Effect Of Sewage Effluent On Growth Of Five Vascular Aquatic Species

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INTRODUCTION

Pollution has always been a problem in densely populated and highly industrialized countries. However, the public has become aware of this problem only in the last few years.

This investigation is concerned with eutrophication, one aspect of water pollution. Natural eutrophication occurs during ecological aging of bodies of water. Difficulties arise when man's activities accelerate this natural process and cause what is referred to as artificial eutrophication (4, 6, 7, 11). The enrichment of waters with nutrients, especially nitrogen and phosphorus, is of major concern and sewage effluents are a prime source of these elements. Sewage effluents are usually rich in nitrogen which is released from biological wastes and in phosphorus which is made available in part by the degradation of detergents. Verduin (12) found that phosphorus enrichment of surface waters is primarily derived from sewage treatment plants and only secondarily from agricultural fertilizers.

Plants and animals require nutrients for survival; therefore a certain amount of nutrient enrichment is necessary for aquatic life. The problem of enrichment becomes one of "how much is too much." The answer is dependent upon what the primary use of the water is. Since most large bodies of water have multiple uses, it is not possible to state precisely at what point "enough" becomes "too much."

One of the characters which distinguishes eutrophic from oligotrophic water is the amount of algal growth. Oligotrophic water has relatively little algal growth, whereas eutrophic water usually has large quantities of algae. Vascular aquatics also tend to be much more numerous in eutrophic waters, but excess plankton growth may limit the rooted aquatics by reducing light availability (4).

Fruh (5) observed that currently the primary method of nutrient control is diversion. This is, at best, only a stopgap measure. Flowing waters are less affected by nutrient enrichment than are lakes because aquatic plants are more likely to grow in calm water. Therefore, diversion of nutrient-bearing waters around a lake into a stream may reduce eutrophication but does not eliminate the source of mineral enrichment (7).

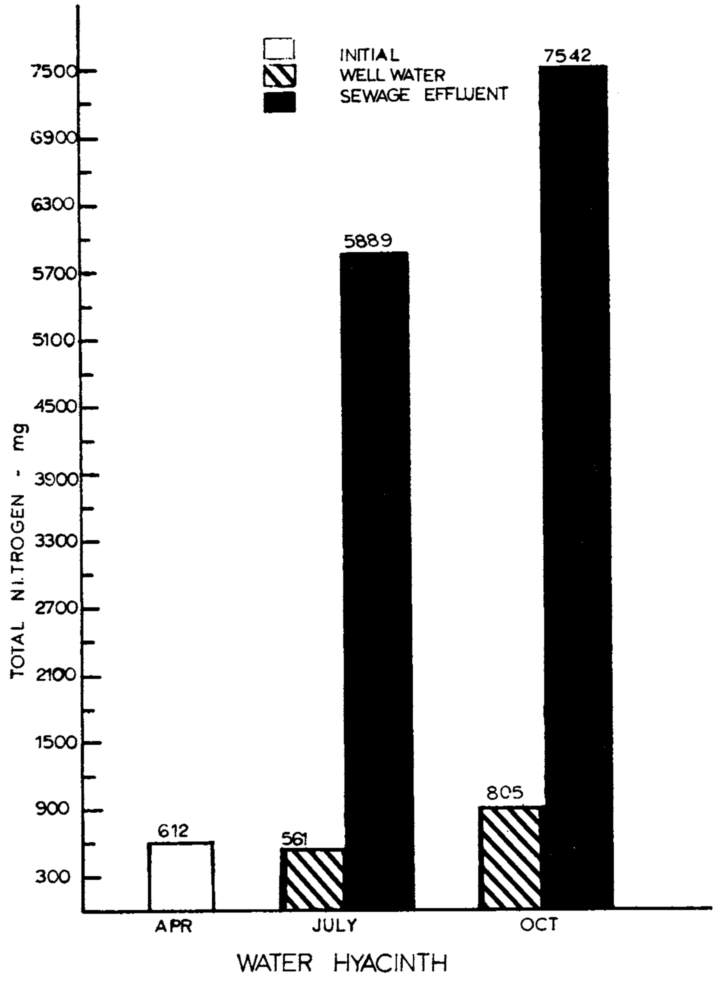

Figure 1, Nitrogen content of water hyacinth when stocked in April, at the July harvest, and the sum of the July and October harvests.

