Proceedings of the Iowa Academy of Science

Volume 77 | Annual Issue Article 16

1970

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John L. Konefes
Iowa State University

Roger W. Bachmann
Iowa State University

Recommended Citation

Konefes, John L. and Bachmann, Roger W. (1970) "Growth of the Fathead Minnow (Pimephales promelas) in Tertiary Treatment Ponds," *Proceedings of the Iowa Academy of Science, 77(1),* 104-111.
Available at: https://scholarworks.uni.edu/pias/vol77/iss1/16

Growth of the Fathead Minnow *(Pimephales promelas)* in Tertiary Treatment Ponds[1]

JOHN L. KONEFES[2] and ROGER W. BACHMANN[3]

Abstract. A series of experimental ponds, utilizing treated sewage effluent as a water source, have been constructed at the Ames Water Pollution Control Plant. Fathead minnow fry were introduced into the ponds in the summer of 1969 and observations were made on their growth rates, reproduction, and food habits during the summer months. Growth was comparable to that previously reported for hatchery ponds. The fish matured by mid-summer and successfully produced a second crop of fry. The use of tertiary ponds for fish production seems to be a useful approach to the conservation of natural resources.

The Ames Water Pollution Control Plant is typical of many municipal sewage treatment plants in Iowa. Through the use of primary and secondary treatment (trickling filters), a large fraction of the total organic load is removed before the effluent is released into the Skunk River. The treated effluent, however, still contains high concentrations of plant nutrients, such as nitrates, ammonia and phosphorus, which can cause unwanted algal blooms in the river or downstream reservoirs. As an experiment in nutrient removal, a small pond was constructed at the plant in 1966, and a portion of the effluent was pumped through it before final release. Raschke (1968) studied the algal dynamics of this pond and found that high algal populations effectively removed significant amounts of plant nutrients during the summer months. In 1967, a series of four additional tertiary ponds were constructed, and Huggins (1969) demonstrated that these highly productive aquatic ecosystems could be used successfully for the production of channel catfish.

In the summer of 1969, we established a study to determine if these ponds could also be used for the production of bait minnows. The fathead minnow (*Pimephales promelas*) was chosen because it is one of the most commonly raised minnows and is well adapted for cultural purposes (Dobie et al. 1956). We also obtained information on limnological conditions in the pond during the study.

METHODS

Our study was centered on tertiary Pond V at the Ames Water

[1] Journal Paper No. J-6575 of the Iowa Agriculture and Home Economics Experiment Station, Ames, Iowa. Project No. 1779. This project was a part of the Undergraduate Research Participation Program sponsored by the National Science Foundation (NSF-GY-6158).

[2] Undergraduate student, Iowa State University, Ames.

[3] Associate Professor, Iowa State University, Ames.

