X_2)\ R^2 = 0.63$$

where Y = the wet weight of hydrilla in kg/m^2, X_1 = the height of hydrilla from the hydrosoil to the top of the plant along the fixmark in m, X_2 = the distance from the top of the hydrilla plant to the surface of the water along the fixmark in m. The sparse hydrilla model, which was

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TABLE 1. DESCRIPTION OF STUDY LAKES SAMPLED FOR SUBMERSED PLANT BIOMASS AND FATHOMETER TRACING CORRELATIONS.

Lake	County	Area (ha)	Mean Depth (m)	Dominant Submersed Species (in order of dominance by wt.)	Trophic State
Compass Lake	Jackson	226	7.1	*Utricularia vulgaris Myriophyllum pinnatum*	Oligotrophic
Dunford Pond	Washington	79	2.5	*Utricularia vulgaris, Myriophyllum pinnatum*	Oligotrophic
Gap Pond	Washington	210	3.3	*Myriophyllum pinnatum, Utricularia vulgaris*	Oligotrophic
Kings Bay	Citrus	170	$\simeq 2$[a]	*Hydrilla verticillata, Ceratophylum demersum Vallisneria americana*	Eutrophic
Lake McKenzie	Calhoun	47	3.4	*Utricularia vulgaris*	Oligotrophic
Mirrow Lake	Calhoun	16	3.5	*Utricularia vulgaris*	Oligotrophic
Orange Lake	Alachua	4,900	2.9	*Hydrilla verticillata, Ceratophylum demersum Cabomba caroliniana*	Eutrophic
Lake Pearl	Orange	25	1.9	*Hydrilla verticillata, Utricularia* spp.	Eutrophic
Lake Stella	Putnam	151	3.5	*Hydrilla verticillata, Vallisneria americana*	Mesotrophic

[a]Tidal exchange occurs

developed for areas where the fathometer could clearly discern the hydrosoil, was:

$$\ln Y = -5.099 + 0.982\ (\ln X_1) + 1.301\ (\ln X_2) - 0.281\ (\ln X_3)\ R^2 = 0.65$$

where Y = wet weight of hydrilla in kg/m^2, X_1 = height of hydrilla from hydrosoil along the fixmark in m, X_2 = percent vertical cover of hydrilla on the tracing and X_3 = the distance from the top of the hydrilla plant to the water surface at the fixmark in m. Description of these independent variables for predicting plant biomass are presented by previous workers (6).

For Kings Bay, Lake Stella, Lake Pearl, and Orange Lake, similar multiple regression models were developed to determine the best fit regression model (Table 2). For Kings Bay, the best fit regressions for thick and sparse hydrilla had the same independent variables as the models developed at Lake Baldwin. Regression coefficients and intercept values, however, were significantly different ($P < 0.05$) and coefficients of determination were less than 0.25. The same independent variables, which were used to predict sparse hydrilla biomass in Lake Baldwin, were also suited for Lake Stella. Although the coefficient of determination ($R^2 = 0.62$) was similar to that found at Lake Baldwin ($R^2 = 0.65$), a positive rather than a negative relationship was found between the distance from the tops of the plant to the water surface and biomass (b = 0.78).

There appears to be three major reasons why different models were necessary to estimate hydrilla biomass in the study areas. First, lakes with wider ranges of water depth sampled demonstrated high coefficients of determination when equations were calculated. This indicates better hydrilla biomass predictability. Second, hydrilla density (kg fresh wt/m^3) is different among lakes (Table 3). For example, samples of "sparse" hydrilla collected from 2-3 m in Kings Bay and Lake Stella had a mean weight/volume between 5.0 and 5.8 kg/m^3, respectively. In Lake Baldwin and Orange Lake, density values were significantly lower, ranging between 0.5 and 1.8 kg/m^3. Overall values ranged as high as ten-fold among lakes. Differences in nutrients and

TABLE 2. BEST-FIT REGRESSION EQUATIONS PREDICTING HYDRILLA BIOMASS FROM FATHOMETER TRACING CHARACTERISTICS IN FIVE LAKES.

