it was found that fishes of rather large size and bulk, such as carp, buffalo, redhorse and drum, were recovered at a much higher rate than smaller fishes, such as threadfin shad, minnows, and brook silversides. The high recovery of sunfish, although most were small in size, may be attributed to their preference for the shallower waters of the coves and the shoreline habitat. Recovery from these areas is almost always greater than that from the open deeper waters.

In rotenone sampling in large reservoirs, one can expect a greater number of small fish than large fish to sink and remain on the bottom. Therefore, a relatively high recovery of the standing crop of the sample area can be expected.

LITERATURE CITED

Ball, Robert C. 1945. Recovery of marked fish following a second poisoning of the population in Ford Lake, Michigan. Tran. Am. Fish. Soc. 75 (1945) 36-42.

Carlander, Kenneth D. and William M. Lewis. 1948. Some precautions in estimating fish populations. Prog. Fish-Cult., 10(3):134-137.

Fredin, R. A. 1950. Fish population estimated in small ponds using the marking and recovery technique. Iowa State Jour. Sci. 24:363-384.

Hall, John F. 1956. A comparative study of two fish-sampling methods in a small Kentucky impoundment. Trans. Kentucky Acad. Sci. 17(3-4):140-147.

Hester, Eugene F. 1959. The tolerance of eight species of warm-water fishes to certain rotenone formulations. Proc. Ann. Conf. S. E. Assoc. Game and Fish Commissioners. 1959. pp. 121-133.

Huish, Melvin T. 1957. Studies of Gizzard Shad reduction at Lake Beulah, Florida. Proc. Ann. Conf. S. E. Assoc. Game and Fish Commissioners. 1957. pp. 66-70.

Jenkins, R. M. 1951. A fish population study of Claremore City Lake. Proc. Oklahoma Acad. Sci. 30(1949):84-93.

Krumholz, Louis A. 1944. A check on the fin-clipping method for estimating fish populations. Pop. Mich. Acad. Sci. Arts and Lett., 1943, Vol. 29, pp. 281-291.

———— 1950. Some practical considerations in the use of rotenone in Fisheries Research. Jour. Wildl. Mgt., 14(4)413-424.

Rupp, Robert S. and Stuart E. DeRoche. 1965. Standing crops of fishes in three small lakes compared with C^{14} estimates of net primary productivity. Trans. Am. Fish. Soc., 94(1)9-25.

Surber, Eugene W. 1959. Suggested standard methods of reporting fish population data for reservoirs. Proc. Ann. Conf. S. E. Assoc. Game and Fish Commissioners. 1959. pp. 313-325.

EXPERIMENTS ON THE USE OF A BIOFILTER TO REMOVE WASTES FROM FISH TANKS[1]

CHUNG LING CHU[2] AND GEORGE N. GREENE
Fisheries Laboratory
Agricultural Experiment Station
Auburn University
Auburn, Alabama

INTRODUCTION

High fish production in a pond can be obtained by feeding. Tiemeier (1962) obtained 1,622 pounds of channel catfish (*Ictalurus*

[1] This paper taken from a thesis presented to the Graduate Faculty of Auburn University in partial fulfillment of the requirements for the degree of Master of Science.

[2] Present address: Department of Food Science, University of Washington, Seattle, Washington 98105.

punctatus) per acre in six months by supplemental feeding. Prather and Swingle (1960) produced 2,187 pounds of white catfish (*I. catus*) per acre in 205 days, using a maximum feeding rate of 30 pounds per acre per day. However, with higher feeding rates organic matter from the feed and wastes contaminates the water and causes an accumulation of carbon dioxide and ammonia and reduces the dissolved oxygen content.

Higher production can be realized in flowing water which removes these wastes. Japanese trout ponds produced 56,000 pounds of trout per acre per year with flowing water and intensive feeding (Lin, 1949). The water must be kept running through the trough or raceway to remove wastes, which otherwise would be harmful to fish. However, a continuous water supply for fish culture may not be available, or the economic utilization of water and nutrients in water may demand that the water not be wasted. Thus it is desirable to have some means to reduce the organic matter and oxygen demand while retaining most of the water. Circulating the water through a biofilter seems to be a promising method.

In a biofilter, or trickling filter, the water is intermittently sprayed over gravel that is coated with a living film of aerobic microorganisms actively feeding upon and oxidizing the organic matter in the water. Oxygen is readily available in the filter for rapid and extensive oxidation. Green *et al.* (1965) obtained a removal of 49-95 per cent of organic matter and 40 per cent of ammonia at 20° and 30°C. by trickling water through a biofilter using stainless steel screens in place of gravel.

The experiment presented here was conducted to determine the effect on water quality and fish production of recirculating through a biofilter water from aquaria in which goldfish (*Carassius auratus* Linneaus) were being raised.

MATERIALS AND METHODS

Four groups of two aquaria each were set up. Each aquarium contained 48 liters. All aquaria were given the same aeration and lighting and were maintained at the same temperature.

Group 1 was the control. Each aquarium was fertilized with 50 g. of Auburn No. 2 fish feed (Prather, 1958) and one liter of liquid medium for algae culture (Umbreit *et al.*, 1957) and was seeded with water collected from various sources to aid in establishment of microorganisms. Water from these aquaria was not filtered.

Each aquarium in Groups 2 and 3 received the same treatment as those in Group 1, but they were also provided with a biofilter consisting of a 39 cm. diameter bucket with a perforated bottom filled 35 cm. deep with washed gravel 0.5 to five cm. in diameter. A two-cm. layer of activated charcoal was spread on top of the gravel.

