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An Empirical Method for Characterizing Standing Crops of Aquatic Vegetation[1]

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ABSTRACT

Data from 55 Florida lakes were used to demonstrate that the maximum measured standing crop of emergent, floating-leaved, and submersed plants can be used to provide a simple characterization of macrophyte standing crops in the littoral zones of lakes. The maximum standing crop was strongly related to the mean standing crop of emergent (R^2 = 0.83), floating-leaved (R^2 = 0.64), and submersed (R^2 = 0.85) macrophytes, and there was also a strong relationship (R^2 = 0.79) when data from all plant types were combined. Our best-fit regression equations were ln EB = 1.07 ln MEB – 1.19, ln FB = 1.28 ln MFB – 2.73, ln SB = 1.20 ln MSB – 1.98, and ln TMB = 1.20 ln MTMB – 2.11 where EB, FB, SB, and TMB are the average standing crops (g dry wt m^{-2}) of emergent, floating-leaved, submersed, and total macrophytes respectively, and MEB, MFB, MSB, and MTMB are the maximum standing crops measured for the different groups. Standard errors of estimates for the average standing crops of the different plant types in individual lakes were of similar magnitude to the errors of estimates obtained for the mean-maximum standing crop regression equations. These analyses suggest that the maximum standing crop of aquatic macrophytes can provide useful information to characterize macrophyte standing crop in the littoral zone of lakes.

Key words: aquatic plants, biomass, lakes, models, littoral, limnology

INTRODUCTION

The overall goal of many aquatic vegetation sampling studies is to obtain an estimate of mean macrophyte standing crop. Standard sampling theory (APHA 1985) indicates that the number of samples necessary to characterize macrophyte standing crop using a random sampling design can be calculated from,

$$N = [(t \times S)/(d \times X)]^2$$

where N = number of sampling stations; t = Student's t at a given probability level; S = standard deviation, X = estimated true population mean; d = permissible error of the final mean. Thus, the number of sampling stations necessary to characterize the mean macrophyte standing crop changes proportionally to the square of the coefficient of variation and to the inverse of the square of the permissible error (Figure 1). Because the coefficient of variation associated with the mean macrophyte standing crop is often > 50 %, the number of sampling stations necessary to estimate the mean macrophyte standing crop, especially with a permissible error of 10 % as is often re-

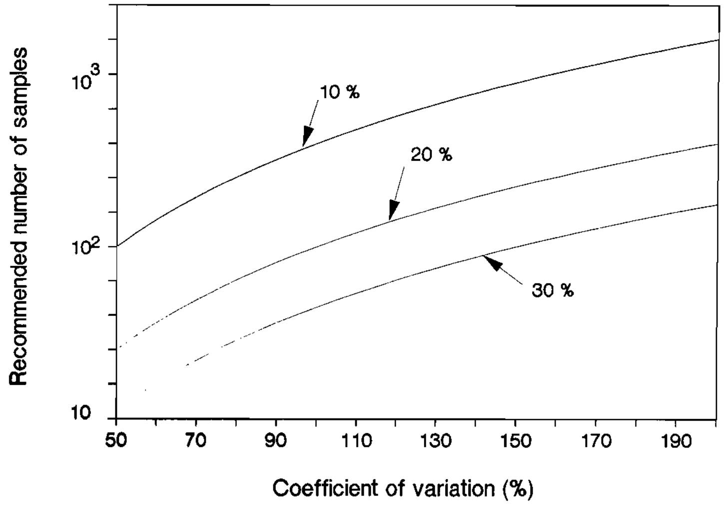

Figure 1. The relationship between the variability of the mean (as the coefficient of variation) and the number of samples necessary to estimate the mean with a permissible error of 10, 20, and 30% (from APHA 1985).

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commended (e.g., APHA 1985), is typically > 200 (Figure 1). A large number of samples is still needed even if more conservative sampling (permissible error > 10 %) or stratified random sampling programs are adopted. For instance, Nichols (1982) concluded that if a stratified random design was used over 100 samples would be needed to adequately estimate the aquatic macrophyte standing crop in Lilly Lake, a small (37 ha) hard-water lake in Wisconsin.

