

1983

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Recommended Citation

Murnyak, M. O., & Murnyak, D. F. (1983). Fish Culture in Minnesota Farm Ponds. *Journal of the Minnesota Academy of Science*, Vol. 49 No.1, 3-6.

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Fish Culture in Minnesota Farm Ponds

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ABSTRACT — This paper presents the results of a three year research and extension project in fish farming in central Minnesota. Fifty-seven farm ponds were stocked with one or more of the following species: channel catfish, largemouth bass, rainbow trout, yellow bullheads, bluegill sunfish, and black crappie. Several stocking densities with and without supplemental feeding were tested. The results indicate that when intensively managed, ponds over 0.05 hectare in size and 1 meter in depth are suitable for the production of food fish. Production of harvestable-size fish is possible during a single season when large fingerlings are stocked in early spring. Trout and catfish demonstrated the highest growth rates. Average yields for different production methods ranged from 18 to 356 kg/ha in warm-water ponds and 114 to 880 kg/ha in cold-water ponds. Fish yields were higher in ponds with supplemental feeding than without feeding. Several harvesting methods were tested and analyzed for efficiency. The findings indicate the importance of proper site selection and pond design for the success of an aquaculture operation. Economic analysis revealed the profitability of trout culture, and relatively high production costs for warm water species. Ways to reduce these costs are suggested.

INTRODUCTION

Aquaculture, the cultivation of aquatic plants and animals under controlled conditions, is becoming increasingly important as a method of food production in the United States today. Farmers are attracted to fish culture because of the high yields possible and the chance to utilize areas unsuitable for traditional crops. Rapid growth in the U.S. catfish and trout farming industries has occurred during the last 20 years, particularly in the Southeast and Pacific Northwest. A recent study in Mississippi indicated that catfish provided the highest financial return per hectare of any agricultural crop in the state (1). Ongoing research and extension programs in this area have contributed substantially to this development.

In the Midwest, the concept of raising fish for food is relatively new (2). Natural lakes in Minnesota have traditionally provided excellent sport fishing opportunities; consequently, the culture of fish in private ponds has received little attention. Climatic conditions such as short growing season, cool water temperatures and severe winters have also deterred aquacultural development in the state (3).

Yet a great need exists to increase the production of food fish for both home and commercial use. According to Minnesota Department of Natural Resources (DNR) statistics, most of the state's 5,000,000 kg annual commercial fish catch is considered "rough fish" (e.g. carp and bullheads) and is shipped out of state (Floyd Hennagir, personal communication). Virtually all of the commercial fish products consumed in the state must be imported. Nationally, fish products constitute the second largest U.S. import in dollars, behind petroleum products (1). With a decline in natural stocks and commercial fisheries because of factors such as overfishing and pollution, there is an increasing need to look for new sources of fishery products.

Minnesota's vast water resources provide great potential for aquacultural development. However, the biological, technical and economic aspects of fish farming must be studied and evaluated before fish farming can become widely practiced in the state.

This paper describes a fish farming research and extension program conducted from 1979 to 1982 through Wright County Community Action of Waverly, Minnesota. Project objectives

were to assist farmers with stocking and raising fish in farm ponds, to monitor fish growth and yields, and to evaluate different management techniques for family and commercial use in the state.

MATERIALS AND METHODS

Fish stocking and management. Fish were stocked into 57 privately owned farm ponds located in seven counties in central Minnesota during the three year project. Study ponds ranged in size from 0.02 to 2.0 ha (\bar{x} = 0.12 ha), and in depth from 0.6 to 5.4 m (\bar{x} = 1.8 m). Ponds were sampled prior to stocking to determine the presence of wild fish; ponds found to contain wild fish (excluding minnows) were not used in the study.

