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Chapter 5

Walleye Fingerling Culture in Drainable Ponds

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Introduction

Intensive culture of walleye from fry to fingerlings is a promising new technology (Summerfelt 1996), but at this time nearly all walleye fingerlings are raised in earthen ponds by state and federal agencies and by the private sector (i.e., commercial farms). Because of the scope and diversity of cultural methodologies for pond culture, the subject has been divided into this chapter on drainable ponds and another for undrainable ponds (Kinnunen 1996). The objective of this chapter is to provide a literature review and a summary of the case studies on culture of walleye in drainable ponds.

Phase I and Phase II fingerlings

walleye harvested at a total length of 1.25 to 3.0 in (32-76 mm) in June to early July are called "summer fingerlings", or "phase I fingerlings"; fish raised to the end of the growing season are called "fall fingerlings" or "phase II fingerlings". Phase I and phase II fingerlings are traditional terminology in the culture of striped bass and its hybrids (Harrell et al. 1990). These terms are not common in walleye culture, but I think they are useful ways to designate the two size groups of fingerlings. Moreover, pond culture of phase I walleye and striped bass have much in common, they both use similar pond management strategies. The chapters by Geiger and Turner (1990) and Brewer and Rees (1990) in the culture manual for striped bass and its hybrids are highly recommended (Harrell et al. 1990).

The similarity between culture of phase II walleye and striped bass fingerlings is far less, but a comparison is instructive, perhaps to make a case for future research. In striped bass culture, phase I fingerlings are fed formulated feed, 1-2 times daily in the pond for at least two weeks before harvest to convert them from live to formulated feed (Smith et al. 1990). After harvest, they may be restocked directly into ponds, sometimes after grading to increase uniformity of size, or brought to the hatchery building for habituation to formulated feed. After restocking in ponds, they are raised on formulated feed and harvested in the fall as advanced juvenile, phase II fingerlings. Because they are raised on formulated feed, stocking densities are generally higher and size at harvest larger (average size of 12.6 fish/lb [27.2/kg]) than practices for raising phase II walleye.

Walleye culturists also produce a phase II fingerling in ponds, typically with minnows, but sometimes on invertebrate prey. For example, at the North Platte State Fish Hatchery, North Platte, Nebraska, small—630-749/lb (1.6- to 1.7-in total length) in 1987 and 702-1,287/lb (1.68- to 1.37-in) in 1988—phase I walleye fingerling were restocked at 10,000/ac (25,000/ha) and raised an additional 79-85 days without minnows (Ellis 1987,1988). At harvest, the phase II fingerlings averaged 74/lb (3.5-in) in 1987 and 97/lb (3.2 in) in 1988. More typically, however, phase II fingerlings are raised by stocking minnows. Jorgensen (1996) raised a **5-** to 6-in (13- to 15-cm) fall fingerlings in a 57-acre (23 ha) undrainable pond; after a partial harvest of phase I

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fingerlings, which also reduces the population density, fathead minnow were stocked weekly to be used as prey. Raisanen (1996) reported that it is cost prohibitive for the private sector to raise walleye fingerlings to advance size by feeding minnows, which can cost $0.5–3.00/lb ($1.10-6.60/kg). With a 4:1 food conversion of minnows to walleye, a 5-in (125 mm) fingerling would consume $0.08–0.45 of minnows. Because minnows are expensive, not always available, and the fact that the conversion ratio is high, the preferred method by many state and federal hatcheries is to transfer phase I fingerlings to hatchery tanks or raceways for habituation to formulated feed. It is less expensive to raise walleye on commercial fish feed than minnows.

Many public hatcheries raise phase II fingerling by the tandem pond-tank culture method (Malison and Held 1996). In this process, pond-raised phase I fingerlings that are 1.4 to 2.5 in (36-65 mm) are transferred to indoor culture tanks and habituated to formulated feed, and raised to 5 to 7 in (127-178 mm) (Bristow 1996; Flowers 1996; Nagel 1996). Once habituated to tank culture, they may be raised to food size (Flickinger 1996). A variety of factors have been studied, including stockmg density, temperature, light, diet, and feedmg frequency (Nickum 1986; Kuipers and Summerfelt 1994).

Research on training phase I walleye to feed in ponds in the manner that is done with striped bass or their hybrids, has not been reported. However, after phase I walleye fingerlings are habituated to feed in hatchery tanks, it is possible to restock them in ponds and raise them on pelleted feed. Nagel (1974. 1976, 1996) has maintained walleye broodstock in ponds by hand feeding floating trout chow during at twilight or before sunrise. Several generations of the London (Ohio) strain walleye have produced a walleye stock that exhibits behavioral characteristics of domestication: reduced excitability and cannibalism, and easier to train to formulated feed (Nagel 1995).