Water flowed from each aquarium through a series of three 300 ml. bottles that acted as settling tanks. It was then lifted by an air lift pump and sprayed over the filter from whence it drained back to the aquarium (See Figure 1). A six-liter-per-hour flow was maintained.

Each aquarium in Group 3 also received 50 g. of powdered $CaCO_3$.

Groups 1, 2, and 3 were filled and the filters of Groups 2 and 3 were operated for 28 days before the fish were stocked to give the microorganisms time to become established in the aquaria and filters.

The aquaria of Group 4 were filled just prior to stocking the fish. The water was changed twice daily, morning and evening, to simulate a running-water environment, but was not filtered. About 90 per cent of the water was replaced at each change.

Samples for chemical analyses were taken periodically before and after the fish were stocked. The water was analyzed for pH, dissolved oxygen, organic matter, ammonium nitrogen, organic nitrogen and nitrate plus nitrite. The pH was measured with a Photovolt model-126 pH meter with glass electrodes. Oxygen determinations were made by the syringe microdetermination of the Alsterberg modification of the Winkler method (Burke, 1962). The Maciolek modification of dichro-

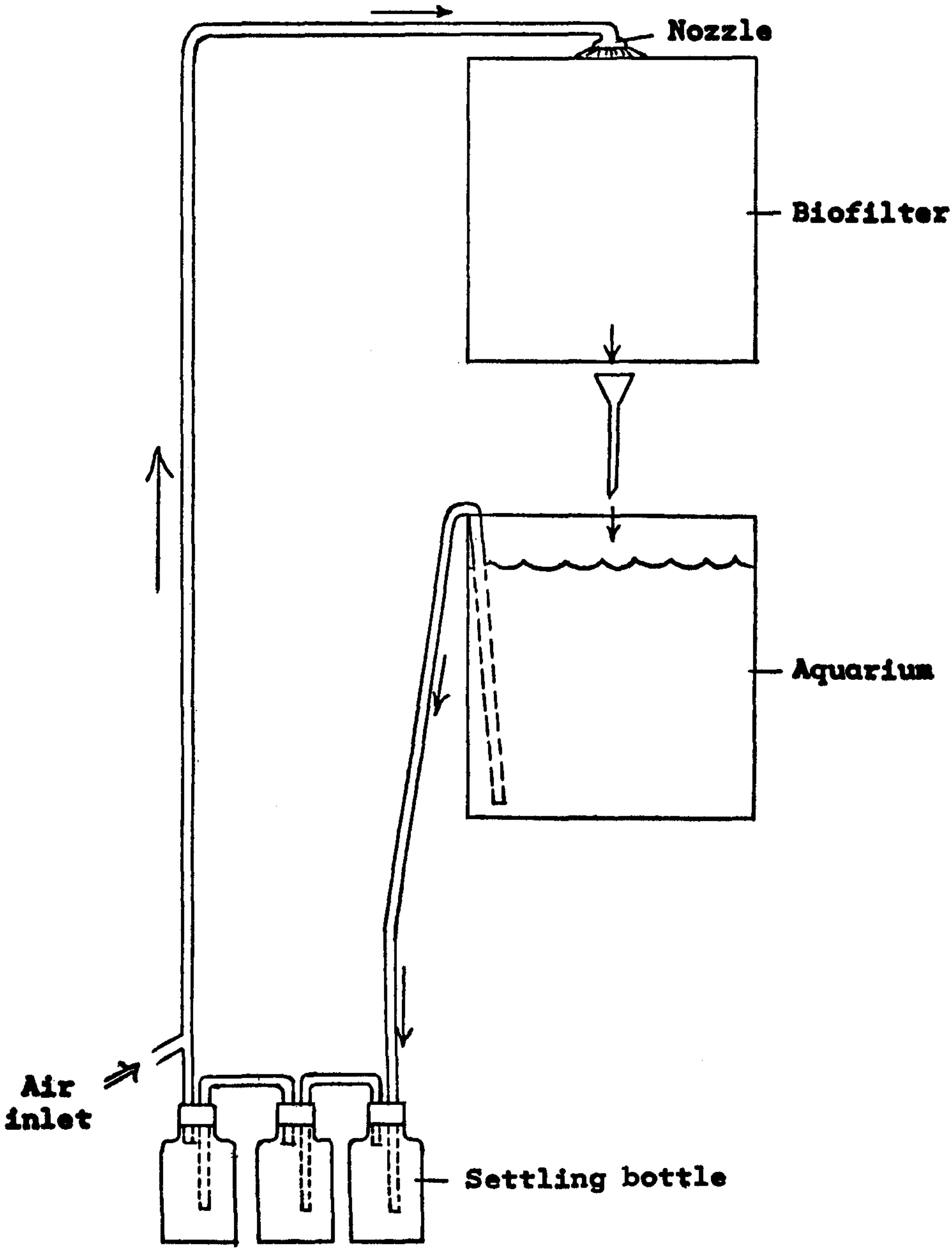


Fig. 1 Diagram of Biofilter Set-up.

mate oxidation was used to determine organic matter (Maciolek, 1962). Ammonium nitrogen was determined by distillation and Nesslerization; organic nitrogen by Kjeldahl digestion; and oxidized nitrogen as nitrate plus nitrite by the phenoldisulfonic acid method (American Public Health Association, 1965).