Several other methods of effluent disposal may be feasible to a degree. Effluents could be sprayed on land to increase its fertility. However, effluents could not be used on crops that are directly or indirectly a source of uncooked food for man because of the potential danger from pathogenic organisms. Thus, effluents could be used on pastures for raising beef cattle because meat is cooked before it is eaten. This method would be unsatisfactory for dairy cows because milk may be consumed untreated. Effluents could be used locally in greenhouses for hydroponic culture of crops not used as fresh food (10).

In this paper we discuss the ability of a variety of vascular plants to remove nutrients from water and thereby reduce the level of eutrophication.

MATERIALS AND METHODS

Twelve circular plastic pools 9 feet in diameter and 26 inches deep were used in this investigation. Six pools were filled with a mixture of 25% sewage effluent and 75% well water and the other six with 100% well water. The pools were located 4 miles north of Auburn on Auburn University land assigned to the Department of Fisheries and allied Aquacultures. None of the pools contained soil. This eliminated a possible "sink" or source for nutrients, especially phosphorus. Soil particles have a high phosphate adsorbing capacity, thus making the phosphate unavailable for plant growth (1, 2, 11).

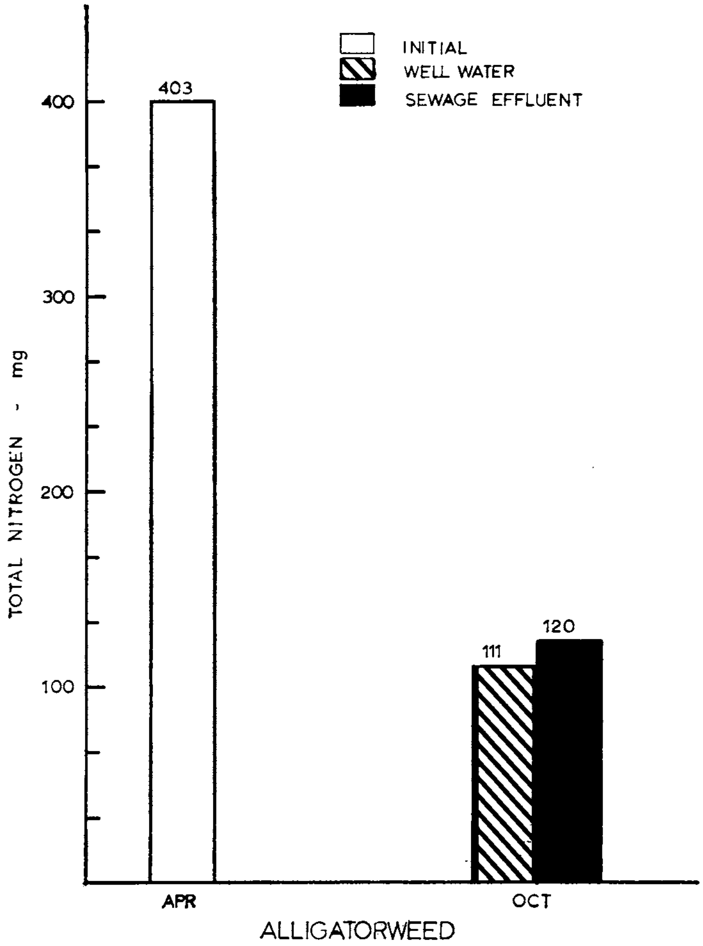

Figure 2. Nitrogen content of alligatorweed when stocked in April and harvested in October.