Fish production in drainable ponds

In the U.S., drainable (levee or diked) ponds are the major type of culture environment for raising channel catfish, golden shiner, goldfish, striped bass, sunfish, and black basses (Dupree and Huner 1984). The choice between drainable or undrainable ponds to raise walleye fingerlings by state agencies in the Midwest is usually influenced by the availability of natural water bodies. Minnesota has an abundance of prairie pothole and shallow lakes that do not sustain a permanent fish population because of winterkill; therefore, more than in any other state, most fingerling production in Minnesota is in undrainable ponds (Daily 1996; Lilienthal 1996). Michigan, Wisconsin, and Iowa use both drainable and undrainable ponds (Gustafson 1996; Jorgensen 1996). Ohio, Indiana, Illinois, Missouri, Kansas, Nebraska, South Dakota, and North Dakota raise most of their walleye fingerlings in drainable ponds. US Fish and Wildlife Service fish hatcheries in North Dakota (Valley City National Fish Hatchery [VCNFH] and Garrison Dam National Fish Hatchery [GDNF]) and South Dakota (Gavins Point National Fish Hatchery [GPNFH]), produced 73% of all fingerlings walleye raised by the federal hatchery system in 1990 (FWS 1991). GDNF has sixty-four 1.5-acre (0.61 ha) ponds which make it the largest pond culture hatchery in the Fish and Wildlife Service raising walleye fingerlings. It seems that the several hatcheries of the Ohio Department of Natural Resources have more total drainable ponds used for walleye fingerling production than any other state agency. The White Lake Fish Culture Station, the only government hatchery in Ontario that raises walleye, produces 200,000 summer fingerlings from 2.6 acres (1.4 ha) of drainable ponds (Flowers 1996).

Comparison of drainable and undrainable ponds

The characteristics of drainable and undrainable ponds and the cultural technology that are used in these ponds differ (Table 1). Apart from the unique, 100-acre (40.5-ha) drainable pond described in the case study by Wright (1996), undrainable ponds are generally much larger than drainable ponds. On the other hand, the key to success and popularity of drainable ponds for production of large numbers of walleye fingerlings is the ability to manage water, fertilize, and harvest efficiently. Survival and yield to a phase I fingerling is greater in drainable than undrainable ponds (Table 4): Clearly, if the cost of fry and labor for harvest is important, drainable ponds are superior to undrainable ponds for production of phase I fingerlings.

Most undrainable ponds lack water level control. They may have an excessive outflow of water, which could cause a loss of walleye; conversely, they may have no

Table 1. Comparative characteristics and management strategies for drainable and undrainable ponds (space contraints did not allow both English and metric units). Detailed information for some items is found in Table 4.

Management options	Drainable ponds	Undrainable ponds
Size (acres)	0.5 to 2.0	1 to 100[1], mean 58[2], 0.5 to 40[3], 5 to 150[4]
Stocking density (No./acre)	25,000 to 240,000 (Table 4) 100,000 to 152,000[5] 100,000 to 158,000[6]	2,500-30,000 (Table 4)
Survival (%)	46 to 76% (Table 4); 61.3-68.4[5] 19-year mean, 60.9%[6]; 3-year mean, 76%[7]	3.2 to 30% (Table 4) 10-15%[1], 5-7.5%[2], 30%[3], 3.5%[4]
Yield (lbs/acre)	61 to 119 (Table 4)	4.6 to 33 (Table 4)
Harvest methods		
Trapping (fyke nets)	Yes	Yes[8]
Seining	Yes	Uncommon
Drain fish to catch basin	Yes	No
Harvest	Harvest all fingerlings that are alive at time of harvest	Impossible to harvest all fish
Options for sequential fish crops	Double-cropping common: • trout-walleye • northern pike-walleye • walleye-catfish	Double-cropping not possible
Fertilized	Standard procedure (Table 3)	Uncommon to fertilize
Water management options	Maintaining level and water quality control	Usually not able to add water to replace evaporation
Drain, dry, and disk pond bottom	Common	Not possible
Seeding of pond bottom with rye grass	Possible option	Not possible
Vegetation control	Pre-emergent treatment of pond bottom before flooding	Must be applied to entire water volume
Presence of unwanted fish (predators or competitors)	Rare (source: inflowing water)	Common, may require fall poisoning

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[1] Commercial ponds (Gunderson 1996); [2] Minnesota DNR (Lilienthall 1996); [3] Michigan DNR (Gustafson 1996); [4] Raisanen (1996); [5] Harding and Summerfelt (1993); [6] Summerfelt et al. (1993); [7] Call (1996); [8] Harvest with traps or fyke nets typically requires several applications of copper sulfate to stimulate movement of fingerlings.

water inputs when it is most needed. Control of water level in drainable ponds can prevent fish loss. Ponds are not filled to the top — a 3- to 6- in (75-150 mm) freeboard is maintained to prevent overflow and fish loss after heavy rain.