Each aquarium was stocked with five goldfish, each weighing about 56 g. and totaling 280 g.

The fish were fed Clark's New Age Complete Regular Trout Feed (J. R. Clark Co., 1674 Beck Street, Salt Lake City, Utah) for 36 days. Eight g. per aquarium per day (about 2.5 per cent of fish body weight) were fed for the first five days, then the rate was adjusted to 12 g. per aquarium per day (about four per cent of body weight) for the following four days and 16 g. per aquarium per day (about five per cent of body weight) for the next four days. However, at this latter rate, a condition of over-feeding was found; therefore, the feeding rate was reduced to 12 g. per aquarium per day for the remainder of the experiment. The daily ration was fed in four equal portions.

The fish were weighed periodically during the experiment.

The chemical data were analyzed with the aid of the "Student's t- distribution" (Snedecor, 1959). The comparisons of water quality within the recirculating systems were analyzed by means of factorial arrangements of treatments (Snedecor, 1959).

WATER QUALITY COMPARISON BETWEEN TREATMENTS

Figures 2 through 6 show the changes in water quality during the experiment.

The water of Groups 1, 2, and 3 at the time the fish were stocked contained similar amounts of oxygen and waste products. Group 4, which was started at stocking, contained more oxygen and essentially no waste products.

As expected, the organic matter, organic nitrogen, and ammonia increased and the oxygen decreased in all aquaria as the experiment proceeded. The water quality in Group 1, the control with no filter, deteriorated rapidly. By the 10th day, in spite of constant aeration, the oxygen was below two ppm and the ammonia near 28 ppm. Fish began to die on the 10th day and all had died by the 12th day. In Group 4, with water changes, the oxygen decreased and the wastes increased, but the oxygen remained higher and the wastes lower than in the others. Groups 2 and 3, with filters, will be considered together since the only effect of the lime appeared to be to slightly increase the pH of the limed aquaria. In these groups the organic matter, organic nitrogen, and ammonia increased rapidly at first, but leveled off about the 15th to the 20th day. The oxygen decreased as the organic wastes increased, and showed a tendency to rise after the 28th day when the organic wastes were decreasing.

The usual pathway for the decomposition of organic nitrogen in the purification of water is from organic nitrogen through ammonia, nitrite, and nitrate to nitrogen. Thus nitrite and nitrate concentrations are indicators of mineralization or purification in progress, but do not build up to the same extent as ammonia or organic nitrogen. In Group 1, with no filter, the nitrate plus nitrite remained at a minimal level indicating little or no purification. The low level in Group 4 is attributed to removal of nitrates and nitrites by the water changes, as well as removal of ammonia from which they were made. The increases in the water of the two filtered groups were indications of the mineralization going on in the filters.

The pH ranged between 6.8 and 7.8 during the entire experiment, with the limed group remaining higher than the others. The temperature ranged from 21.5° to 26°C. during the experiment with the mean of each group being close to 24°C.