Table 1. Average Initial and Harvested Dry Weights Per Pool After 23 Week.

Plant	Initial Weight	Harvested weight Well water	Harvested weight 25% Sewage
	(g)	(g)	(g)
Water Hyacinth	2.0	59.0a/	736.6a/
Alligatorweed	0.6	7.9	20.4
Curly Pondweed	0.5	0.9	4.7
Egeria	0.2	0.0	0.0
Slender Naiad	0.1	0.0	0.0

a/ Includes the 11-week harvest.

Three of the pools with sewage effluent and three without were stocked with five vascular aquatic species and the other pools were left unstocked. The plants were water hyacinth [*Eichhornia crassipes* (Mart.) Solms], alligatorweed (*Alternanthera philoxeroides* Griseb.), curly pondweed (*Potamogeton crispus* L.), egeria (*Egeria densa* Planch.), and slender naiad [*Najas flexilis* (Willd.) Rostk. Schmidt]. Ten egeria plants, 12 water hyacinth, and 20 plants of each of the other species were stocked in each pool. Dry weights of representative samples of these plants were determined before they were put into the pools (Table 1). Observations on plant growth and competition were made periodically from late April to late October, 1969. Treatments were randomly distributed among the pools.

The effectiveness of water hyacinth and alligatorweed in removing nitrogen, phosphorus, and potassium from sewage effluent and from well water was measured. Curly pondweed, egeria, and slender naiad were examined for their ability to absorb these elements where there was sufficient plant material to permit analyses. Total nitrogen was determined by the Kjeldahl method (8). The macro-Kjaldahl method was used when there was 0.5 gram or more of dried plant material and the semi-micro-Kjeldahl method when the material was less than 0.5 gram. The vanadomolybdate colorimetric method was used for phosphorus determination (3, 12); readings were made on a Klett-Summerson Photoelectric colorimeter. A Perkin-Elmer flame photometer was used for measuring potassium (8). Plant samples were taken before the study began and again at the end of the study in October. Water hyacinth was also harvested at mid-season in July. Harvested plants were oven-dried. Large amounts of plant material were ground in a Waring blender and smaller amounts in a semi-micro Wiley mill.

RESULTS AND DISCUSSION

Growth and Competition Studies. After 11 weeks the dominant species in sewage effluent pools was water hyacinth. At that time the water hyacinths in pools containing