Many public hatcheries double-crop their drainable ponds; trout-walleye (Flowers 1996), northern pike-walleye (Call 1996); or walleye–channel catfish (personal observation). At White Lake Fish Culture Station in Ontario, ponds may be used to raise salmonids over winter, then drained and dried for at least 10 days before refilling for the walleye culture season. At GDNFH, incubation temperature for walleye is deliberately lowered to delay walleye hatch of until a crop of northern pike can be harvested (Call 1996).

Harvest from undrainable ponds requires the use of seines, traps, or fyke nets. The cost of seines, traps, and nets, annual maintenance, and substantial personnel time needed to harvest undrainable ponds should be considered when comparing costs for raising of fingerlings in drainable vs undrainable ponds. The large drainable pond described in the case study by Wawronowicz and Allen (1996) was also harvested by seining and use of fyke nets, but complete harvest of drainable ponds is generally accomplished by draining.

Draining ponds eliminates unwanted fish, tadpoles, and crayfish. Unless a complete winterlull is obtained, a piscicide must be applied to undrainable ponds (usually in the fall), to eliminate the carryover of walleye and other fish which will prey on or compete with walleye for food. Although the unharvested portion of walleye stocked in the pond may die from winterkill, bullheads, fathead minnow and other fish that are more tolerant to winter conditions may survive. After harvest, drainable ponds can be planted with a cover crop, or the pond soil can be dried and disked. Drying before refilling reduces aquatic vegetation and oxidizes accumulated organic matter (Flowers 1996).

Watershed ponds

The visual image of a pond by many people would be a watershed (hill) pond; they are abundant and more likely to have been observed than drainable fish hatchery ponds. The US Soil Conservation Service **(SCS)** provided technical assistance for the construction of more than 2.5 million farm watershed ponds between the mid-1930s and 1980; since 1980, an additional 50,000 ponds have been installed without **SCS** assistance (Henry and Gabell 1981). Watershed ponds may be equipped with drains, but these ponds were not designed for culture fish, and once drained, they may require one or more years to refill from runoff. Thus, when watershed ponds are used for fish culture, they are seldom drained and they best fit the category of undrainable rather than drainable ponds. Also, unless fish culture was intended when they were first constructed, seining may be ineffective because the pond may have snags or be too deep.

Watershed ponds represent a sizable water resource: they are valuable for watering livestock and for sport fishing. For the most part, the use of watershed ponds for commercial fish culture is limited. Even so, watershed ponds are used for walleye fingerling production by a few commercial producers.

Other types of undrainable ponds

There are other types of undrainable ponds, including shallow lakes, marshes, borrow pit ponds, and dug ponds that are filled to the level of the water table (Kinnunen 1996). Commercial producers of walleye in Minnesota mainly operate in the west-central part of the state where there are numerous natural winterlull ponds; they are used for production of walleye, baitfish, and leeches by the private sector (Raisanen 1996).

Design criteria for drainable ponds

Typical drainable ponds are small artificial bodies of water with levees on four sides that are designed to grow fish. Harvest is done by draining the pond through an upright structure called a "monk." Details on design features of drainable ponds can be found in most general aquaculture texts (e.g., Piper et al. 1982; Huner and Dupree 1984; Huet 1986; Stickney 1994). A summary of the major criteria for drainable ponds are listed in Table 2.

Water supply

Water supply issues will not be discussed, but water requirements for filling ponds are substantial: a 1-acre (0.4 ha) production pond with an average depth of 4 feet (1.2 m), requires 4 acre-feet (4,934 m^3) or 1.3 million gallons for filling without accounting for seepage or water absorption in the levees. A flow of 300 gpm (1,135 Lpm) is needed to fill this a pond in **3** days. Over the culture season, addtional water is needed to

Table 2. Design characteristics for drainable earthen ponds.