Lake surveys have been used to identify large-scale limnological patterns in lakes (cf. Peters 1986). Although the average precision of lake survey data is low because of limited (3 to 4 samples) sampling on individual lakes (e.g., Knowlton et al. 1984), data from these surveys have been used successfully to develop simple empirical models that assess the relationships between environmental factors and organismal abundance (cf. Peters 1986). These simple models have found wide spread use in lake management (Peters 1986), but only a few empirical models have been proposed to describe relationships between aquatic macrophytes and other organisms or to predict the abundance of aquatic macrophytes in lakes (e.g., Canfield et al. 1984; Durocher et al. 1984; Duarte et al. 1986; Canfield and Duarte 1988).

We believe the limited development of empirical macrophyte models is a direct consequence of the constraints (e.g., costs) imposed by the large number of samples required to statistically characterize macrophyte abundance in lakes (e.g., Nichols 1982; Downing and Anderson 1985). Large-scale limnological studies of aquatic macrophytes and the development of empirical models would be encouraged if macrophyte abundance in lakes could be characterized by the use of fewer samples. Here, we discuss the use of maximum measured macrophyte standing crop as a possible measure for characterizing macrophyte abundance within lakes.

METHODS

Data used in this study were primarily taken from an unpublished study (Canfield and Joyce 1985) of the macrophyte communities of 55 lakes located in Florida's Ocala National Forest (Latitude 29° 15′ S, Longitude 81° 45′ W). These lakes are generally small (area range 1 to 722 ha), shallow (mean depth < 6 m), and acidic (mean pH = 5.0), but they differ greatly in water transparency (range 0.3 to 5.8 m) and nutrient concentrations (total phosphorus range 6 to 142 mg m^{-3}; cf. Greis 1985). The macrophyte communities were sampled between July and September of 1985. Using existing bathymetric maps (Greis 1985), 10 sampling transects were uniformly located around the perimeter of each lake prior to visiting the lake. At the lake, sampling stations were randomly established in the emergent, floating leaved, and submersed plant zones (30 stations per lake). All above-ground plant standing crop within a 0.25 m^2 quadrate were collected at each station. Sampled plants were placed in nylon mesh bags and spun to remove excess water. Samples were then weighed to the nearest 0.10 kg fresh weight.

Additional data were also obtained from the published literature (e.g., Adams and McCracken 1974; Wile 1974; Duarte 1987a). To compare data from the Florida lakes with values reported elsewhere, which are generally expressed as g dry weight per m^2, plant water content was assumed to be 90% of the fresh weight (Westlake 1965). Relationships between the mean and the maximum standing crop for each plant type (emergent, floating leaved, and submersed) and for the macrophytes as a group were established by least squares regression analyses, following logarithmic transformation of the independent and dependent variables to meet the assumptions of least squares regression analysis. For our purposes here, maximum standing crop refers only to the largest standing crop measured during the sampling period.

RESULTS AND DISCUSSION

Relationships between mean and maximum macrophyte standing crop. Average emergent standing crops in the Ocala National Forest lakes ranged from 22 to 720 g dry wt,/m^2 with a median value of 342 g dry wt/m^2. Average floating-leaved standing crops ranged from 0 to 876 (median = 120) g dry wt/m^2 and mean submersed standing crops ranged from 0 to 510 (median = 112) g dry wt/m^2. There, however, were strong relationships between the measured mean and maximum standing crops for the three major aquatic macrophyte (emergent, floating-leaved, and submersed) types (Table 1; Figure 2). Further, the relationships between the maximum and mean macrophyte standing crop were very similar for the different plant types (Figure 2a-c) and there also was a strong relationship (R^2 = 0.79) between the measured mean and maximum standing crop when all plant types were combined (Eq. 4, Table 1; Figure 2d). Only the equation for floating-leaved standing crop (Eq. 2) was statistically (t-test, $p<0.05$) different from the equations describing the relationship between the mean and maximum standing crop for emergent and submersed macrophytes (Eq. 1 and 3; Table 1).