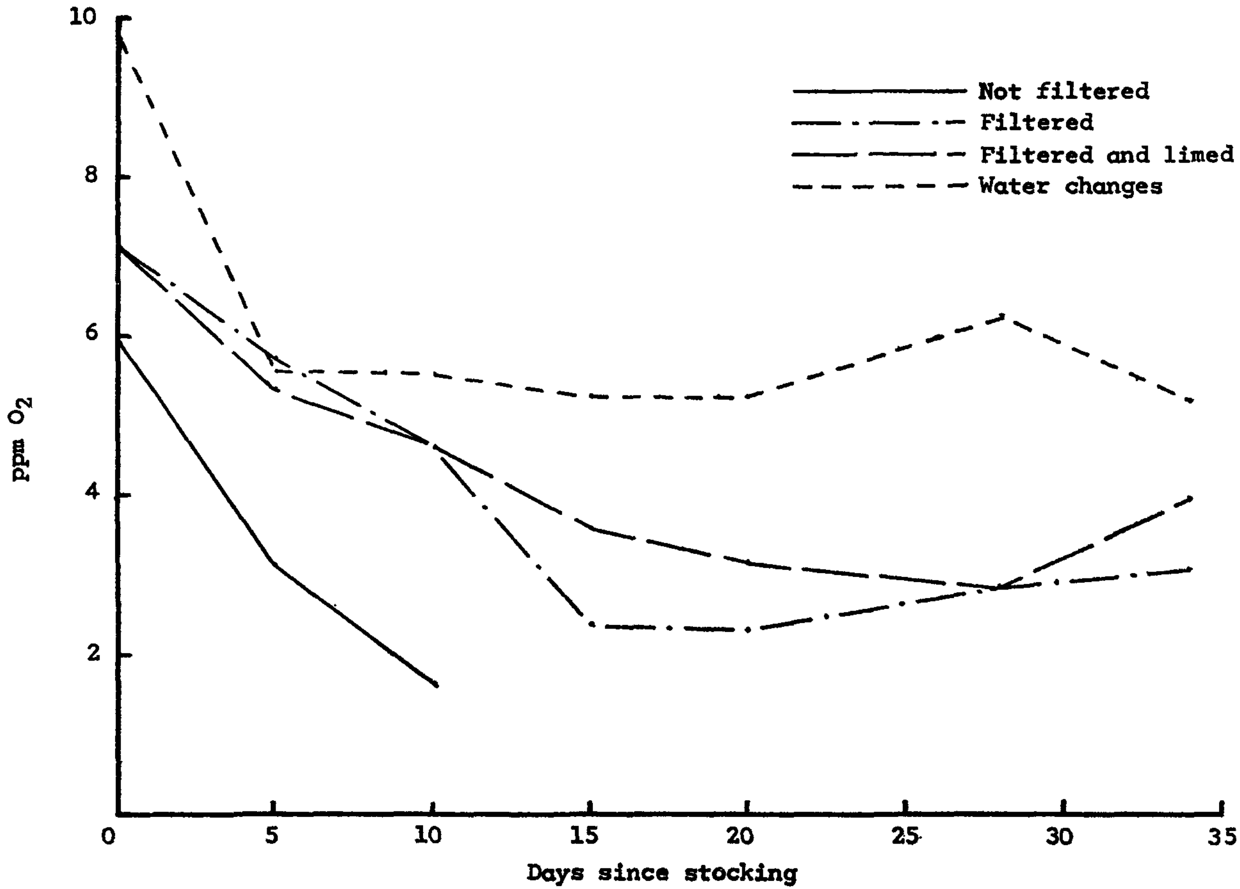


Fig. 2 Dissolved Oxygen in Aquaria with Filtration, No Filtration and Twice Daily Water Changes.

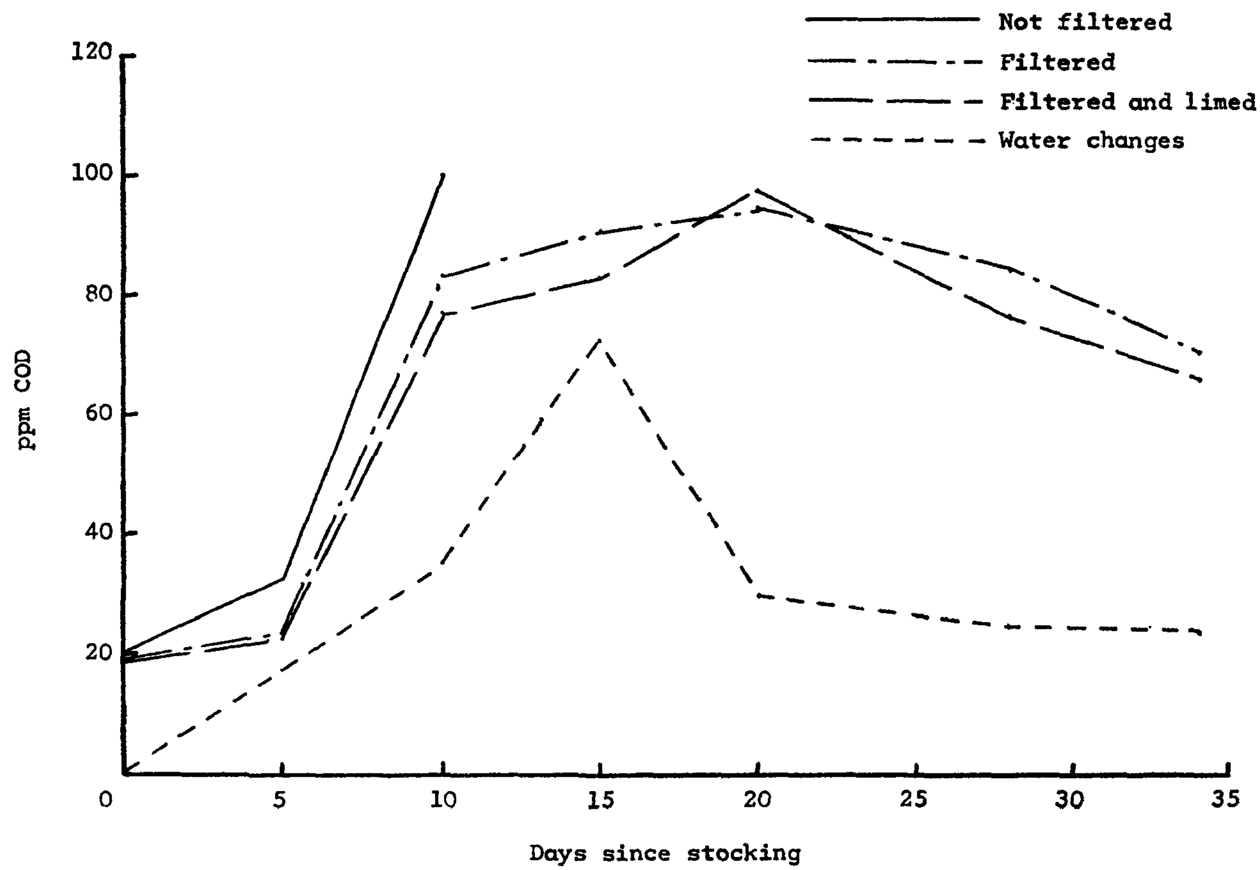


Fig. 3 Organic Matter Changes in Aquaria with Filtration, No Filtration and Twice Daily Water Changes.