Item	Characteristics
Water supply	Sufficient to fill individual ponds in 2 to 3 days, and all ponds to be used in the culture season must be fillable in 20 days.
Size	1 to 2 acres (0.4 to 0.8 ha)
Shape	Rectangular, length (L):width (W) ratio = 2:1
Depth’	Deep end, 4-6 ft (1.2-1.8 m), shallow end 3-4 ft (0.9-1.2 m)
Basin slope	0.2 to 1 ft per 100 ft pond length
Freeboard	1.5 to 2 ft (0.5-0.6 m) between water level and crown.
Levee slope	Inside levee = 3:1; range from 2.5 to 4:1. Outside levee, 2:1
Fish collection basin for harvest	Location outside of the pond is superior to inside location.

’Depth is for a production pond, not one used to overwinter fish.

replace losses from seepage and evaporation. The volume needed for a fish hatchery can be substantial. For example, at North Platte State Fish Hatchery (NPSFH), North Platte, Nebraska sixteen 1-acre (0.4-ha) ponds (Figure 11) are filled in one week (Harding and Summerfelt 1993). Most state and federal hatcheries are located below large dams where they can gravity flow of large volumes of water. However, nearly all catfish farms in Mississippi, which held 65% of the inventory of the number of food-size (small, medium and large) catfish in the **US** (ERS 1996) pump ground water to fill ponds.

Site selection

Site selection is critical. Ponds must be located close to their water supply and where the subsoil has enough clay to retain water. As a rule to prevent excessive leakage, the soil profile to a depth 5 ft (1.5 m) below the projected pond surface should have at least 20% clay. Sandy soils, gravely areas, and fissured rock substrates are unsuitable because they will not hold water. Plastic-lined ponds, which are very expensive, are required when ponds are constructed on highly permeable soils.

Size and dimensions

Although Wright *(1996)* reports the use of a 100-acre (40-ha) drainable pond in northern Michigan, a desirable size for levee ponds for fingerling production is 1 to 2 acres (0.4 to 0.8 ha). Small ponds allow for complete and sufficient draining and harvest. Large ponds require partial harvest by staged draining and seining or night harvest (Figure 9) with lift nets or seines.

A 2:1(L:W) ratio of length (L) to width (W) for a rectangular pond is suitable. The dimensions for a given pond to achieve this ratio can be calculated from the pond size: e.g., for a 1 acre (43,560 ft^2) (0.4 ha) pond, the $W = \sqrt{area/2}$ and $L = 2W$: thus, $W = \sqrt{43{,}560\ ft^2/2} = 147.6$ ft (45.0 m) and L = 295.2 ft (90.0 m).

The bottom must slope gradually to the outlet (drain): Huner and Dupree (1984) suggest 2.5 in (6.4 cm) per 100 ft (30.4 m) of linear distance (probably with 10 to 20 acre ponds in mind); Stickney (1994) states that 1% (1 ft drop per 100 ft of linear distance) is an acceptable ratio for smaller ponds. **A** 1:100 ratio would require a 3 ft (0.9 m) difference in depth (3 ft (0.9 m) at the shallow end and 6 ft (1.8 m) at the deep end for a pond 300 feet long, which may be somewhat steep for a 1-acre (0.4 ha) pond.

Monk and catch basin

A water control structure (“monk”) and catch basin (“kettle”) for harvest are two essential components. The monk is usually an upright structure of poured concrete (Figures 1 and 2) that contains a drain pipe with a gate valve (Figure 3), a slot for a screen, and two slots for dam boards to regulate water depth. Plastic gate valves with simple push-pull design are available. **A** wooden monk also is available from a commercial source that can be installed for much less than the large concrete structures. A less elaborate, and lower cost monk and drain setup is illustrated in Figure 4. The most basic alternative is to use only a turndown standpipe (i.e., one that has a threaded elbow or swivel that can be turned down at the elbow) and a depression in the pond bottom to serve as the catch basin for harvest.