The within-lake standing crop variability was considerable for the macrophyte communities in the Ocala National Forest lakes. Average coefficients of variation (CV) for the individual lake-average standing crop of emergent, floating-leaved, and submersed macrophytes were 60%, 120%, and 86%, respectively. The large errors associated with the estimation of the mean macrophyte standing crop of emergent, floating-leaved, and submersed macrophyte standing crop in the individual lakes, however, were of similar magnitude to the errors of the relationship between the maximum and mean macrophyte standing crop (Eqs. 1-4,

TABLE 1. REGRESSION COEFFICIENTS FOR MODELS ESTIMATING AVERAGE MACROPHYTE STANDING CROP (Ab) FROM THE MAXIMUM STANDING CROP (Mb) IN G DRY WT. M^{-2}. THE COEFFICIENTS CORRESPOND TO THE MODEL: $\ln Ab = a + b * \ln Mb$. THE TABLE ALSO SHOWS THE COEFFICIENT OF DETERMINATION (R^2) AND STANDARD ERROR OF THE TRANSFORMED ESTIMATES ($S.E._{\ln est}$) AS AN INDICATION OF FIT. $P < 0.0001$ FOR ALL EQUATIONS.

Macrophytes	a	b	R^2	$S.E._{\ln est}$	Eq.
Emergent	–1.19	1.07	0.83	0.26	(1)
Floating-leaved	–2.73	1.28	0.64	0.52	(2)
Submersed	–1.98	1.20	0.85	0.42	(3)
All Plant Types	–2.11	1.20	0.79	0.43	(4)