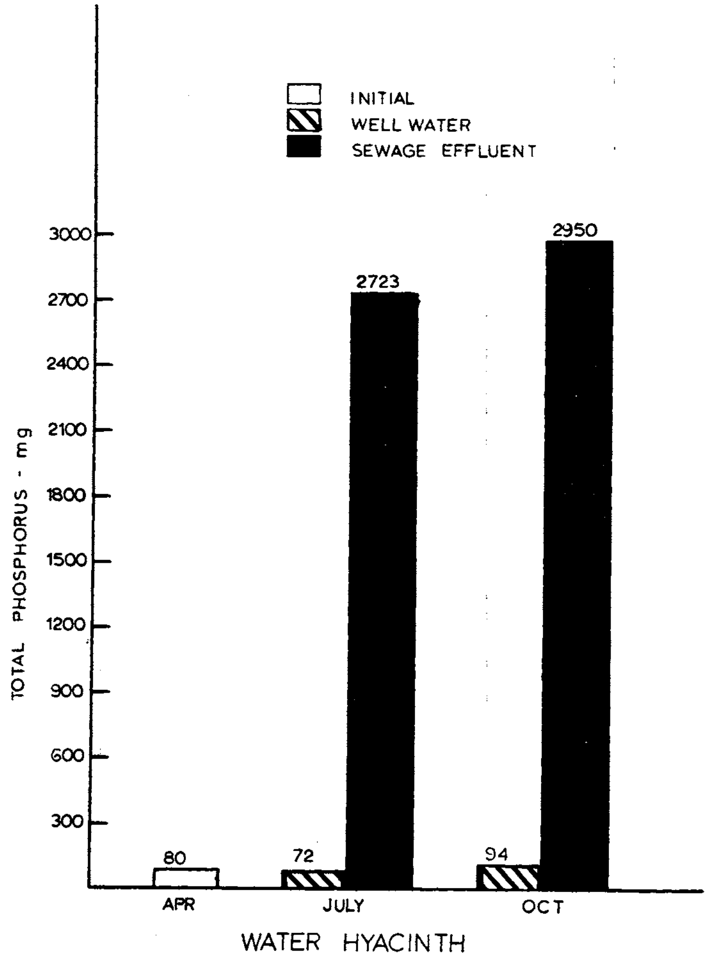

Figure 3. Phosphorus content of water hyacinth when stocked in April, at the July harvest, and the sum of the July and October harvests.

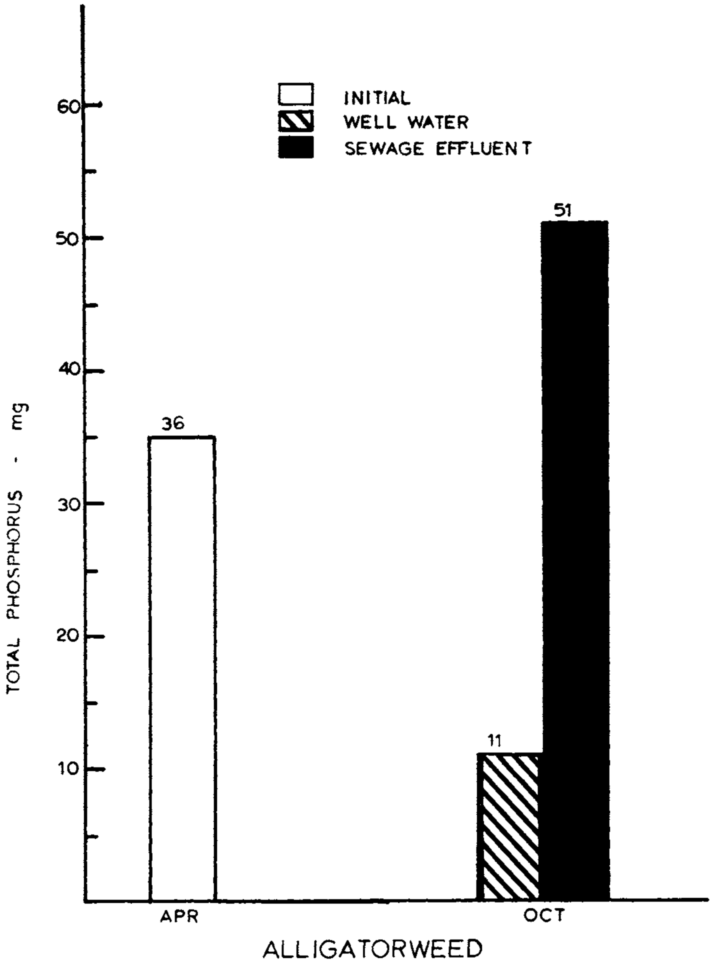

Figure 4. Phosphorus content of alligatorweed when stocked in April and harvested in October.