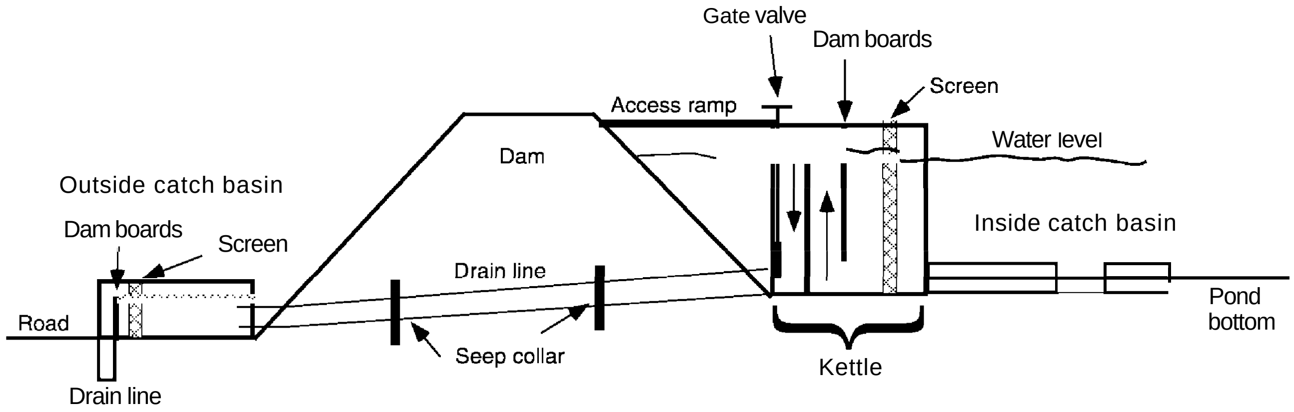

Figure 1. Cross section through the monk and dam of a drainable pond to illustrate the location of a catch basin inside (right) and outside (left) of the pond.

The dam boards in the monk may be set to discharge water from the bottom of the pond (Figure 1);however, because fry cannot be effectively screened, there should be no outflow from the pond as the “fry go with the flow.”Fry losses from overflow may be considerable. Water should be maintained sufficiently below the level of overflow to receive a normal rain without an overflow.

Whatever the type of control structure, a catch (capture) basin for harvesting the fish is essential. The catch basin increases the efficiency of harvest and reduces stress to the fish. The catch basin may be located inside or outside of the pond. When located inside the pond it is commonly an integral part of the monk. At some state and federal hatcheries, ponds with an inside catch basin are equipped with a concrete stairway between the catch basin and the top of the dike to facilitate carrying the fish from the catch basin to the top of the levee (Figure 2). Two types of external catch basins for fish harvest are illustrated in the case studies by Call (1996) and Wright (1996).

The catch basin should be provided with **a** water supply to maintain water quality in the basin during harvest (Figure 5). At other hatcheries, the catch basin is located outside of the pond (Figure 6), which is highly recommended to facilitate harvest. The external catch basin that is accessible by the hatchery truck for direct loading of the fingerlings increases the efficiency with which ponds can be drained and the fish shipped out. Although individual ponds may require 2 to **3** days to drain, an outside catch basin is an asset that allows a small staff at public hatcheries to efficiently harvest three to four ponds each day, each with 136,000 fingerlings/acre (336,000/ha). Staff at the Garrison Dam National Fish Hatchery harvest 10 million walleye

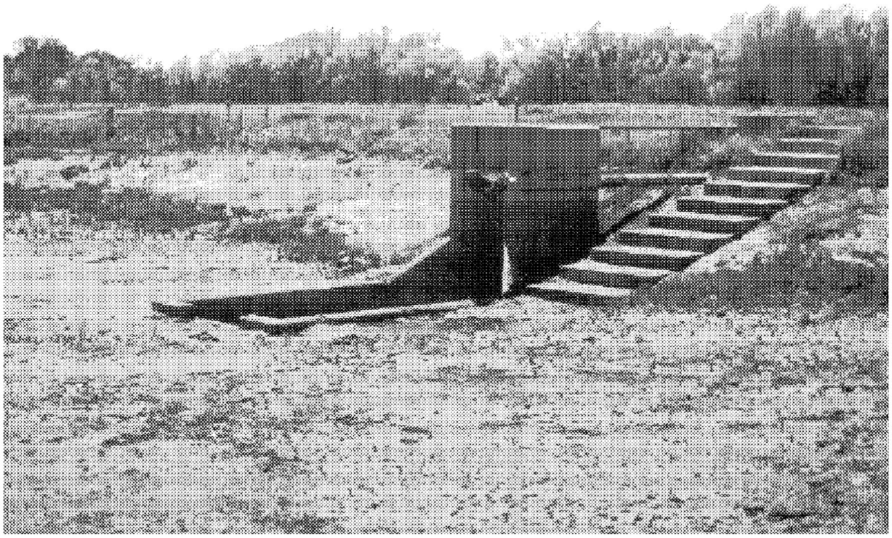

Figure 2. Culture pond with concrete outlet structure, inside catch basin (kettle), and stairs. It is important that the pond slope to the catch basin for complete drainage into the kettle.