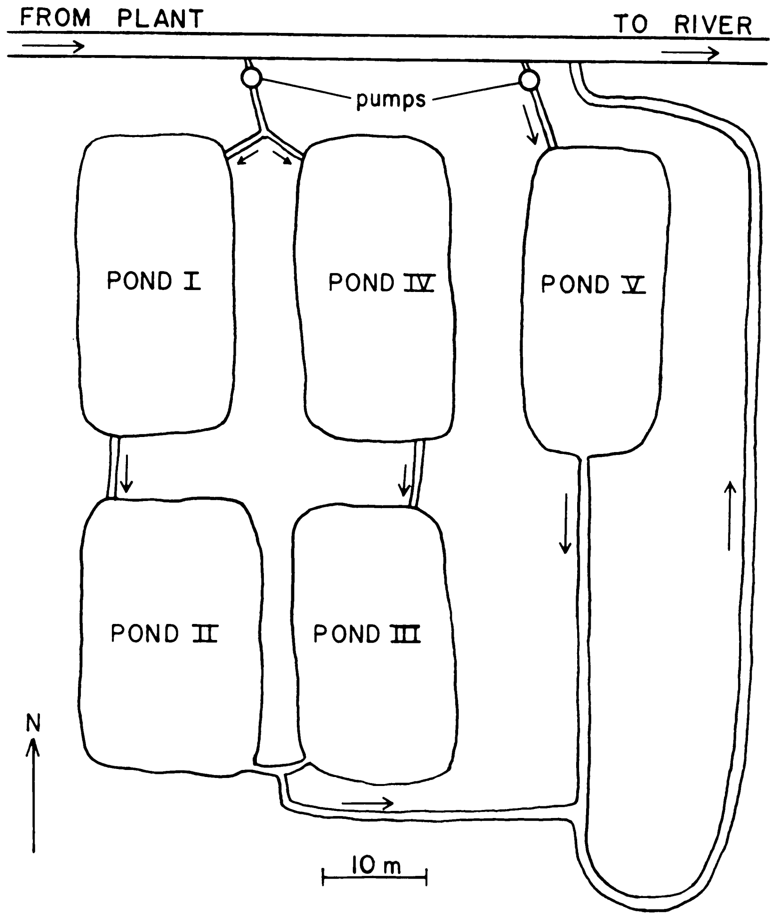

Figure 1. Diagram of tertiary ponds system at Ames, Iowa. Arrows indicate diection of water flow.

Pollution Control Plant (Fig. 1). The pond has a surface area of 494 m^2, a volume of 327 m^3, and a mean depth of 0.66 m. The inflow was treated effluent from the Ames plant pumped in at the rate of 98 m^3 per day so that the turnover time would be about 3.3 days. Actually, seepage and evaporation were significcant, so that during dry periods of the summer, no outflow was noted. The overflow ran into a surface channel that led the water back to the effluent conduit to the Skunk River. A separate pump supplied water to the other four ponds, run as two pairs during 1969 with their overflow running into the same outlet channel as Pond V. Although these four ponds were not originally included in our study, they were added when some of the fish escaped into them through the outlet channel system.

At the time this experiment was being conducted, a small group of water hyacinth plants (*Eichornia crassipes*) were stocked in Pond V by another investigator. By mid-August they covered one half the surface of the pond and probably influenced some of the limnological parameters.

On June 11, 1969, fathead minnows were seined from a pond located in Backbone State Park, Delaware Co. They had been produced from eggs laid earlier in the spring. About 3800 were released into Pond V on the same day. A random sample of 100 was weighed and measured. They had an average length of 18.6 mm and an average weight of 0.04 grams.

A sample of 50 fish was taken from Pond V every two weeks, with the last sample made on August 20, 1969. Collections were made with minnow seines, tow nets, and minnow traps. Average weights and lengths were determined, and on June 25, July 11, and July 29 the stomachs of five fish were examined under a dissecting microscope to determine food habits. Water samples for plankton chlorophyll were taken in open water with a glass jar dipped 5 cm below the water surface. A known volume was filtered through a Gelman type AA glass fiber filter. The filter was stored over a desiccant in a freezer, until the extraction could be made. The filter was ground for one minute in a tissue-grinding tube with 90% acetone and 0.1 g of magnesium carbonate. The volume was made up to 7 ml, and the suspension was centrifuged to remove the particulate materials. Optical density readings were made in a Beckman DU-2 spectrophotometer at wavelengths of 630, 645, 665, and 750 nanometers. Chlorophyll was calculated by using the method of Parsons and Strickland (1963).

Zooplankton were sampled with a plastic tube, 37 mm in diameter and 91 cm in length, pushed down through the water and into the sediments. A rubber stopper was inserted into the upper end. the tube was removed from the pond, and the water was filtered through No. 25 silk bolting cloth. The tube was rinsed with tap water, and the washings were also filtered through the bolting cloth. The organisms were preserved in 70% ethanol until they were counted.

Water samples for nutrient analyses were taken by immersing a BOD bottle approximately 5 cm below the surface of the pond near the outlet. The samples were taken to the laboratory immediately and analyzed for ammonia, nitrite and nitrate nitrogen, and orthophosphate. The methods and reagents are those described in Catalog No. 10, second revised, edition of the Hach Chemical Co. (Ames, Iowa).