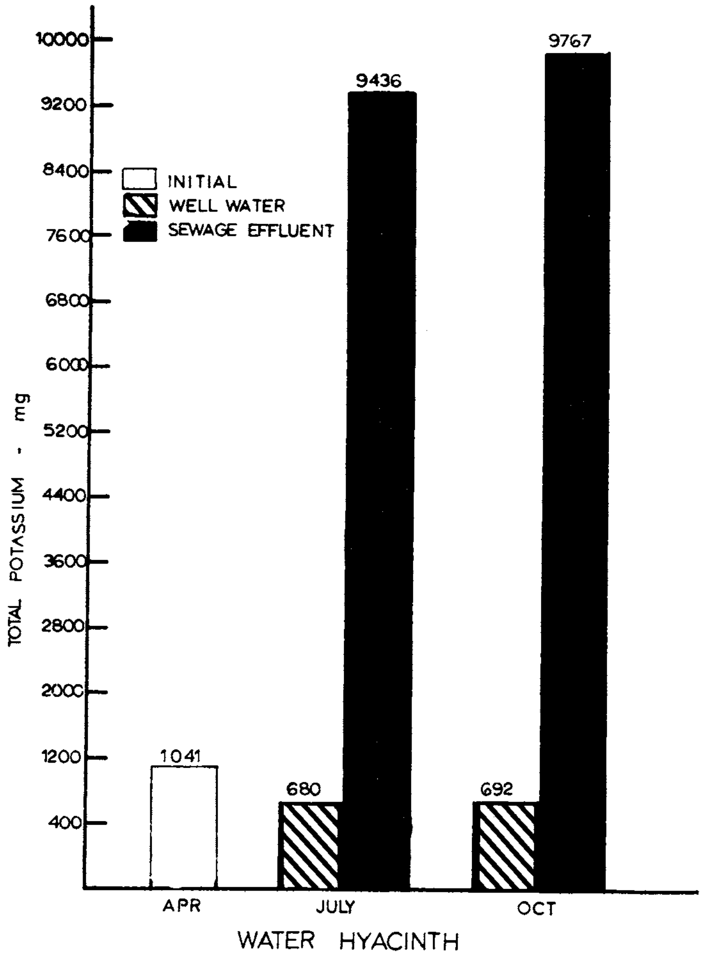

Figure 5. Potassium content of water hyacinth when stocked in April, at the July harvest and the sum of the July and October harvests.

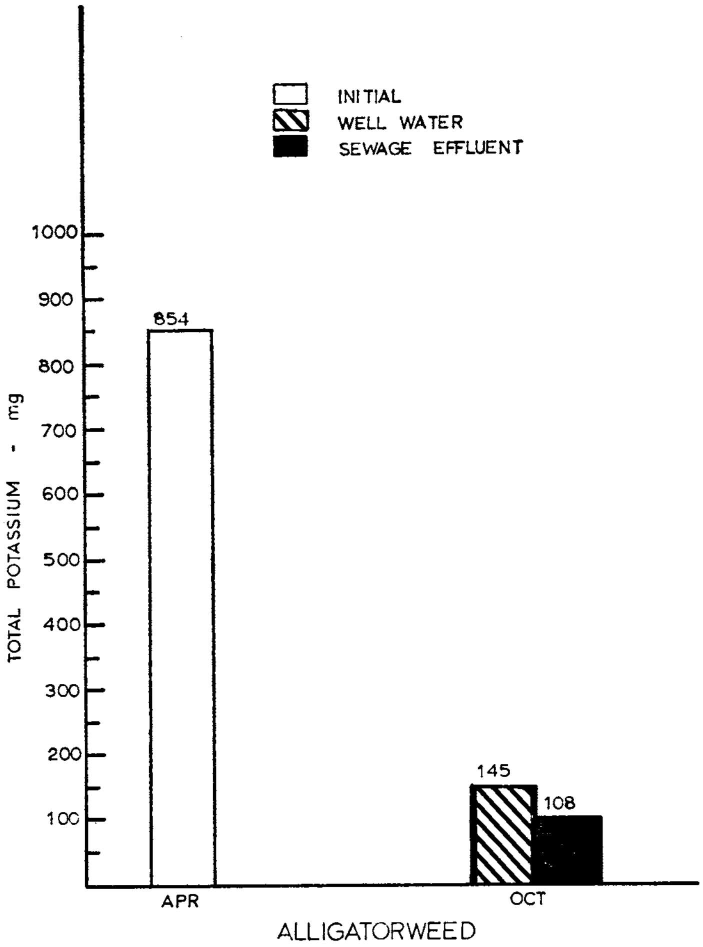

Figure 6. Potassium content of alligatorweed when stocked in April and harvested in October.