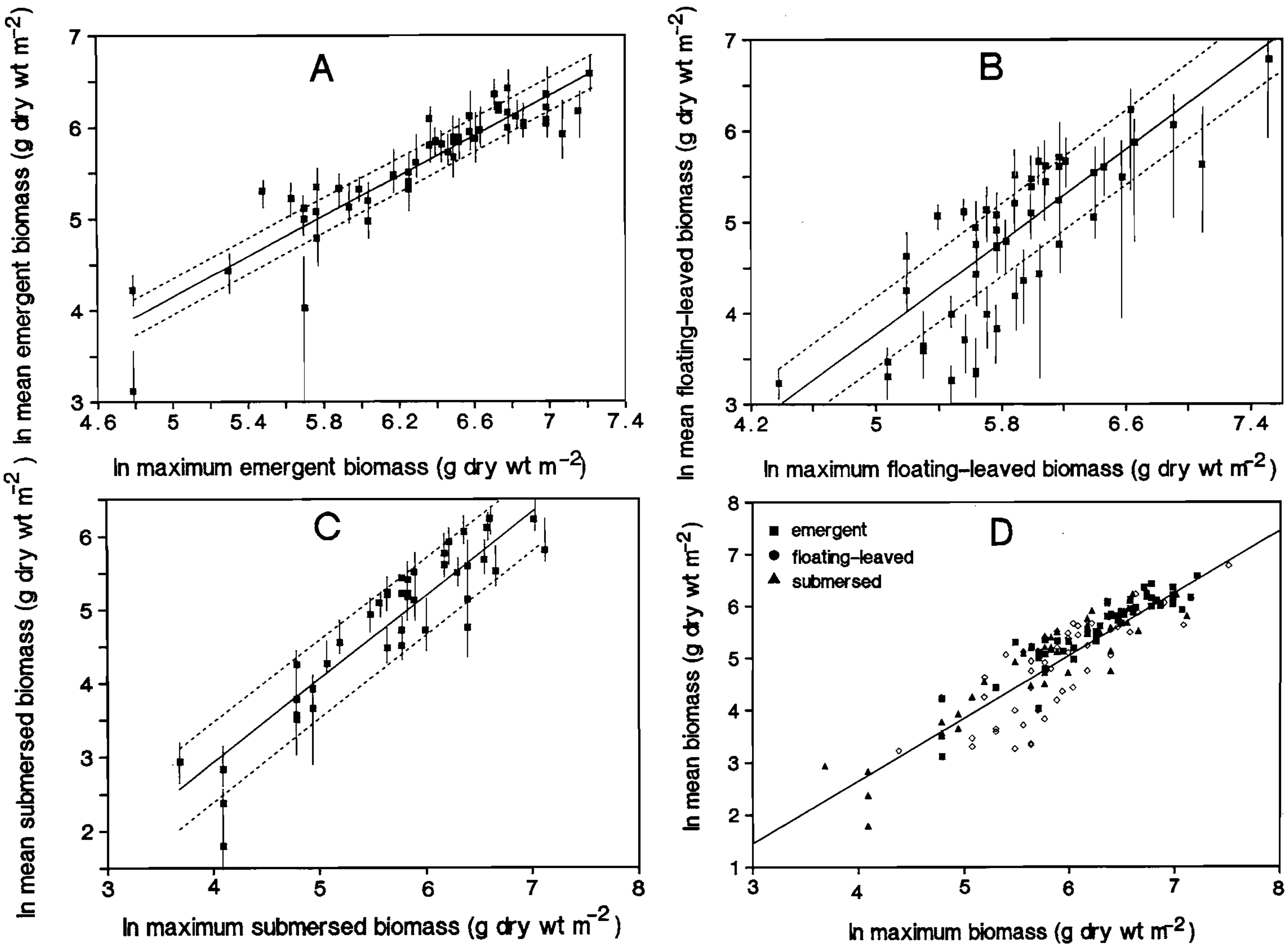

Figure 2. The relationship between the maximum and mean standing crop of (a) emergent, (b) floating-leaved, (c) submersed macrophytes, and (d) all groups combined. The lines correspond to the regression equations in Table 2. Vertical bars are ± one standard error.

Table 1; Figure 2a-c). This suggested that little additional information about the mean standing crop was gained by placing more effort in sampling than that necessary to estimate the maximum plant standing crop in the lake.

Our data base consisted of lakes located in a limited geographic area, the Ocala National Forest of Florida. Because the limnological characteristics of these lakes are not typical of lakes elsewhere, we tested the generality of Eqs. 3 and 4 by comparing our results with independent data derived from aquatic systems located throughout the world (Table 2). We tested only Eqs. 3 and 4 because studies that provide the required information for emergent and floating-leaved macrophytes are rare. Although the studies from the published literature differed greatly in sampling design and intensity, both Eqs. 3 and 4 produced unbiased estimates (slope = 1, $P > 0.5$; intercept = 0, $P > 0.5$) of average submersed standing crop from the recorded maximum standing crop (Figure 3), and both equations were equally precise (S.E. ln estimate from Eq. 3 = 0.51, S.E. ln estimate from Eq. 4 = 0.52). Only 11 of the 25 published studies provided enough information to calculate the error around the estimated average submersed standing crop. The magnitude of these errors, however, was comparable to the standard error for the predicted values (Eqs. 3 and 4, Table 1; Figure 3). These results confirm the generality of the relationship between maximum and mean standing crop, and further suggest that this relationship may be applicable to other aquatic ecosystems besides lakes for the literature data included 2 coastal ecosystems (Table 2).

Estimating macrophyte standing crop in lakes. A normal distribution of macrophyte standing crop within lakes is often assumed when plant sampling programs are initiated (APHA 1985). This assumption, however, is often violated because of the patchiness and skewed distribution of plant standing crops. For example, the distribution of submersed macrophyte standing crop in four northern lakes sampled intensively (N > 200; Duarte 1987a) shows strong (1.2 to 4.1) skewness (Figure 4). Strong skewness in the distribution of any population causes average values obtained from random sampling to provide a biased estimate of the central tendency of the distribution (Snedecor and

TABLE 2. MEAN AND MAXIMUM STANDING CROP (g DRY WEIGHT PER m^2) OF SUBMERSED MACROPHYTES REPORTED IN 22 LAKES AND 2 COASTAL SYSTEMS.