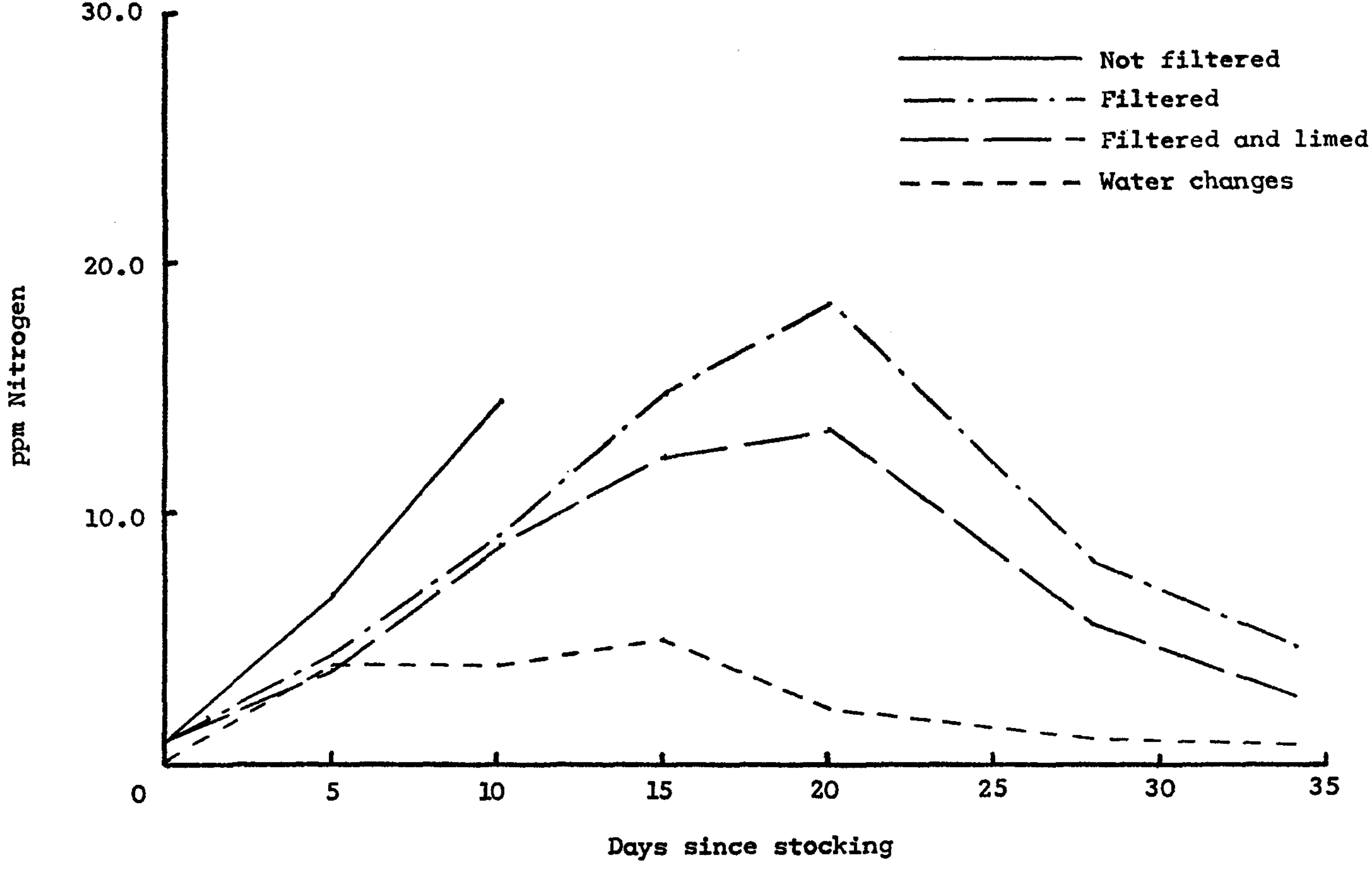


Fig. 4 Organic Nitrogen Changes in Aquaria with Filtration, No Filtration and Twice Daily Water Changes