Six species of fish were stocked into study ponds. Channel catfish (*Ictalurus punctatus*), largemouth bass (*Micropterus salmoides*), yellow bullheads (*I. natalis*) and rainbow trout (*Salmo gairdneri*) fingerlings were purchased from private hatcheries in Minnesota, Iowa and Wisconsin. Stunted bluegill sunfish (*Lepomis macrochirus*) and black crappie (*Pomoxis nigromaculatus*) were obtained with traps and seines from overcrowded public lakes in the Wright County area under a special research permit from the DNR. Some ponds were stocked with only one species of fish (monoculture), while in other ponds two or more species were stocked (polyculture).

Pond management guidelines were formulated by pond owners and project staff. Warm-water fish species (catfish, bluegill, bass, crappie and bullhead) were stocked into standing water ponds at densities ranging from 16 to 600 fish per hectare. In several ponds catfish and bluegills were raised in floating cages one cubic meter in size. Stocking densities ranged from 80 to 240 bluegills or 200 to 1000 catfish per cage. The cold-water species, trout, was stocked into ponds with a constant flow of water from a spring or well. Trout stocking densities were based on the volume of water flow, ranging from 1 to 4 fish/liters per second. Fish stocked at higher densities received a pelleted catfish or trout ration, while supplemental feeds were not used at low stocking densities (Table 1). The amount of feed used was 3 percent of the estimated total weight of fish in the pond.

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Table 1. Fish stocking densities and species combinations in study ponds.

Species	Density (fish/ha)		Polyculture species
	Without feeding	With feeding	
Channel catfish	350-500	1250-3375	Bluegill, bass or bullhead
Bluegill sunfish	1150-2325	1400-3750	Catfish, bass, crappie bullhead or trout
Black crappie	100	100-500	Bluegill
Yellow bullhead	165-250	1750	Catfish or bluegill
Largemouth bass	290-500	500	Catfish or bluegill
Rainbow trout	5000	3125-45,000	Bluegill

Pond owners and project staff recorded the number and weight of fish at stocking and harvest, weekly water temperatures and dissolved oxygen levels, weight of feed used, and amount of time and money spent on pond management. These data were used to analyze and evaluate the various production methods tested.

Fish harvests and yields. Warm-water fish were stocked in May and June and harvested between September and November. Except where aerators were used to prevent winterkill, total fish harvests were attempted after one growing season in warm-water ponds. In cold-water ponds trout were stocked in the spring or fall. Selective harvesting, removing only fish larger than a given size, began after three months and continued throughout the following year.

Fish were harvested with seines, hoop nets, trap nets, gill nets, lift nets, set lines, and hook and line. The efficiencies of different harvest methods were compared based on yields in ponds where total harvests were attempted after one season. Yields from ponds with low survival due to factors cited in the discussion have not been included in the analysis of harvest efficiency.

The results presented for fish growth and yields represent an average of production values from all ponds after a single growing season. The figures on trout growth are based on the average weight of fish sampled after one season, even though not all fish were harvested at that time. Bass and bullhead have been excluded from this analysis since a very limited number of trials were conducted with these species, and bass were not harvested until after a second growing season. A complete tabulation of yields for all ponds is presented in the project's final report (4).

Production costs. Production costs for catfish, bluegills and trout were calculated based on average costs and yields obtained from ponds where 50 percent or more of the fish were recovered at harvest. Crappies are excluded from this analysis because of low recovery rates at harvest. Documented costs included the price and delivery charge for fingerlings and feed, fee for a private fish hatchery license, rental charges for equipment based on cooperative use through a fish farmers association, electrical costs to run pumps and aerators, and labor costs for managing and harvesting fish ponds. Comparison of live weight and dressed weight of fish is based on a dress-out percentage of 75% for trout and 60% for catfish.

RESULTS AND DISCUSSION

Growth and yields. Good fish growth and survival were observed for single season production in ponds as small as 0.04 ha averaging 0.9 m or more in depth. Trout and catfish demonstrated the best growth, with a 483 percent and 280 percent

increase in weight, respectively, after one growing season (Table 2).