Lake	Mean	S.E.	N	Maximum	Reference
Par pond	214	128	12	423	Grace and Tilley (1976)
Swartvlei	914			1950	Howard-Williams & Liptrot (1980)
St. Clair	137	106	14	427	Schloesser *et al.* (1985)
Warniak	130			278	Bernatowicz (1969)
Opinicon	335			1559	Crowder *et al.* (1977)
Mirror	7.1			100	Moeller (1985)
Wingra	253			400	Adams & McCracken (1974)
Mondarra	1459	1484	20	6410	Finlayson *et al.* (1984)
Stemsfjord	333			750	Roslett *et al.* (1984)
Halverson	196			390	Engel (1985)
Memphremagog	57	60	44	212	Duarte (Unpub. results)
d'Endine	202	298	23	991	Guilizoni & Sarraceni (1974)
Simcoe	67	100	51	586	Neil & Kamaitis (1985)
Lunzern Untersee	256	218	20	814	Schlott & Malicky (1984)
Lunzer Untersee	310	229	17	778	"
Cocburn Sound[1]	470	230	21	1300	Cambridge & McComb (1984)
Delta Marsh	120	78	18	250	Anderson (1978)
Biwa	336			1000	Ikusima (1984)
Stechlin	450			1000	Krausch (1985)
Pigeon	237			470	Wile (1974)
Chemung	260			663	"
Rice	193			408	"
Clear and Stony	30			162	"
Ninigret[1]	645	569	150	1584	Thorne-Miller and Harlin (1984)

[1] Coastal ecosystems.

Cochran 1979). Consequently, plant sampling programs such as those proposed by Nichols (1982) or Downing and Anderson (1985) should be used whenever possible to obtain accurate estimates of mean standing crop.

The prospect of collecting a large number of plant samples (e.g., Nichols 1982) along with the associated costs in time and personnel has discouraged many scientists from characterizing macrophyte standing crop in their study lakes whenever the primary focus of their study was not aquatic vegetation. The strong skewness of macrophyte standing crop distributions (e.g., Figure 4), however, has important implications for the characterization of macrophyte standing crop in lakes because it implies that failure to sample the most dense macrophyte stands will result in a biased estimate of the mean standing crop. The maximum macrophyte standing crop also not only constrains the average value, but it is statistically related to the standard error of the mean (see Snedecor and Cochran 1979). In addition, the maximum standing crop is an important characteristic of aquatic macrophyte populations

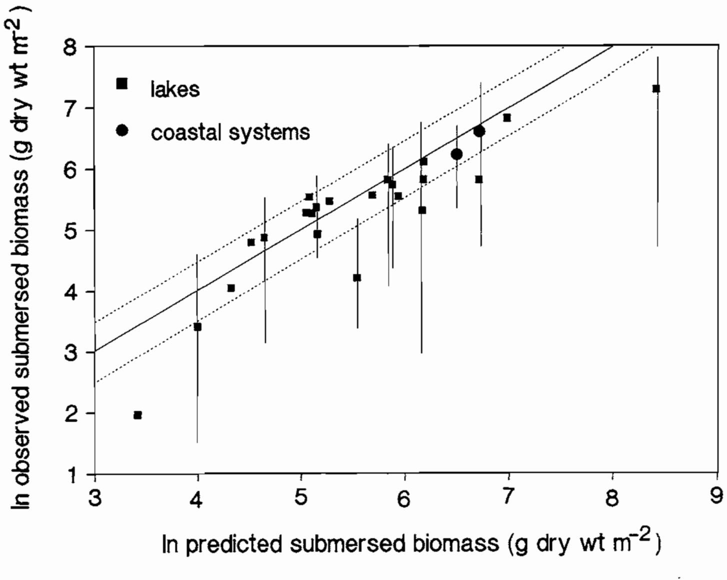

Figure 3. The relationship between the lake-average standing crop of submersed macrophytes and the values predicted from Eq. 4 (solid line). Vertical bars are + one standard error around the mean estimate, and broken lines represent the 95% confidence limits for Eq. 4 (Table 2). Equation 3 not shown because it is not significantly different ($P > 0.05$) from Eq. 4 (Table 1).