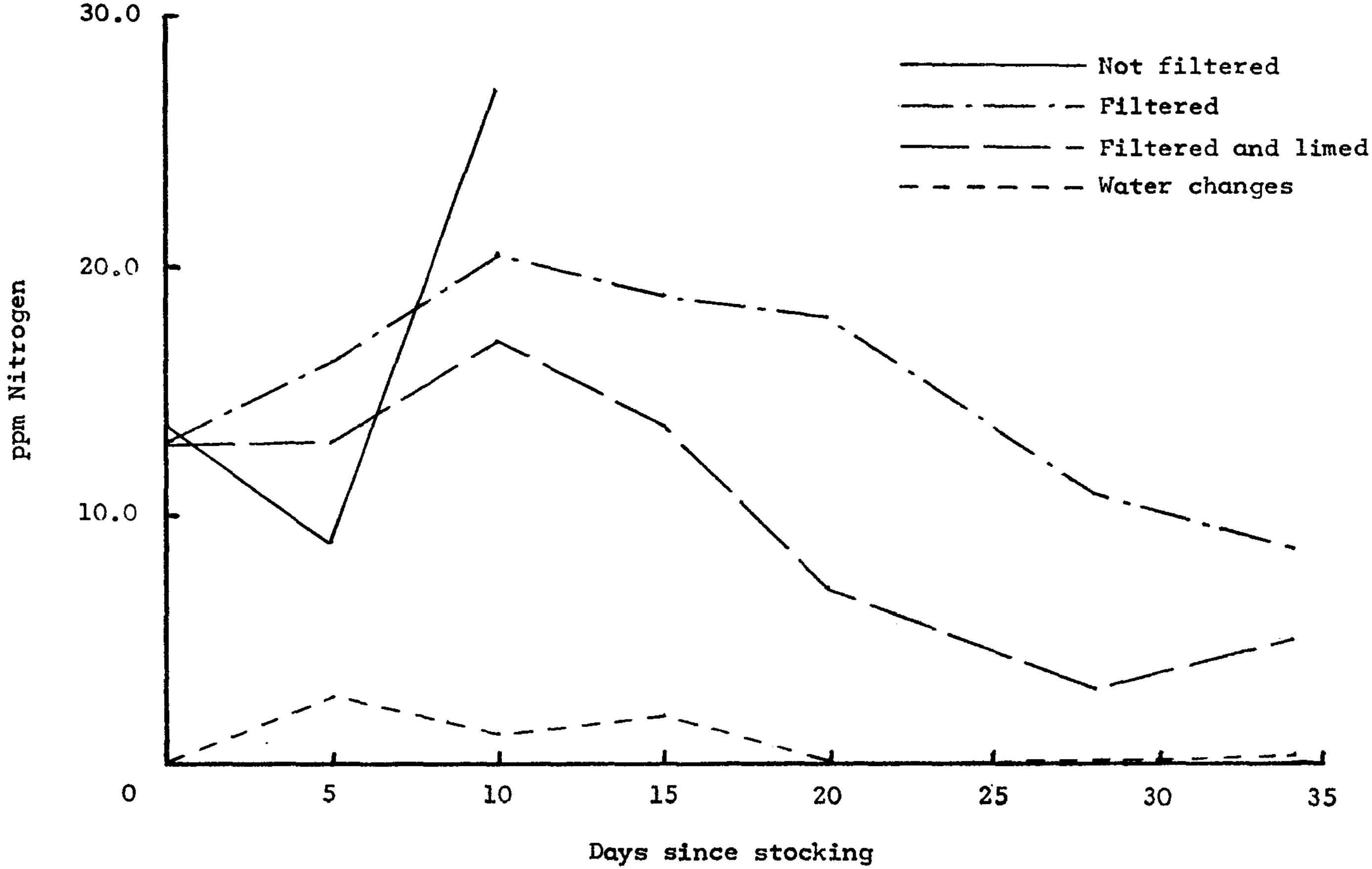


Fig. 5 Ammonia in Aquaria with Filtration, No Filtration and Twice Daily Water Changes

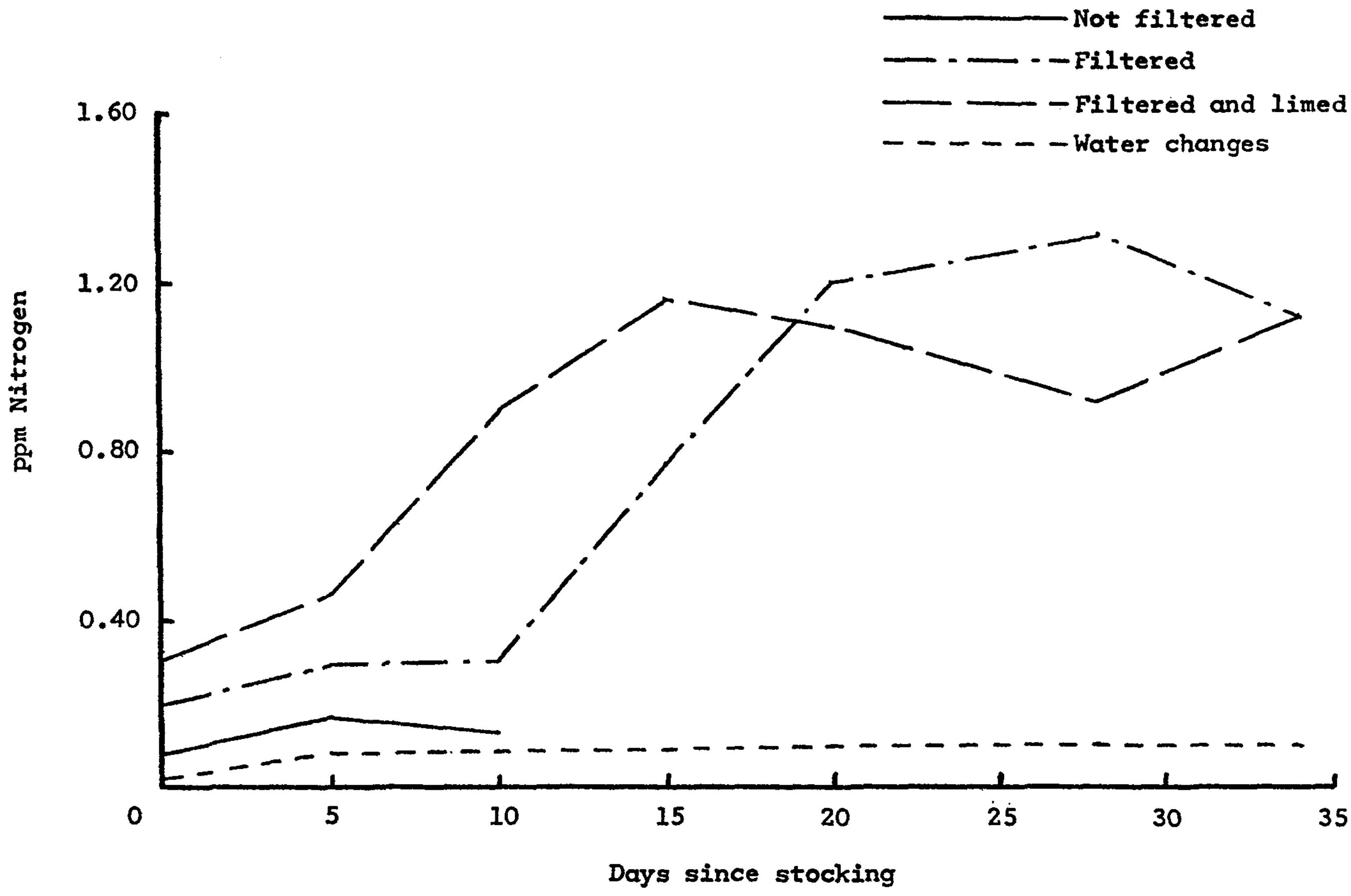


Fig. 6 Nitrate plus Nitrite in Aquaria with Filtration, No Filtration and Twice Daily Water Changes