Catfish and trout growth rates were higher with supplemental feeding than without feeding. Conversely, the growth rates for bluegills and crappies were higher without feeding (Figure 1). These differences could reflect the different species ability to adapt to supplemental feeds. The hatchery-reared species, catfish and trout, were accustomed to supplemental feeds and readily accepted the pellets, while the fish obtained from the wild, bluegills and crappies, did not. These differences could also be attributed to hatchery selection for desirable characteristics (5).

Total yields of fish were generally higher in ponds with supplemental feeding than without feeding, and higher in polyculture than monoculture (Table 3). Higher yields reflect not only growth rates, but also higher stocking densities used in ponds with feeding and polyculture. Rainbow trout produced the highest yields (880 kg/ha). High trout stocking densities were possible with the constant supply of fresh water in these ponds. Since trout were not completely harvested at one time, total production was much higher than observed yields. The highest yields among warm water species were obtained with bluegills (119 kg/ha) in ponds without feeding, and catfish (254 kg/ha) in ponds with feeding.

While these yields are encouraging in Minnesota, where little work has been done with pond fish culture, they appear low when compared to production on commercial fish farms in the South, where yields over 1500 kg/ha are common (5, 6). Lower yields in Minnesota can be attributed to a shorter growing season resulting in smaller fish at harvest. Also, overall recovery of fish was poor; harvests averaged less than 50% of the number of fish stocked.

Poor fish survival was one cause of low recovery at harvest. Improper pond construction or poor management reduced fish survival through 1) flooding, which allowed fish to escape, 2) predation or competition from wild fish, 3) disease, or 4) summer-kill or winter-kill from low oxygen levels.

Low recovery also resulted from the use of inefficient harvesting techniques. Most study ponds had not been designed for

Table 2. Individual weights of fish at stocking and harvest after one growing season (3-5 months) in study ponds.

Species	Stocking weight(g)		Harvest weight(g)		Increase(%)
	Mean	Range	Mean	Range	
Catfish	50	35-85	190	55-450	280
Bluegill	65	30-85	120	55-280	85
Crappie	80	55-85	155	85-225	94
Trout	30	30-55	175	85-335	483

fish farming and were therefore difficult to harvest. The use of drainable ponds could have facilitated and improved fish recovery (7,8).

The efficiency of the harvest methods tested varied with species (Figure 2) and pond designs. Seining was effective for all species in ponds that had a smooth bottom and were not wider or deeper than the seine (4 m by 33 m). Fish traps and nets were used in ponds when seining proved ineffective. Bluegills and crappies were captured with hoop nets and trap nets. Catfish could not be captured with hoop nets, trap nets, gill nets, or lift nets. Some fish were caught with hook and line, but this could only be considered a technique for sampling rather than complete harvest.

Harvest efficiency was maximized with the use of cages, each of which could be completely harvested by two people in less than one hour. Good catfish growth and survival was observed in cages, and yields of 45 kg/m³ were obtained in one growing season. Slower growth and higher mortality rates of bluegills were observed with yields averaging 11 kg/m³. This appeared to result from aggressive territorial behavior of caged bluegills which prevented some fish access to the feed. Higher stocking densities in cages could have inhibited this behavior, as has been demonstrated for catfish (9).

Acceptability and profitability. Pond owners considered the majority of fish harvested after one season to be of acceptable size for home consumption. However, most fish were too small for commercial sale, where the minimum desired size is 175 to 225 g for panfish (bluegills and crappies) and 225 to 335 g for catfish and trout (3).

With few exceptions, owners evaluated the flavor and texture of pond-raised fish as good to excellent. Off-flavors were noted in several cases where fish were harvested from ponds with abundant weed growth. When this occurred owners postponed harvests for several weeks into the fall or held the live fish in fresh flowing water for several days prior to cleaning. Both techniques were effective for removing off-flavors from the fish flesh.