Water samples for dissolved oxygen were taken with a Van Dorn water bottle between 9 and 10 AM. On each sampling day, one sample was taken near the surface and one near the bottom. The first two Winkler reagents were added in the field, with the sulfuric acid being added in the laboratory just before titration.

Water temperatures were taken with a Whitney resistance thermometer. Readings were made in the morning at the surface and at the bottom of the pond.

RESULTS

During the study, measurements of the surface temperature varied from 17.3 C (June 17) to 25.7 C (July 13). The average for the surface was 22.9 C and for the bottom water was 22.4 C. Since these are morning temperatures, they underestimate the true average temperature and obscure the temporary stratifications built up during the heat of the day. This stratification is more evident from the dissolved oxygen data which showed a surface average of 4.11 mg/liter and an average in the bottom waters of 2.89 mg/liter.

The concentrations of plant nutrients illustrated the potential for high biological productivity in such ponds. Orthophosphate phosphorus averaged 18.6 mg/liter, while nitrogen averaged 4.2 mg/liter in ammonia, 0.3 mg/liter in nitrites, and 1.3 mg/liter in nitrates. These concentrations are well above the levels thought necessary for maintaining algal blooms.

The pond did not maintain a continuous algal bloom. The chlorophyll concentrations illustrated in Figure 2 show relatively low levels in June, with rising levels in July, reaching a peak on July 8, followed by a decline into August. Similar fluctuations had been noted by Raschke (1968) in his study of this pond and by Huggins (1969) in his study of the series of four ponds. There has been no satisfactory explanation for this phenomenon. Huggins suggested that zooplankton grazing may play a role in holding down algal populations. We found total zooplankton densities (in numbers of individuals /liter) of 450 on June 16 and 1306 on June 26. On July 7, 15, 22, and 29, no individuals were found in the samples. The population then rose to 23 /liter on July 31, 432 on August 7, and 106 on August 14. This inverse relationship between zooplankton and phytoplankton supports, but does not prove Huggins' hypothesis. The expanding water hyacinth population that covered half the pond surface by mid-August and the entire pond by October may have been another contributing factor in our study. This, however, would not account for the low values in June. More study is needed on this aspect of the tertiary pond ecology.

The dynamic response of various parameters to the mid-July bloom is illustrated in Figure 2. Dissolved oxygen levels rose as the photosynthetic capacity of the pond was increased. At the same time orthophosphate levels dropped as did levels of the ammonia nitrogen, presumably through algal uptake and assimilation as well