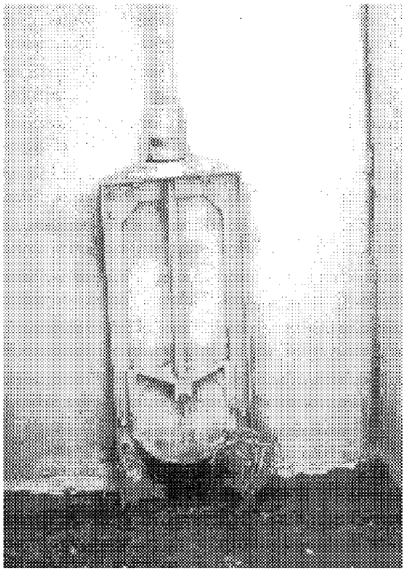

Figure 3. Gate valve located in monk.

Figure 4. Pond at commercial fish farm with simple concrete monk that is built into the levee of culture pond. A supply of freshwater has been provided near the monk. Bumps in the catch basin are mostly turtles.

fingerlings per season using this system (Call 1996). Although such structures may seem to be luxuries, the alternatives are to use a crane to lift the fish, which is how catfish are harvested in the south, or personnel will have to slog up and down wet pond banks with tubs of fish and water. Ponds of the Ohio Department of Natural Resources London Fish Hatchery have been constructed to drain ponds directly to a tank in the hatchery building (Nagel 1996). A similar feature has been used at a large walleye farm in Minnesota, however, they have found that because mechanical damage occurs when fish are drained to the hatchery building, they remove most fish from the pond by seining. The inside catch basin is used only to capture fish that would otherwise escape during pond draining (Tom Hertz, Brandon Fisheries, Brandon, Minnesota, personal communication).

Management of drainable ponds

Management of drainable ponds include options for pond preparation, scheduling pond filling in relation to the anticipated hatch interval, fertilization (kinds, amounts, and application schedule), stocking density, zooplankton inoculation, control of problem organisms (aquatic insects, clam shrimp and vegetation), water quality management (aeration, etc.), and harvest (drain, drain and seine, or night harvest with lights).

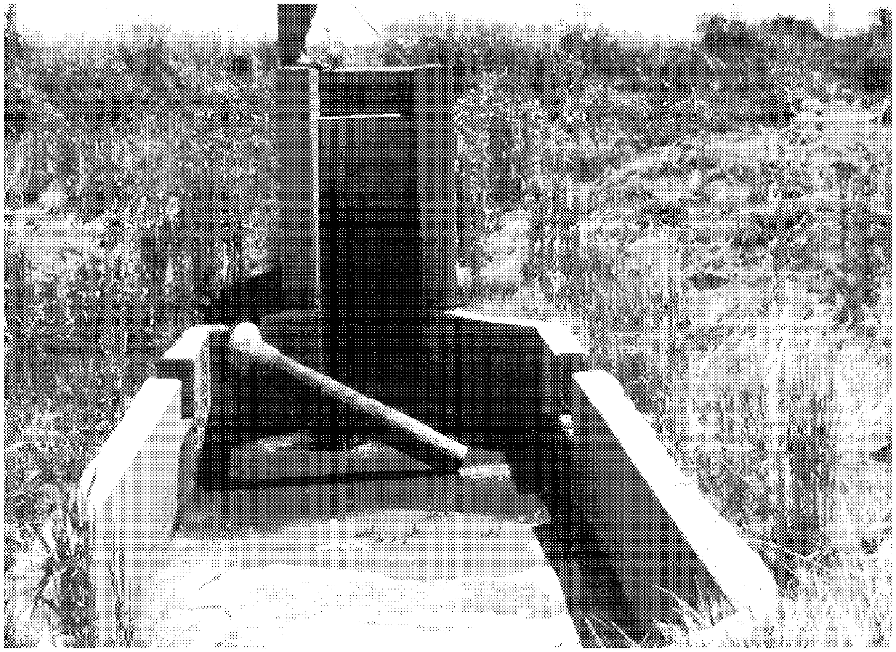

Figure 5. The catch basin in this pond has a water supply to maintain water quality during harvest.

Figure 6. An outside catch basin at the Garrison Dam National Fish Hatchery, Riverdale, North Dakota. A schematic design for this catch basin is given in the case study by Call (1996).

Pond preparation

At some hatcheries, pond preparation begins immediately after harvest. The wet pond bottom is seeded with rye grass (Call 1996; Wawronowicz and Allen 1996). In other hatcheries, the pond may be used again in the same season to culture phase II fingerlings or to culture another species. The pond can be dried and disked in the fall. After harvest, ponds on the Lac du Flambeau Indian Reservation are seeded with rye grass, but they are usually allowed to "seep" dry, which they regard as a natural way to trigger crustaceans to produce resting eggs for the next production season (Wawronowicz and Allen 1996); their ponds remain dry over winter.

