Nutrient Removal Potentials of Various Aquatic Plants[1]

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Nutrient enrichment of natural waters resulting from man's activities has been strongly implicated as a major cause of nuisance growths of aquatic plants. Fifteen chemical nutrient elements are recognized as essential for normal plant growth and development. Nitrogen and phosphorous levels, however, are usually the limiting factors for aquatic plant growth since naturally occurring concentrations of the remaining elements are seldom low enough to be growth limiting. Ferguson (5) reports that nearly 4 billion pounds of nitrogen and 850 million pounds of phosphorous enter receiving waters annually. The sources of nutrients are varied. They are derived from domestic and industrial sewage, domestic animal wastes, detergents, and agricultural fertilizers. The relative contributions of man-generated nutrients are listed in Table 1. Phosphates in detergents are estimated to contribute 280 million pounds, approximately 33% of the phosphorous in domestic sewage (5).

TABLE 1. SOURCES OF NUTRIENTS ENTERING SURFACE WATERS
(Data from Ferguson 1968)

	N %	P %
Domestic sewage	33	50
Runoff from cultivated land	51	27
Urban land	5	3
Land on which animals are kept	11	20
Billions of pounds	4	0.85

When bodies of water no longer meet use requirements because of eutrophication and the resulting growths of algae and higher plants, it becomes necessary to establish corrective measures. Suggestions that harvesting aquatic growths containing bound nutrients as a means of bringing waters into nutrient balance are compelling, particularly when a usable product may result.

A number of studies concerned with aquatic plant utilization have suggested as well as demonstrated several actual uses (1, 2, 6, 10, 13). They may be utilized as cattle or chicken feed, as soil amendments to increase organic matter content, as mulches and compost, as protein, amino acid, carotene, furfural and cellulose sources as nutrient media for yeast cultures, as paper pulp, as cigar wrappers and as a fuel. Assuming then that the harvested plant material can be used, the monetary or utilitarian value of the product will, in effect, lower the cost of removal.

The quantities of nutrients that are potentially removable by various aquatic plants can be calculated from yield and mineral composition data. For example a plant type which produces 2 tons of dry matter per acre per year and containing 2% by weight of potassium can remove up to 80 pounds of potassium per acre.

Information which most closely approximates yield data has been gathered principally by ecologists and limnologist. These data are given as standing crop, biomass, or productivity estimates. Plants randomly sampled from a known area and weighed, preferably after oven drying (105°C) to a constant weight, give estimates of standing crop. If the entire plant such as roots and underground organs are included it is an estimate of biomass. Productivity is simply the amount of plant material produced on a given area, over a given time period.

Having a method available for estimating the nutrient removal capabilities of aquatic plants the next questions are, what may be expected of the various types, and do some types perform better than others? The compiled information of Table 2 helps in formulating answers.

The productivity and compositional estimates listed in Table 2 are maximums in the range of reported values. The quantities of nitrogen and phosphorous which may be removed are, therefore, maximum values (Table 2, column "Crop content").

The most striking differences among the various hydryphytes are among habitat groups. After viewing a body of water completely choked with a submersed weed such as hydrilla or watermilfoil, one is left with the impression that these plants are highly productive. However, when evaluated against quantitative criteria, the submersed aquatics with the exception of the tropical marine species (e.g. thalassia), are poorly productive. The emergent types, particularly the reeds and also the floating plants, are more highly productive. This may be related to a more abundant supply of light and carbon dioxide for photosynthesis.

A scarcity of productivity data under natural field conditions prevents the proper evaluation of the nutrient reduction potential of aquatic plants. However, the high production potential of water hyacinth, which was predicted by Westlake (15) and supported by Yount (534 lbs per acre per day, 16), favors this plant as a nutrient absorber. The ease of harvesting a floating plant when compared with the difficulties of cutting and harvesting rooted emergent types is another important factor.

Plants have been successfully used for pollution abatement. Sheffield and Kaleel (12) appear to have successfully restored the nutrient balance of a small eutrophic lake by growing water hyacinths in a fenced area in the center of the lake. After one year the lake was clear and supporting fish.

Rudescu (10) states that bulrush (*Juncus lacustris*) is being utilized in Germany to purify industrial affluents. He reports purification of effluents at the rate of 5 million cubic meters per day by passage through 20 basins 400 meters long by 50 meters wide, planted with bulrush (13.2 million gals per acre per day).

Nitrogen and phosphorous are present, on an average, in plant tissues at a ratio of 10:1. This is the ratio at which these elements often occur in natural waters and is suggested as a guideline for indicating normal conditions (14).

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TABLE 2. NUTRIENT REMOVAL POTENTIALS OF VARIOUS AQUATIC PLANTS.

Growth Habit and plant	Location	Annual Productivity (T/A-D.M.)[1]	Composition (% of D.W.) N	P	Crop Content (lb/A) N	P	Reference for Productivity estimates
SUBMERSED							
Sagittaria subulata	Florida	9.3	4.0	0.4	744	74	Odum 1957
Thalassia testudinum	Puerto Rico	13.4	4.0	0.4	1072	107	Burkholder 1959
Hydrilla verticillata	Florida	1.0[2]	3.9	0.4	78	8	Blackburn 1968
Myriophyllum exalbescens	Wisconsin	1.0[2]	4.0	0.4	80	8	Seinwill 1968
EMERGENT							
Typha latifolia	Minnesota	20.5	1.5	0.18	615	61	Bray 1959
Cyperus papyrus	Tropics	33.4	1.5	0.15	1002	100	Westlake 1963
Phragmites communis	Rumania	13	1.5	0.15	390	39	Rudescu 1969
FLOATING							
Eichhornia crassipes	Louisiana	14.7	4.0	0.4	1176	118	Penfound & Earle 1948
	Sub-Tropic	67.0[3]	4.0	0.4	5360	536	Westlake 1963

[1]Tons per acre—dry matter.
[2]Standing crop estimates. Productivities up to 3 tons per acre possible (Westlake 1963).
[3]Projected value for optimum growth conditions.