GROWTH OF FISH

Figure 7 shows growth of the fish in the four groups. The stocking weight in each aquarium was approximately 280 g. All fish grew well the first five days. The growth rate of the control fish had decreased by the 10th day in response to the deteriorating water quality. The fish died between the 10th and 12th days. The mean weight of fish in both filtered groups was 382 g. by the end of the experiment. The mean growth rate was about 1.1 per cent of the original weight per day. The decrease in growth between the 10th and 20th days experienced by the fish in both filtered groups resulted from deterioration in the water quality caused by over-feeding on the 10th through 13th days. As the water quality improved after the over-feeding, growth resumed so that by the end of the experiment fish in the filtered water had almost caught up with those in the water changes group.

FOOD CONVERSION

During the experiment 418 g. of feed were added to each aquarium. The mean weight gain of the two filtered groups was 102 g., making a conversion of 4.1 g. of feed per g. of fish. The water changes group gained 114 g., making a conversion of 3.7. These conversions could have been improved if (1) a lower stocking rate had been used so that less food would have gone for maintenance, and (2) over-feeding and consequent cessation of growth and waste of food had not occurred.

While it may not be appropriate to scale up this experiment to pond size, it is nevertheless informative to do so. The stocking rate was equivalent to 13,450 lb. per acre and the final weight in the filtered aquaria was equivalent to 18,330 lb. per acre. The feeding rate of 12 g. per aquarium per day was equivalent to 575 lb. per acre per day. This stocking rate and feeding rate is much higher than can be maintained in a standing water situation. This is illustrated by the fact that the fish in the control aquaria died within 12 days.

SUMMARY AND CONCLUSIONS

Circulation of the water from aquaria through a biofilter reduced the concentration of organic wastes from the feed and fish and increased the oxygen when compared with similar aquaria without filtration.

The aquaria in which the water was changed twice daily contained the fewest wastes and the most oxygen.

At the stocking rate used, fish died within 12 days in aquaria without filtration, but lived and grew well in aquaria with filtration and aquaria with water changes.

When stocked at 280 g. per aquarium (equivalent to 13,450 lb. per acre) and fed at rates diminishing from 4.0 to 3.1 per cent of the body weight per day, the fish grew an average of 1.1 per cent per day. This growth was not significantly different from the growth in the aquaria with water changes.

The mean conversion factor for the filtered groups was 4.1, and it was 3.7 for the water changes group.

LITERATURE CITED

American Public Health Association. 1965. Standard methods for the examination of water and wastewater including bottom sediments and sludge. New York.

Burk, J. D. 1962. Determination of oxygen in water using a 10-ml. syringe. J. Elisha Mitchell Sci., 78(2):145-147.

Green, M. B., B. E. Cooper and S. H. Jenkins. 1965. The growth of microbial film on vertical screens dosed with settled sewage. Int. J. Air Wat. Pollu., Pergamon Press, 9:807-821.

Lin, S. Y. 1949. Pond culture of warm water fishes. UNESCO Conference, Warm Springs.