sewage effluent had covered 71% of the water surface. Consequently, water hyacinths were harvested back to the original stocking rate of 12 per pool. No other species had grown sufficiently to necessitate harvesting. The average wet and dry weights of the harvested water hyacinth are given in Table 2. Considerably more water hyacinth was removed from the pools containing sewage effluent than from those with well water in which the plants covered only 16% of the surface. Those growing in sewage effluent were greener and appeared to be more healthy than those in well water.

In October, 23 weeks after the beginning of the experiment, all plants were harvested and dry weights determined (Table 1). The differences in the dry weights of water hyacinth grown in sewage effluent and in well water was not as great in October as it had been at mid-season. There was not as much growth from 12 plants after July as there had been before July. It seems probable that the first harvest of water hyacinth effectively decreased the nutrients in the water, leaving it relatively nutrient poor for the second period. If this were the case, it would explain the small amount of growth after the first harvest.

TABLE 2. AVERAGE HARVESTED WEIGHTS OF WATER HYACINTH PER POOL AFTER 11 WEEKS.

Treatment	Wet weight	Dry weight
	(g)	(g)
Well water	916	42.5
25% Sewage	13,547	633.3

Water hyacinth responded most vigorously to sewage effluent enrichment. Alligatorweed was second in response although its growth was considerably less vigorous. Alligatorweed was, however, the only significant survivor in the 100% well water pools, indicating its tolerance to prolonged exposure to low nutrients levels. While it survived in well water, its growth was limited and it had only a few small yellowish-green to yellow leaves and sparse roots. The water hyacinth in well water pools turned brown and finally sank to the bottom of the pools.

Algal Samples. Samples were taken periodically from all pools for algal identification. Algal genera prominently associated with sewage pools were *Anabaena* (Cyanophyta) and *Kirchneriella* and *Pediastrum* (Chlorophyta). *Gloeocystis* and *Oocystis* (Chlorophyta) were found most often in the 100% well water pools. The genera common to both the sewage effluent and well water pools were *Scenedesmus, Staurastrum,* and *Ankistrodesmus,* all members of the Chlorophyta.

Plant Analysis. Analyses for nitrogen, phosphorus, and potassium were made on plant material obtained before the study began, at mid-season (for water hyacinth), and at the end of the study. Because of lack of growth, there was not sufficient plant material for complete analyses for curly pondweed, egeria, and slender naiad.

Plant nitrogen of water hyacinth increased throughout the season (Figure 1). The increase was more pronounced in plants from sewage effluent than in those from well water. At the end of the season, water hyacinth in well water had removed 0.19 g of nitrogen per pool, whereas those in sewage effluent removed 6.93 g of nitrogen per pool. Nitrogen contents in alligatorweed are given in Figure 2. There was no mid-season value for alligatorweed to complete the comparison with water hyacinth. Though alligatorweed was not harvested at mid-season, plants remaining at the end of the study were few and the total nitrogen in the plants was less than that present in the plant when the pools were stocked.

The phosphorus analyses for these two species are given in Figures 3 and 4. Water hyacinth in well water was deat at the end of the study and the decomposing remains contained 10 mg of phosphorus. The plants in sewage effluent were living and their growth accounted for the removal of 2.87 g of phosphorus per pool during the 23-week period. Alligatorweed harvested from the well water pools after 23 weeks contained less phosphorus than the originally stocked plants but those from the sewage pools had 15 mg more than were present at the beginning.

Potassium of water hyacinth grown in sewage effluent (Figure 5) showed, as would be expected, a rapid uptake, or luxury consumption. Alligatorweed, however, showed a significant decrease in potassium from the initial to the final value (Figure 6). This decrease is, perhaps, explainable in light of the observation by Humphries (9) that potassium occurs in all parts of the plant, but especially in meristematic regions and that concentration decreases with age. The alligatorweed grew very little during the experimental period and some plants died.