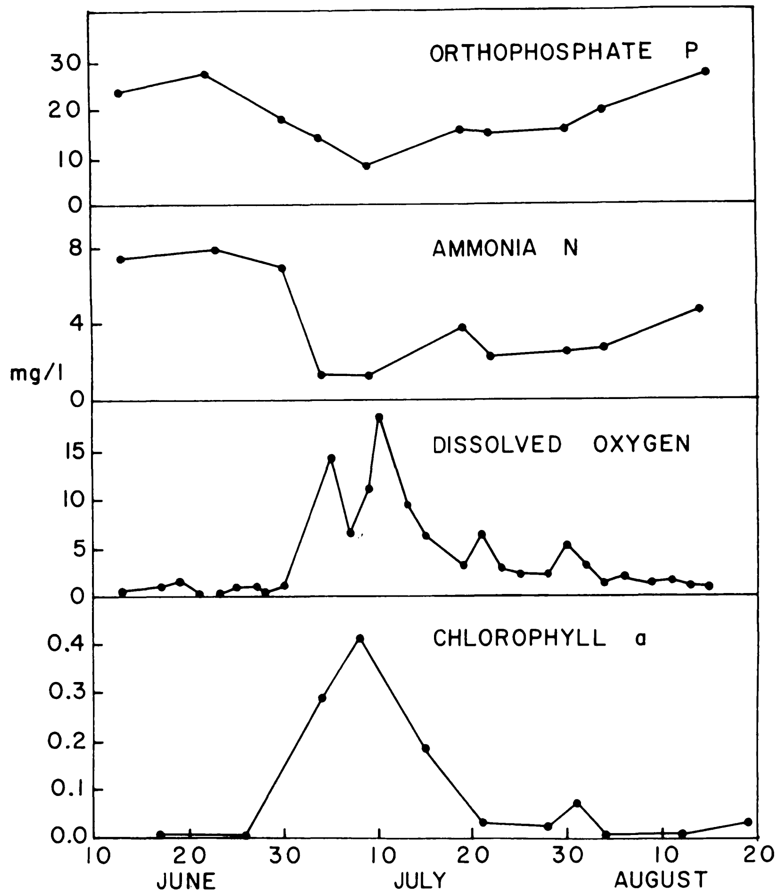

Figure 2. Pond V concentrations of chlorophyll a, surface dissolved oxygen, ammonia nitrogen, and orthophosphate phosphorus in mg /*l* for the summer of 1969.

as possible nitrification of the ammonia in the presence of high levels of dissolved oxygen. Huggins (1969) found similar changes related to increases in algal densities.

The growth in length of the fathead minnows is illustrated in Figure 3. They followed a sigmoid-shaped curve and reached an average length of 57.6 mm by August 20. For comparison, a typical growth curve for fathead minnows in hatchery ponds (Dobie et al. 1956) between the ages of 40 and 120 days is plotted on the same graph. Although the shapes of the curves are somewhat different, the initial and final lengths are almost the same. The growth rate in tertiary ponds seems suitable for raising fathead minnows.

Because the water hyacinth experiment was conducted at the same time, it was not possible to drain the pond to make a complete

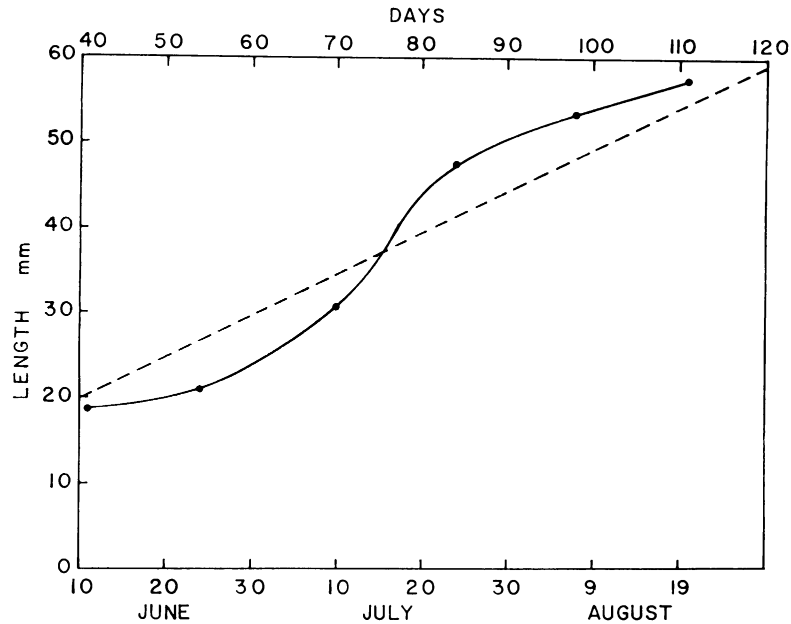

Figure 3. Solid line represents the average length of fathead minnows in Pond V during the summer of 1969. The dashed line represented the typical values of lengths of pond-reared fathead minnows between 40 and 120 days of age (Dobie et al. 1956).

population estimate. Even if we had made such an estimate, the survival rate would have been too low, since we observed that some fish had migrated into ponds II and III. This was first noted on July 10. Samples were taken in the ponds on August 16 and 18. The average lengths were 59.4 mm for pond II and 64.1 mm for pond III. These are slightly larger than the 57.6 mm average for Pond V found on August 20. This is not surprising because of the low dissolved oxygen levels in Pond V combined with relatively high levels of ammonia. Huggins (1969) found that if several ponds were arranged in a series, the water quality progressively improved throughout the series and that channel catfish growth and survival showed parallel improvements.