Maciolek, J. A. 1962. Limnological organic analyses by quantitative

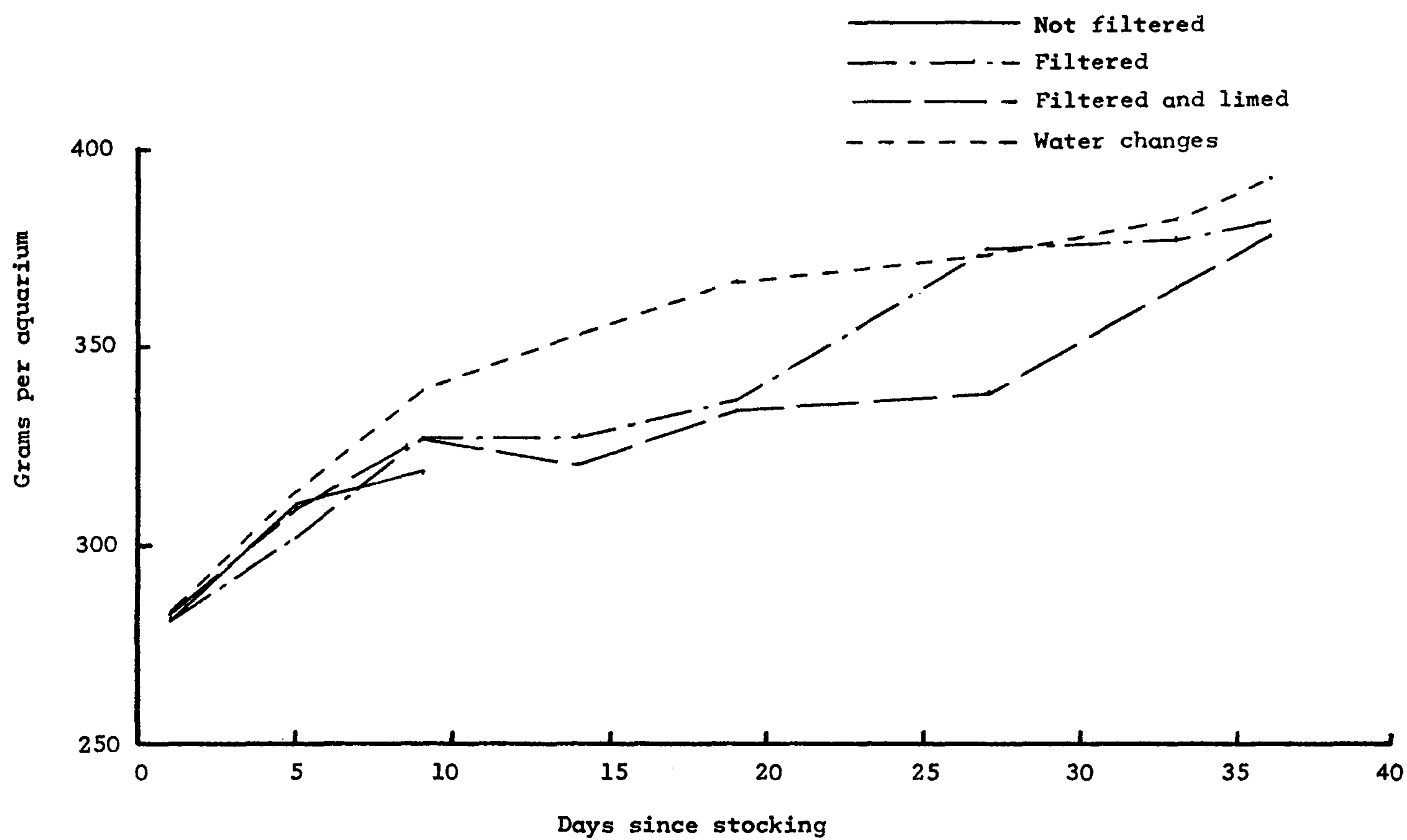


Fig. 7 Growth of Fish in Aquaria with Filtration, No Filtration and Twice Daily Water Changes

dichromate oxidation. U. S. Fish Wildl. Ser. Bur., Sportfish Wildl. Res. Report 60.

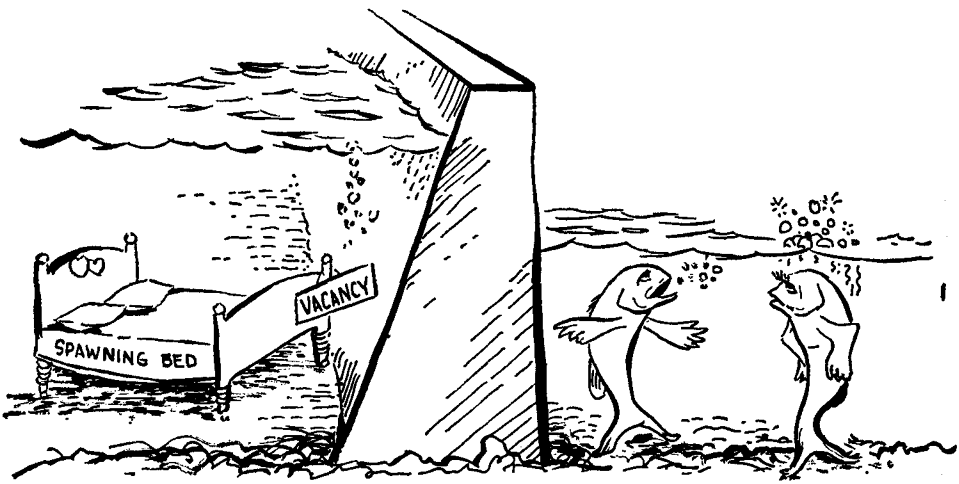
Prather, E. E. 1958. Further experiments on feeds for fathead minnows. Proc. Ann. Conf. Southeastern Assoc. of Game and Fish Commrs. 12:176-178.

———— and H. S. Swingle. 1960. Preliminary results on the production and spawning of white catfish in ponds. Proc. 14th Ann. Conf., Southeast Assoc. Game and Fish Comm., Biloxi, Miss.

Snedecor, G. W. 1959. Statistical methods. Iowa State College Press, Ames, Iowa.

Tiemeier, O. W. 1962. Supplemental feeding of fingerling channel catfish. Prog. Fish-Cult., 24(2):88-90.

Umbreit, W. W., R. H. Burris and J. F. Stauffer. 1957. Manometric techniques. Burgess Publishing Co., Minneapolis, Minn.



A "FISH LOK" FOR PASSING FISHES THROUGH SMALL IMPOUNDMENT STRUCTURES

W. Donald Baker
Division of Inland Fisheries
North Carolina Wildlife Resources Commission
Raleigh, North Carolina
— 1966 —

ABSTRACT

A method of locking fishes through a model representing a small impoundment structure was tested and found successful. Ten species of fishes were passed both upstream and downstream through two gates which were operated alternately and in such a manner as to provide attracting flows during the entire cycle.

INTRODUCTION

A major problem facing fishery scientists is that dams built to impound water also impound fishes from both sides of the structure. This problem is especially critical where the spawning runs of anadromous species are concerned. Flood control, power, water supply, and