Lake	Hydrilla Type	Water Depth Sampled (m)	Regression Equation[a]	Total D.F.	Prob >F	R^2
Kings Bay	Sparse	0.7-3.5	ln (BIOMASS) = −2.784 + 0.867 ln (HYDHT) + 0.896 ln (COVER) −0.292 ln (HYDSUR)	82	0.001	0.215
	Thick	0.8-3.3	Biomass = 3.413 + 2.344 HYDHT − 0.095 ln (HYDSUR)	39	0.008	0.231
Stella	Sparse	0.8-5.2	ln (BIOMASS) = − 1.808 + 1.004 ln (HYDHT) + 0.037 (COVER) + 0.781 ln (HYDSUR)	39	>0.001	0.616
Pearl	Thick	1.8-2.9	BIOMASS = 7.489 − 2.797 HYDHT − 1.328 ln (HYDSUR)	43	0.036	0.150
Orange	Sparse	2.0-2.7	ln (BIOMASS) = −3.717 + 0.066 COVER	18	0.006	0.473
	Thick	1.7-2.5	ln (BIOMASS) = 2.361 − 3.341 HYDSUR	12	0.006	0.534
Baldwin[b]	Sparse	1.6-6.2	ln (BIOMASS) = −5.099 + 0.982 ln (HYDHT) + 1.301 ln (COVER) −0.281 ln (HYDSUR)	150	>0.001	0.651
	Thick	2.6-5.7	BIOMASS = 1.977 + 1.029 HYDHT −1.341 ln (HYDSUR)	50	>0.001	0.634

[a]BIOMASS = wet weight of hydrilla in kg/meter^2, HYDHT = height of hydrilla from the hydrosoil to the top of the plant in meters, COVER = percent vertical cover of hydrilla, HYDSUR = the distance from the top of the hydrilla plant to the surface of the water in meters.
[b]Data included from Lake Baldwin derived from a previous study (6).

TABLE 3. MEAN WEIGHT/VOLUME VALUES OF HYDRILLA (KG/METER³) IN FOUR LAKES AT VARIOUS DEPTH STRATA.[1]

Hydrilla type	Depth strata (m)	Kings Bay	Lake Stella	Lake Baldwin	Orange Lake	Lake Pearl
Sparse	1.0-1.9	4.74[a]	3.34[a]	4.74[a]	—	—
	2.0-2.9	5.06[a]	5.77[a]	1.80[b]	0.54[b]	—
	3.0-3.9	3.27[a]	5.12[b]	1.76[c]	—	—
	4.0-4.9	—[2]	2.08[a]	1.12[a]	—	—
	5.0-5.9	—	1.52[a]	0.50[b]	—	—
Thick	1.0-1.9	5.25[a]	—		2.88[b]	3.03[b]
	2.0-2.9	4.98[a]	—	2.98[ab]	2.49[b]	1.77[b]
	3.0-3.9	3.68[a]	—	1.62[b]	—	—
	4.0-4.9	—	—	1.45	—	—
	5.0-5.9	—	—	0.87	—	—

[1]Values in horizontal rows with the same letters are not significantly different ($P < 0.05$).
[2]Dashes indicate data were not collected because lakes sampled were of different depths. For example, the maximum depth in Kings Bay was only 3.9 m, and sparse and thick hydrilla did not occur at all depths sampled.

light penetration contribute to variation in hydrilla density. Third, differences in model success and similarity may be due to the circular core biomass sampler efficiency in different substrate types. For example, samples were collected over silt, sand, and silt covered limerock at Kings Bay, whereas in Orange Lake samples were collected over a relatively homogeneous organic bottom. On hard bottoms, such as limerock, complete collection of a vegetation sample is difficult because the sampling bucket does not penetrate the substrate and complete samples are not removed.

Individual equations developed for each water body (coefficients of determination ranged from 0.15 to 0.65) were generally comparable to estimates derived with the biomass sampler (Table 4). In Lake Baldwin, Lake Pearl, and Lake Stella, biomass estimates derived from the biomass sampler and individual equations were not significantly ($P > 0.05$) different from each other. In Orange Lake, however, average biomass estimated by use of the circular core biomass sampler was higher than predicted by the fathometer. In King's Bay, biomass values estimated by use of the fathometer were generally higher. This may have been due to the incomplete removal of hydrilla with the core biomass sampler. Although some differences occur, the calculated 95% confidence intervals for the two methods overlap. This is similar to the findings at Lake Baldwin when independent estimates of mean total biomass had a percent error between 23% for the fathometer and 19% for the biomass sampler. In Orange Lake, the Lake Baldwin equations produced similar results when compared to the first two methods. In Lake Pearl, however, the Baldwin equations appeared to overestimate biomass and underestimate plant biomass in Lake Stella and Kings Bay. These differences were probably due to variable hydrilla densities among lakes which cannot be discerned with the fathometer (Table 3) and variation in water depths sampled. Therefore, based on these results (Tables 2 and 4), models developed in one water body should not be used indiscriminantly in others.