These studies show that, of the five plant species tested, water hyacinth responded most vigorously to the extra fertility present in sewage effluent. It would seem possible that water hyacinth might be used in certain situations to decrease unwanted nutrient enrichment from sewage effluent. It could be introduced into enriched lakes and a certain percentage harvested at regular intervals to remove excess minerals. Water hyacinth is prolific and, being free-floating, would be easier to harvest than a rooted aquatic. Nutrients could be recovered in this way from eutrophic waters. This would be of limited uses in areas where the temperature is below freezing for part of the year. Nutrient rich waters are produced throughout the year, but in a state like Alabama water hyacinth grows only during the warmer period. They would have to be re-stocked each spring. Further studies are needed to determine whether this procedure might be of any practical value.

SUMMARY

The aim of this investigation was to determine the effect of sewage effluent and well water on the growth of five vascular aquatic species and to determine how effective water hyacinth and alligatorweed are in removing nitrogen, phosphorus, and potassium from water. Water hyacinth responded the most vigorously to sewage effluent enrichment of water. The dry weight of these plants increased from 24.0 g to 736.6 g per pool in 23 weeks in sewage effluent and they absorbed 6.93 g of nitrogen, 2.87 g of phosphorus, and 8.73 g of potassium during this period. Alligatorweed was the only significant survivor in 100% well water pools, and its growth was limited. When grown in sewage effluent, it increased in dry weight from 1.2 g to 20.4 g per pool and absorbed 20 mg of phosphorus but lost 0.28 g of nitrogen and 0.75 g of potassium during the 23 weeks. Algal genera predominantly associated with pools containing sewage effluent were *Anabaena, Kirchneriella,* and *Pediastrum*.

LITERATURE CITED

1. Bear, Firman E. (ed). 1964. Chemistry of the Soil. 2nd ed. Reinhold Publishing Corp., New York. 515 p.
2. Biggar, J. W. and R. B. Corey. 1967. Agricultural drainage and eutrophication. Agr. Sci. Res. 4:22-28.
3. Chappman, Homer D. and Parker F. Pratt. 1961. Methods of Analysis for Soils, Plants, and Waters. Univ. of Calif. Press 309 p.
4. Fruh, E. Gus, Kenton M. Stewart, G. Fred Lee, and Gerard A. Rohlich. 1966. Measurements of eutrophication and trends. J. Water. Pollut. Control Fed. 38:1237-1258.
5. Fruh, E. Gus. 1967. The overall picture of eutrophication. J. Water Pollt. Control Fed. 39:1449-1463.
6. Hasler, Arthur D. 1947. Eutrophication of lakes by domestic drainage. Ecology 28:383-395.
7. Hasler, Arthur D. 1969. Cultural eutrophication is reversible. BioSscience 19:425-431.
8. Horwitz, William (ed.). 1965. Official Methods of Analysis. 10th ed. Association of Official Agricultural Chemists, Washington, D.C. 957 p.
9. Humphries, E. C. 1956. Mineral components and ash analysis, pp. 468-485. *In* Modern Methods of Analysis. K. Peach and M. Travey (eds.) Springer-Verlag, Berlin, Gottingen, and Heidlebery, 542 p.
10. Hynes, H. B. W. 1963. The Biology of Polluted Waters. Liverpool Univ. Press. Liverpool, England. 202 p.
11. Oglesby, R. T. and W. T. Edmondson. 1966. Control of eutrophication J. Water Pollt. Control Fed. 38:1452-1460.
12. Olsen, S. R. and L. A. Dean. 1965. Phosphorus. Methods of Soil analysis. Amer. Soc. Agron. Monogr. 90:1059-1063.
13. Verduin, Jacob. 1954. Phytoplankton and turbidity in western Lake Erie. Ecology 35:550-561.