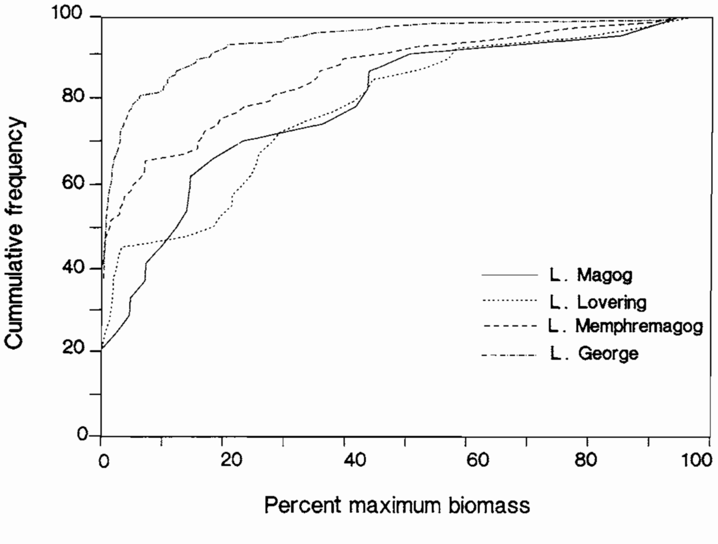

Figure 4. Cumulative frequency distributions for the standing crops of submersed macrophytes in four northern lakes ($N > 200$; data from Duarte 1987a).

because it represents the limit to macrophyte standing crop achieved within the lake and therefore provides information on the potential of the lake for macrophyte development.

To overcome the constraints imposed by traditional intensive sampling strategies (e.g., APHA 1985), we suggest that individuals interested in characterizing the standing crop of macrophytes in lakes for either comparative or descriptive purposes use a limited sampling program such as that described in this paper and the measured maximum standing crop of the different groups of macrophytes as their state variable when time or budget constraints make it difficult to accurately estimate the mean standing crop. We further suggest that the maximum measured macrophyte standing crops in a lake be used as a simple descriptor of macrophyte standing crop because (1) it sets the range of macrophyte standing crop for the lake studied, (2) it provides information on the potential of the lake for macrophyte development, (3) it is strongly related to the mean standing crop value (Figure 2 and 3), and (4) the identification of the maximum macrophyte standing stock in the lake is an important requirement to obtain reliable estimates of the mean no matter what type of sampling program is used (see Snedecor and Cochran 1979). Further, the regression equations we have provided (Table 1) seem to be sufficiently robust as to allow their use to estimate what the average standing crop in the lake may be from the maximum standing crop recorded, especially if the results are combined with fathometer techniques that have also been used to predict submersed plant standing crop (Maceina *et al.* 1984; Duarte 1987b).

Finding the maximum aquatic macrophyte standing crop in a lake is not difficult. The location where the maximum standing crop of emergent or floating-leaved macrophytes occurs can generally be found easily by visual surveys of the lake shoreline. The location where the maximum standing crop of submersed macrophytes occurs is more difficult to find, but can be found relatively easily by using (1) existing models that predict the depth where the maximum standing crop of submersed plants occurs (Chambers and Kalff 1985, Duarte and Kalff 1987), and (2) bathymetric charts to locate the areas where the littoral slope is most gentle (Duarte and Kalff 1986). Further, the maximum standing crop often corresponds to the tallest vegetation (Duarte 1987b), thus recording fathometers are particularly useful in finding this vegetation in large lakes. Although there is no simple way of assessing how far the estimated maximum standing crop may be from the true maximum standing crop in the lake, application of our regression equations to lakes for which detailed macrophyte data were available (i.e., L. Magog, L. Lovering, L. Memphremagog, L. George; data from Duarte 1987a) showed that the mean standing crop predicted from our regression equations (Eqs. 3 and 4; Table 1) was within the 95% confidence limits of the observed mean biomass whenever the estimated maximum biomass was within 50 to 70 % of the observed maximum biomass. This suggests that our estimation procedure is not extremely sensitive to inaccurate estimates of the maximum plant standing crop.

Accurate estimation of the mean standing crop of aquatic macrophytes in lakes is difficult. We, however, believe that the use of the simple procedures described here will encourage future standing crop determinations of aquatic macrophytes in lakes and therefore begin to provide the badly needed data base that will permit large-scale limnological studies of aquatic macrophytes and the development of empirical macrophyte models. Our approach, however, should be considered a tentative method. Additional studies are needed on a broader range of lakes elsewhere to confirm the empirical relationships described in this paper.