Pond filling

In the case studies cited in this manual, the drainable ponds are filled from surface water sources containing fish; therefore, the water is filtered in various ways to exclude fish and fish eggs: metal microstrainer, sand filter, or screens. When ponds have been left empty over winter, filling is usually timed in relationship to the expected date that walleye eggs hatch and in relationship to strategies for zooplankton development. The time between pond filling and fry stoclung varies from 1 to 28 days: "just before fry are ready to be stocked" (Culver 1996); 9 days after pond filling at GDNF (Call 1996); 10 days after pond filling (Raisanen 1996); 2 weeks at the Ontario Ministry of Natural Resources White Lake Fish Culture Station, Ontario (Flowers 1996); and 4 weeks on the Lac du Flambeau Indian Reservation (Wawronowicz and Allen 1996). Some differences are a matter of scheduling but definite differences in opinion on pond-filling strategy are also evident: two weeks for zooplankton development (Flowers 1996), to that of choosing to fill the ponds only a few days before fry are stocked, "...so that the abrupt plankton decline that occurs 4-5 weeks after ponds are filled will occur as late into the production season as possible" (Culver

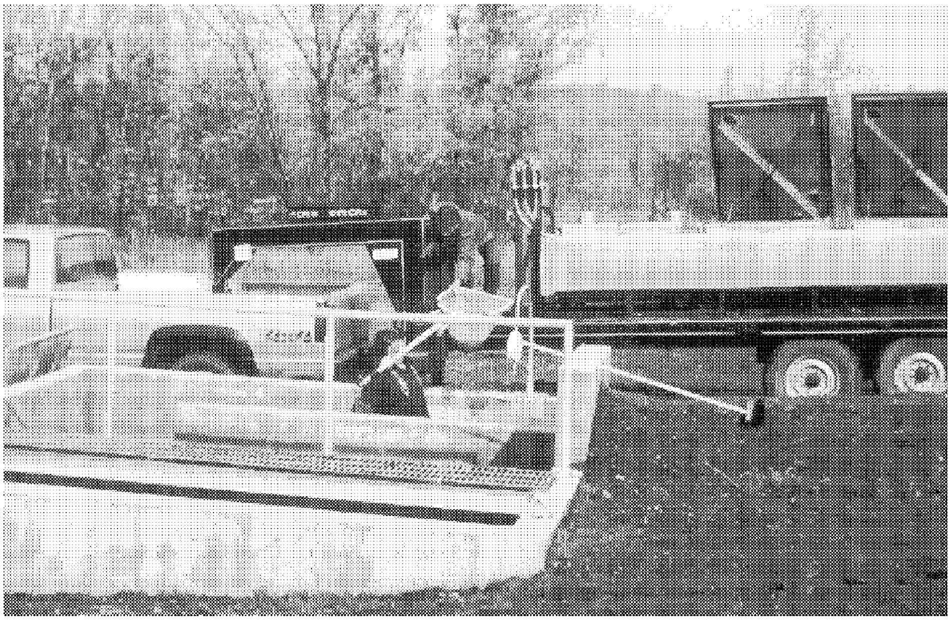

Figure 7. Direct loading of phase I walleye fingerlings from the external catch basin to the hatchery truck for distribution at the Garrison Dam National Fish Hatchery.

1996). However, in using organic fertilizers, chironomid larvae and pupae, not zooplankton, are more important prey for walleye after 2 to 3 weeks, or when fingerlings reach about 1 in (22 mm) (**Fox** et al. 1989; **Fox** and Flowers 1990; Summerfelt et al. 1993).

At most hatcheries, once pond filling is started, ponds are filled in 1 to 3 days, basically as quickly **as** the water supply will allow. On the other hand, a staged- or gradual-filling process is a purposeful procedure to concentrate newly stocked fry and zooplankton to facilitate first-feeding, and production of new hatches of zooplankton with each subsequent increment in pond filling. Bushman (Richard Bushman, Illinois Department of Conservation, personal communication) fills ponds slowly to continually add zooplankton from the water supply; the pond filling strategy is designed to take advantage of an abundance of zooplankton in the water supply. Slow pond filling has not in itself been a subject of research, it is often inadvertently done when a continuous addition of water is necessary to replace water loss from evaporation and/or seepage. At NPSFH, the addition of water may be equivalent to the total volume of the pond every 10 days. Inflow water at this hatchery contained about 500 zooplankton/L. The inflow represented 54 zooplankton/L of pond volume, which was as much as 15% of the average density of zooplankton in the pond (Hardmg and Summerfelt 1993).