Ferguson's (5) estimates indicate that nitrogen and phosphorous are entering waters at a ratio of nearly 5:1. The yearly per capita domestic contributions in sewage occur at a ratio of 3:1 (7). With nitrogen and phosphorous present at these ratios, plants could only remove one-third to one-half of the entering phosphorous, since nitrogen supplies would be limiting (Table 3) The relationship is evident when comparing the nutrient removal potential of plants on a per capita basis (Table 4). For example, water hyacinth with a theoretical productivity of 67 tons of dry matter per acre per year could effectively remove the yearly contribution of nitrogen from 595 people and the phosphorous from 180 people. The phosphorous contributed by 415 of these people (595 minus 180) would not be removed (Table 4).

TABLE 3. RELATIONSHIP BETWEEN CONCENTRATION RATIOS IN PLANT TISSUE AND WATER

	N	P
	lbs.	lbs.
Entering water (3:1)	270	90
Removed by plants (10:1)	270	27
Remains in water	0	63
Population equivalent[1]	30	9

[1]Based on the yearly per capita contributions of N = 9 lbs, P = 3 lbs.

TABLE 4. NUTRIENT REDUCTION POTENTIAL OF VARIOUS HYDROPHYTES ON A POPULATION BASIS

Growth habit and plant	Location	Annual Productivity (T/A-D. M.)	Population equivalent[1] N	P
SUBMERSED				
Sagittaria subulata	Florida	9.3	83	25
Thalassia testudinum	Puerto Rico	13.4	119	36
Hydrilla verticillata	Florida	1.0	9	3
Myriophyllum exalbescens	Wisconsin	1.0	9	3
EMERGENT				
Typha latifolia	Minnesota	20.5	68	20
Cyperus papyrus	Tropics	33.4	111	33
Phragmites communit	Rumania	13	43	13
FLOATING				
Eichhornia crassipes	Louisiana	14.7	130	40
	Sub-Tropic	67.0	595	180

[1]Based on the yearly per capita contributions of N = 9 lbs, P = 3 lbs.

In summary, growing aquatic plants utilize mineral nutrients present in water. Harvesting these plants has a potential as a method of reducing nutrient pollution and of bringing eutrophic waters into proper nutrient balance. Floating plants such as water hyacinth have a greater potential than submersed plants because of higher productivities. The problems of harvesting plants with high water content and their utilization or disposal need to be weighed against the possible advantages or regaining the intended uses of the waters.

REFERENCES CITED

1. Boyd, Claude E. 1968. Evaluation of some common aquatic weeds as possible feedstuffs. *Hya. Control J.*, 8:26-27.
2. Boyd, Claude E. 1968. Fresh-water plants; a potential source of protein. *Economic Botany*, Vol. 22, No. 4, October-December, 1968. pp 359-368.
3. Bray, J. R., D. B. Lawrence and L. C. Pearson. 1959. Primary production in some Minnesota terrestrial communities for 1957. *Oikos*, 10:38-49.
4. P. R. Burkholder, L. M. Burkholder and J. A. Rivero. 1959. Some chemical constituents of turtle-grass, *Thalassia testudinum*. *Bull. Torrey Bot. Club*, 86:88-93.
5. Ferguson, F. A. 1968. A nonmyopic approach to the problem of excess algal growths. *Environmental Science and Technology*, 2:188-93.
6. Little, E. C. S. Ed. 1968. Handbook of utilization of aquatic plants. *Food and Agriculture Organization of the United Nations*, Rome, Italy. 123 pp.
7. Mackenthun, Kenneth M. and William M. Ingram. 1967. Biological associated problems in freshwater environments, their identification, investigation and control. USDI, FWPCA. United States Government Printing Office.
8. Odum, H. T. 1957. Trophic structure and productivity of Silver Springs, Florida. *Ecol. Monogr.*, 27:55-112.
9. Penfound, W. T. and T. T. Earle. 1948. The biology of the water hyacinth. *Ecol. Monogr.*, 18:447-72.
10. Rudescu, Ludovic. 1969. Rumanian Inst. of Limnology, Bucharest, Rumania, Personal Communication.
11. Seinwill, Gerald D. 1968. Mechanical harvesting of lake weeds appears promising for halting aging process. *University-Industry Research Newsletter*, Vol. 3:16-17. Aug. Univ. of Wisc., Madison.
12. Sheffield, C. W. and R. T. Kaleel. 1969. Orange County Pollution Control Dept., Orlando, Fla. Personal Communication.
13. Taylor, K. G. and R. C. Robbins. 1968. The amino acid composition of water hyacinth (*Eichhornia crassipes*) and its value as a protein supplement. *Hya.Control J.*, 8:24-25.
14. *Water Quality Criteria* Report of the National Technical Advisory Committee to the Secretary of the Interior April 1, 1968. Federal Water Pollution Control Administration, Washington, D.C. U.S. Government Printing Office, Washington, D.C.
15. Westlake, D. F. 1963. Comparisons of plant productivity. *Biol. Rev.*, 38:385-425.
16. Yount, James L. 1964. Aquatic Nutrient Reduction-Potential and Possible Methods. Report of the 35th annual meeting, *Florida Anti-Mosquito Association* 83-85.