At Compass Lake, Dunford Pond, Gap Pond, Lake McKenzie and Mirrow Lake, plant biomass of other species of plants besides hydrilla was correlated with fathometer tracing characteristics. Estimation of spikerush (*Eleocharis baldwinii* Torrey) was not possible with the fathometer because fathometer resolution was insufficient to adequately measure spikerush heights of 0.1 to 0.2 m. It was possible, however, to distinguish areas vegetated by bladderwort (*Utricularia vulgaris* L.) and watermilfoil (*Myriophyllum pinnatum* Walt.). In these lakes, biomass samples were pooled because the vegetation in each lake was similar in density. Vegetation height in each lake was measured with the fathometer and varied among lakes. To develop a good regression model, density data from all lakes were pooled. The best fit regression model for the pooled data was:

$$B = 64.2 + 62.8\ (VEGHT) - 31.7\ LOG\ (VEGSUR)$$

where B = dry weight of bladderwort and watermilfoil, (g/m^2) VEGHT = height of plant (m) VEGSUR = distance from the top of plant to the water surface (m). The coefficient of determination for this model was 0.56 which is similar to the values obtained for hydrilla. These data suggest that the fathometer is a potentially valuable tool for predicting the biomass of other plant species once fathometer tracings are correlated with actual biomass samples.

TABLE 4. A COMPARISON BETWEEN THE AVERAGED BIOMASS (KG FRESH WT/M²) MEASURED WITH A BIOMASS SAMPLER AND PREDICTED WITH A RECORDING FATHOMETER. VALUES IN PARENTHESIS REPRESENT THE 95% CONFIDENCE LIMITS.

Lake	Date	Biomass Estimate $\bar{x}$	Fathometer Estimate $\bar{x}$	Baldwin Estimate $\bar{x}$
Orange	5/80	2.45 (1.57-3.33)	1.67 (1.30-2.19)	2.29 (1.89-3.70)
Pearl	3/80	3.32 (2.83-3.81)	3.39 (2.86-3.92)	5.31 (4.97-5.65)
Stella	9/81	3.56 (2.95-4.17)	3.41 (2.57-4.52)	1.06 (0.81-1.40)
Baldwin	3/79	1.21 (0.94-1.48)	1.04 (0.80-1.31)	—
Kings Bay	9/80	3.96 (3.17-4.75)	3.11 (2.52-3.88)	1.92 (1.42-2.52)
	12/80	2.89 (2.22-3.56)	3.72 (2.89-4.80)	1.87 (1.13-2.56)
	5/81	2.89 (2.01-3.77)	3.52 (2.45-4.25)	2.05 (1.66-2.53)
	8/81	2.17 (1.30-3.04)	3.21 (2.59-4.02)	2.02 (1.61-2.52)

With the recording fathometer, important measurements of submersed macrophyte abundance other than plant biomass can be collected. For example, whole-lake vegetation coverage and percent volume infestation can be rapidly and inexpensively determined. Both of these determinations adequately describe plant abundance. Successful hydrilla control with the grass carp (*Ctenopharyngodon idella*) based on area coverage determined with a fathometer has been reported (9). Aquatic herbicide applicators generally base application rates on area coverage not biomass. Therefore, use of a recording fathometer to estimate weed infestations is practical. Ecosystem response to changes in submersed macrophyte coverage and volume, measured with a recording fathometer, have been successfully used to correlate fish growth and condition (5, 7) and water chemistry values with macrophyte abundance (3). Planktonic chlorophyll *a* levels are strongly correlated with hydrilla volume as determined with the recording fathometer (4).

Results from this study indicate that the recording fathometer can be used to provide a first approximation of the biomass of submersed plant species in water bodies ranging from oligotrophic to eutrophic. Predictive equations, however, must be developed independently for different lakes if greater accuracy is desired. This approach, however, involves the use of additional personnel and a biomass sampler. Once regression equations are developed, the fathometer can be used alone to estimate changes in plant biomass over time. This reduces the number of times direct sampling, which is costly and time consuming, has to be done. In situations where estimates of total plant biomass are not needed but only that of plant coverage and volume infestation are desired, the recording fathometer is a rapid and inexpensive technique.

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