Trout was the most economical species cultured in this study (Table 4). Lower production costs for trout were possible because of the lower price of fingerlings (Figure 3) and better fish growth due to the longer growing season for cold water species. Current retail prices for trout range from \$6.50 to \$11.00/kg (dressed weight). Production costs for trout based on a 10 month growing season ranged from \$3.00 to \$8.00/kg, dressed weight, indicating a good potential for commercial culture of trout in Minnesota.

Current retail prices for crappies and catfish in Minnesota range from \$6.50 to \$13.00/kg (dressed weight), depending on the season and availability. Retail prices for bluegill are not available. In the present study, the cost of producing catfish for home use was within the range of current retail prices, but commercial production costs were not. This indicates that farmers can economically raise warm-water fish for home consumption but not for commercial sale.

Table 3. Average fish yields in study ponds after one growing season.

Species	Yields (kg/ha) without feeding		Yields (kg/ha) with feeding	
	Monoculture	Polyculture	Monoculture	Polyculture
Catfish	—	34 (114) ^a	178	254 (356)
Bluegill	121	119 (120)	186	118 (304)
Crappie	—	1 (120)	—	18 (95)
Trout	114	—	880	—

^a parenthesis indicates total yields of all species in the pond

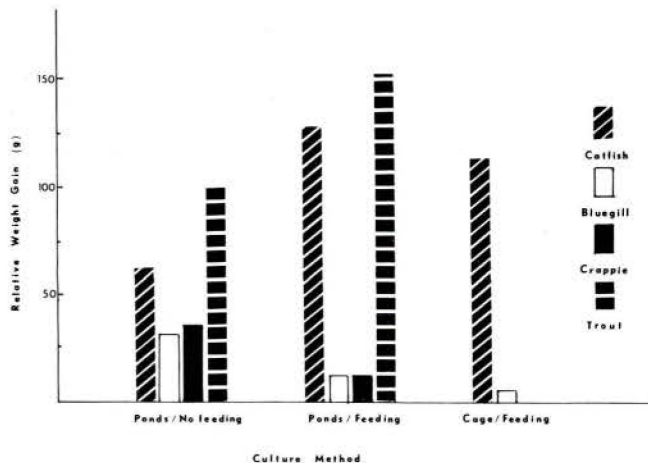


Figure 1. Relative weight gain (harvest weight/stocking weight) in grams for different fish species in study ponds after one growing season of 3 to 5 months, based on the culture method used.

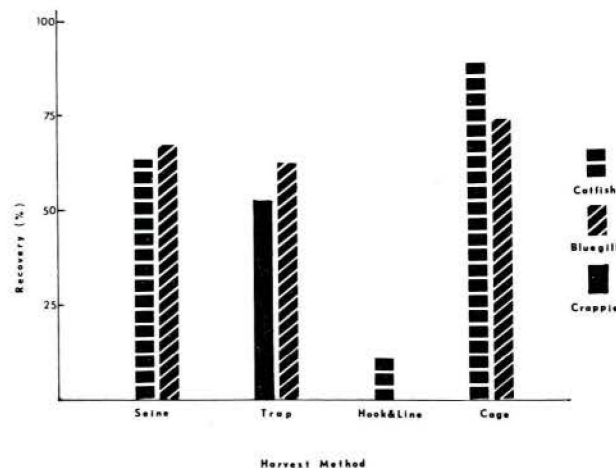


Figure 2. Average recovery (number of fish harvested/number or fish stocked) of different fish species in study ponds after one growing season of 3 to 5 months, based on the harvest method used.

While trout appears to be most suited to commercial culture, several factors could restrict its widespread application in Minnesota. There are a limited number of sites with cold flowing water available, and production costs would increase substantially if constant pumping of water was required. Also, the rising cost of ingredients in the high protein feed required by trout may reduce profitability in the future.

Warm-water fish culture could have wide application in Minnesota because of the many farm ponds and pond sites available. High production costs for warm-water species could be reduced in several ways: 1) establishing local hatcheries to lower fingerling costs, 2) using ponds designed for fish farming to enable efficient harvest and higher yields, 3) raising fish for two years with winter aeration instead of one year to produce larger fish. However, further studies are needed to assess the costs and yields of a two-year production system.