The stomach contents of five fish from Pond V were examined on each of three dates. On June 25, the stomachs contained primarily the remains of chironomid larvae. Daphnia were noted in two stomachs, but formed only a small fraction of the contents. On July 11, the two smallest fish had eaten a few chironomids, but their stomachs were filled mostly with algae. The three other fish had eaten chironomids in greater quantities, the largest fish having large numbers of them. All the stomachs of fish caught on July 29 contained chironomid larvae, although not as many as in the two previous samplings. Copepods formed a lesser part of the diet in two fish, while two other stomachs yielded the remains of small insects. Food habits probably were related to food availability. Burrage (1961) found that captive fathead minnows preferred cladocerans and copepods to chironomids, but Starrett (1948) reported only bottom ooze and small dipterous larvae in the stomachs of fathead minnows taken from the Des Moines River, Iowa.

Males in spawning condition were noted in ponds II, III, and V in early August, and fry were later noted in the ponds. Spawning of young- of-the-year fathead minnows has been reported previously (Dobie et al. 1956). To estimate spawing success, one haul was made with a 12-foot minnow seine in Pond IV in October. About 1675 individuals were obtained. The length frequency distribution of 365 of those sampled is given in Figure 4. Judging from the growth curve for the fish originally stocked (Fig. 3), the 16 individuals more than 65 mm long probably represent the original fish, and the remainder represent fish hatched during the summer. Spawning was evidently highly successful.

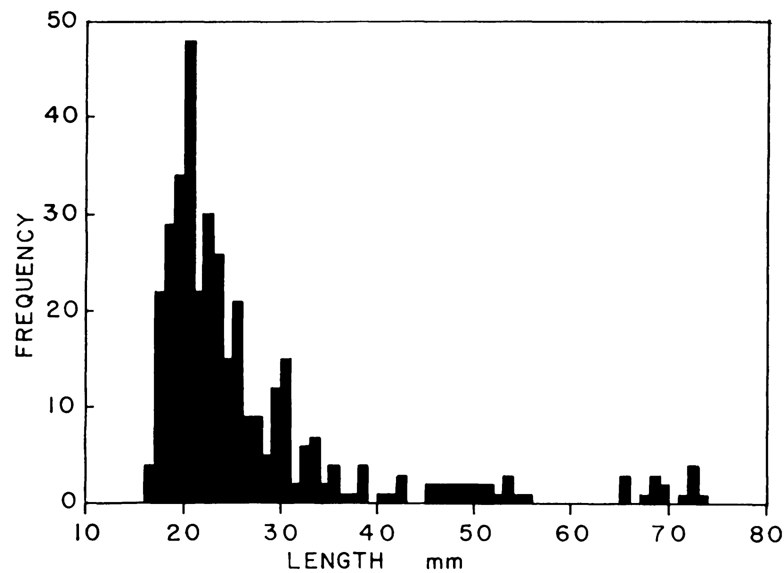

Figure 4. Length frequency distribution of 365 fathead minnows seined from Pond IV in October, 1969.

Discussion

The use of tertiary ponds for fish production seems to be an approach toward both environmental preservation and conservation of natural resources. The plant nutrients present in the effluent from conventional municipal sewage treatment plants lead to the degradation of aquatic environments through the acceleration of eutrophication while, at the same time, fish culturists purchase chemical fertilizers containing the same elements and disperse them in their ponds to increase productivity. The tertiary pond approach might lead to a reduction in the nutrient contribution of municipal plants and also help conserve mineral resources. This study demonstrated that in the Ames ponds the fathead minnow will successfully grow and reproduce during the summer months. Since they are a popular bait fish with a ready market, their production might be used to help offset the costs of construction and maintainence of the ponds.

ACKNOWLEDGEMENTS

We wish to thank the City of Ames and Dr. Harris Seidel, Director of Water Pollution Control, for their cooperation in making the pond systems available. The Iowa Conservation Commission assisted by providing the fish used in this study.

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