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LITERATURE CITED

Adams, M., and M. D. McCracken. 1974. Seasonal production of the *Myriophyllum* component of the littoral of Lake Wingra, Wisconsin. J. Ecol. 62:457-465.

American Public Health Association. 1985. STANDARD METHODS for the Examination of Water and Wastewater. 16th edition. American Public Health Association. Washington D.C., 1268 p.

Anderson, M. G. 1978. Distribution and production of Sago pondweed, (*Potamogeton pectinatus*) on a Northern prairie marsh. Ecology 59:154-160.

Bernatowicz, S. 1969. Macrophytes in the Lake Warniak and their chemical composition. Ekol. Polska 27:447-467.

Cambridge, M. L., and A. J. McComb. 1984. The loss of seagrasses in Cockburn Sound, Western Australia. I. The time course and magnitude of seagrass decline in relation to industrial development. Aquat. Bot. 20:229-243.

Canfield, D. E., Jr., and C. M. Duarte. 1988. Patterns in biomass and cover of aquatic macrophytes in lakes: a test with Florida lakes. Can. J. Fish. Aquat. Sci. 45:1976-1982.

Canfield, D. E. Jr., and J. C. Joyce. 1985. Aquatic macrophytes of 55 Ocala National Forest Lakes. Final Report (Contract #43-4283-5-369) to National Forests in Florida. U.S. Department of Agriculture. Tallahassee, Florida.

Canfield, D. E. Jr., J. V. Shireman, D. E. Colle, W. T. Haller, C. E. Watkins, II, and M. J. Maceina. 1984. Prediction of chlorophyll *a* concentrations in Florida lakes: Importance of aquatic macrophytes. Can. J. Fish Aquat. Sci. 41:497-501.

Chambers, P. A., and J. Kalff. 1985. Depth distribution and standing crop of submersed macrophyte communities in relation to Secchi depth. Can. J. Fish. Aquat. Sci. 42:701-709.

Crowder, A. A., J. M. Bristow, and M. R. King. 1977. Distribution, seasonality, and standing crop of aquatic macrophytes in Lake Opinicon (Eastern Ontario). Naturaliste Can. 104:441-456.

Downing, J. A., and M. R. Anderson. 1985. Estimating the standing crop of aquatic macrophytes. Can. J. Fish. Aquat. Sci. 42:1860-1869.

Duarte, C. M. 1987a. Biomass and distribution of submersed macrophytes in lakes. Ph.D. dissertation. Department of Biology. McGill University, Montreal, Canada. 126 p.

Duarte, C. M. 1987b. The use of echosounder tracings to estimate the standing crop of submersed plants in lakes. Can. J. Fish. Aquat. Sci. 44:851-855.

Duarte, C. M., and J. Kalff. 1986. Littoral slope as a predictor of the maximum standing crop of submersed macrophyte communities. Limnol. Oceanogr. 31:1072-1080.

Duarte, C. M., and J. Kalff. 1987. Latitudinal influences in the depths of maximum colonization and maximum standing crop of submersed angiosperms. Can. J. Fish. Aquat. Sci. 44:1759-1764.

Duarte, C. M., J. Kalff, and R. H. Peters. 1986. Patterns in the standing crop and cover of aquatic macrophytes in lakes. Can. J. Fish. Aquat. Sci. 43:1900-1908.

Durocher, P. P., W. C. Provine, and J. E. Kraai. 1984. Relationship between abundance of largemouth bass and submersed vegetation in Texas reservoirs. North Amer. J. Fish. Manage. 4:84-88.

Engel, S. 1985. Aquatic community interactions of submersed macrophytes. Wisconsin Department of Natural Resources Technical Bulletin 156. Madison, Wisconsin. 79 pp.

Finlayson, C. M., T. P. Farrell, and D. J. Griffiths. 1984. Studies of the hydrobiology of a tropical lake in North-western Queensland. III. Growth, chemical composition and potential for harvesting of the aquatic vegetation. Aust. J. Mar. Freshwat. Res. 35:525-536.