CONCLUSIONS

Substantial differences in fish growth and yields were found among ponds in this study (Table 2). Since the project was conducted under field conditions rather than controlled experimental conditions, replicated trials were not possible. Location, water quality and management varied between ponds. Therefore, the results of this study need to be further tested and refined before

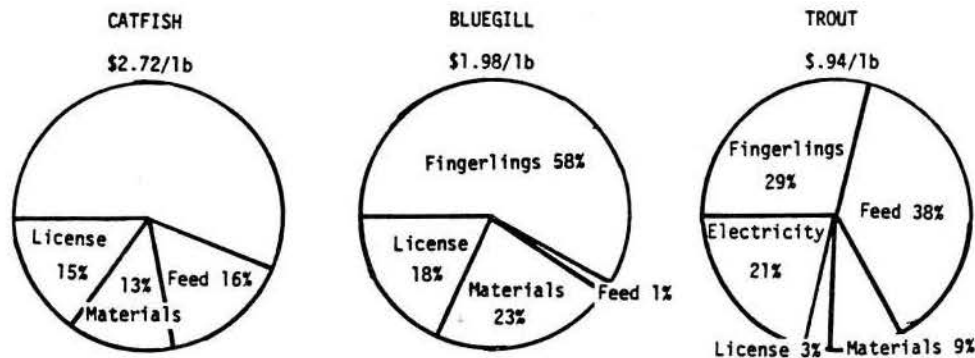


Figure 3. Breakdown of production costs (\$/kg, live weight) for different fish species in study ponds after a 3 to 5 month growing season for catfish and bluegills, and a 10 month growing season for trout.

definitive conclusions can be made. However, some general conclusions can be reached on the results.

It appears that harvestable-size catfish, bluegills and trout can be produced in a single growing season in Minnesota when large fingerlings (25 to 75 g) are stocked in early spring. Raising fish to marketable size, however, would require a second growing season. Average yields ranged from 18 to 356 kg/ha in warm-water ponds and 114 to 880 kg/ha in cold-water ponds. Poor fish survival and inefficiency of harvest methods were two factors contributing to low yields. These findings indicate the importance of proper site selection and pond design in the success of an aquaculture operation.

Although many opportunities in fish farming have been identified in the present study, a great deal of work remains to establish sound fish culture practices in Minnesota. Key areas needing further study include fingerling production, aeration, renovation of existing ponds for fish culture use, selection of fish types best suited to Minnesota conditions, and marketing considerations. The advantages of an increasing use of aquaculture in Minnesota include greater opportunities for small farm diversification, higher returns to landowners from presently underutilized acreage, and a deepening awareness of the benefits associated with the state's valuable wetland areas.

Table 4. Average production costs for fish reared in study ponds.

Species	Production cost (\$/kg, live weight)	
	Home use ^c	Commercial use
Catfish	6.04	9.42
Bluegill	4.40	5.47
Trout ^a	3.87	9.82
Trout ^b	2.09	5.18

^a Based on 3 to 5 month growing season, similar to warm water species.

^b Based on a 10 month growing season.

^c The cost of production for "home use" does not include the cost of labor, while commercial production costs include a charge for labor.

ACKNOWLEDGMENTS

We would like to thank the following organizations which provided funding for the project: Minnesota Governor's Council on Rural Development, Wright County Community Action, Twin Cities Presbytery of the Presbyterian Church, Otto Bremer Foundation and Minnesota Green Thumb. An advisory committee comprising representatives of the Soil Conservation Service, University of Minnesota, Department of Natural Resources, Department of Agriculture, and the Agricultural Extension Service provided valuable assistance throughout the project. Special thanks are due to Vernon Hedner and Gregory Vaut for their contributions and support, and especially to the fish farmers who participated in the program.

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