Grace, J. B., and L. J Tilley. 1976. Distribution and abundance of submersed macrophytes, including *Myriophyllum spicatum* L. (Angiospermae), in a reactor cooling reservoir. Arch. Hydrobiol. 77:475-487.

Greis, J. G. 1985. A characterization of Ocala National Forest lakes. National Forests in Florida, U.S. Forest Service, Tallahassee, FL.

Guilizzoni, P., and C. Sarraceni. 1974. Populamento a macrofite pp. 183-224. *In*: Barbanti, L., C. Bonacina, A. Calderoni, A. C. R. De Bernardi, P. Guilizzoni, A. M. Noccenti, D. Ruggiu, C. Saraceni, and L. Tonolli (Eds.). Indagini ecologiche sul lago d'Endine. Istituto Italiano di Idrobiologia, Pallanza, Italy.

Howard-Williams, C., and M. R. M. Liptrot. 1980. Submersed macrophyte communities in a brackish South African estuarine-lake system. Aquat. Bot. 9:101-116.

Ikusima, I. 1984. Aquatic macrophytes. pp 303-311. *In*: S. Horie (Ed.). Lake Biwa. Monogr. Biol. vol 54. Dr. Junk Publ., Boston.

Knowlton, M. F., M. V. Hoyer, and J. R. Jones. 1984. Sources of variability in phosphorus and chlorophyll and their effects on use of lake survey data. Water Resour. Bull. 20:397-407.

Krausch, H. D. 1985. Aquatic macrophytes in the Lake Stechlin area. pp 130-149. *In*: S. J. Casper (Ed.) Lake Stechlin. A temperate oligotrophic lake. Dr. W. Junk Publ., Boston.

Maceina, M. J., J. V. Shireman, K. A. Langeland, and D. E. Canfield Jr. 1984. Prediction of submersed plant standing crop by use of a recording fathometer. J. Aquat. Plant Manage. 22:35-38.

Moeller, R. E. 1985. Macrophytes. pp. 177-191. *In*: G. E. Likens (Ed.), An ecosystem approach to aquatic ecology. Mirror Lake and its environment. Springer-Verlag, New York.

Nichols, S. A. 1982. Sampling characteristics of macrophyte standing crop. Water Resour. Bull. 18:521-523.

Neil, J. H. and G. A. Kamaitis. 1985. Aquatic plant assessment Cook's bay, Lake Simcoe. Ontario Ministry of the Environment. 28 pp.

Peters, R. H. 1986. The role of prediction in limnology. Limnol. Oceanogr. 31:1143-1159.

Rorslett, B., D. Berge, A. H. Erlandsen, S. W. Johansen, and P. Brettum. 1984. Vasspest i steinfjorden, Ringerike. Innvirkning pa vannkvalitet 1978-83 og behov for tiltak. Norwegian institut for Vannforskning no. 0-82132. Oslo. 52 pp.

Schlott, V. G., and G. Malicky. 1984. Standing crope und phosphorgehalt de Makrophyten in der NO-Buchtdas Lunzer Untersees (Austria) in Abhangigkeit von nahrstoffreichen Zuflussen und vom Sediment. Arch. Hydrobiol. 101:265-277.

Schloesser, D. W., T. A. Edsall, and B. A. Manny. 1985. Growth of submersed macrophyte communities in the St. Clair - Detroit river system between Lake Huron and Lake Erie. Can. J. Bot. 63:1061-1065.

Snedcor, G. W. and W. G. Cochran. 1979. Statistical Methods. 6th edition. Iowa State University Press. Ames, Iowa. 593 p.

Thorne-Miller, B., and M. M. Harlin. 1984. The production of *Zostera marina* L. and other submerged macrophytes in a coastal lagoon in Rhode Island, USA. Bot. Mar. 27:539-546.

Westlake, D. F. 1965. Theoretical aspects of the comparability of productivity datas. Mem. Ist. Ital. Idrobiol. 18(Suppl.):313-322.

Wile, I. 1974. The macrophytes of the Kawartha lakes—1972. pp. 62-82. *In*: The Kawartha lakes water management study—water quality assessment (1972-1976). Ontario Ministry of the Environment.