Monitoring growth and survival

Walleye may be seined or trapped to monitor growth and abundance (i.e., survival). Walleye are strongly attracted to light when they are 9 to 32 mm total length, thereafter they change from positive to negative phototaxis (Bulkowski and Meade 1983). During the interval when they are attracted to light, they can be attracted into an illuminated container, the so-called night-light trap (Figure 8). When the container is quickly removed from the pond, fish and zooplankton that swam into the circular openings are swept to the bottom of the trap, which allows water to be drained away but retains zooplankton and fish. This night-light trap was made by staff at the Southern Illinois Univer-

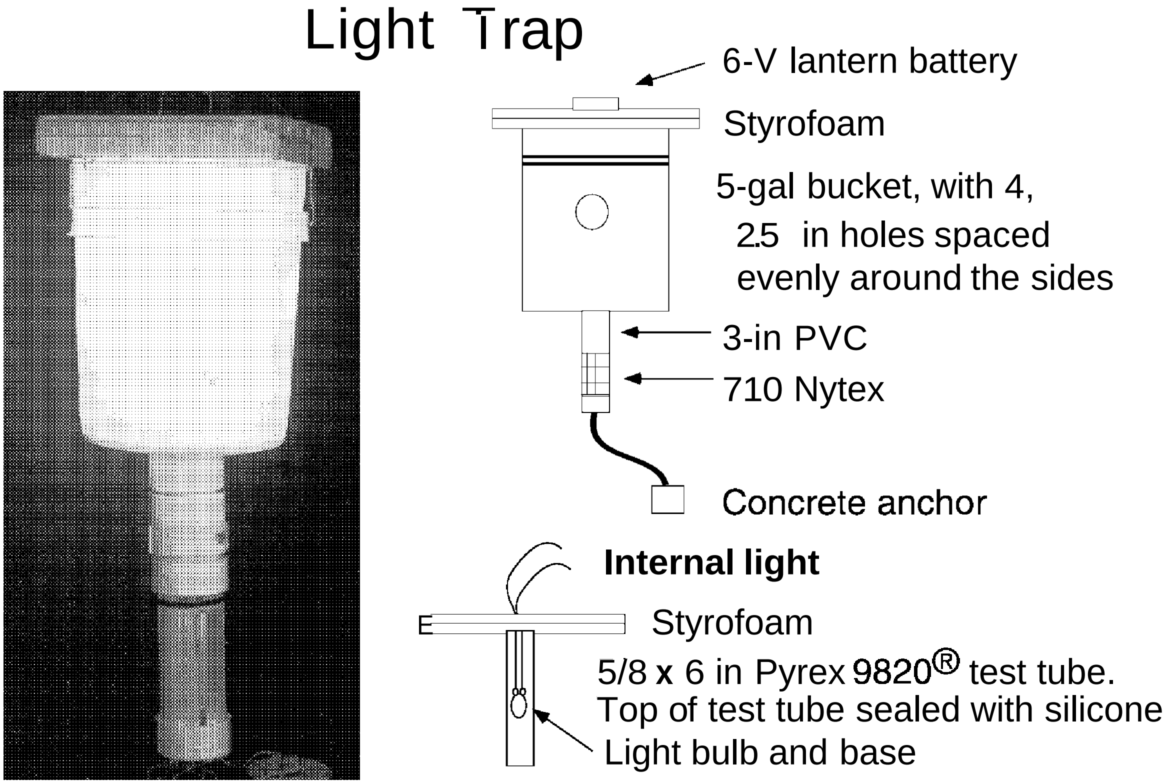

Figure 8. Night-light trap used to sample walleye fry in ponds: Left photograph illustrates the trap in the dark as it might appear to walleye fry in the pond; schematic design (right) for the light trap.

sity Fisheries Research Laboratory. It is a modification of one of several light traps designs described in the literature that are used in hatchery ponds for sampling fish larvae and juveniles (Floyd et al. 1984; Secor et al. 1992).

Catch per unit effort (CPUE) of larvae captured in the light trap may be used as an index of abundance. Annual monitoring in many ponds at the same hatchery can provide a data base; a regression equation developed from CPUE at specific days posthatch may be used to estimate mortality or survival rates from which the final population can be estimated. Also, fish that are captured in the trap may be measured to determine growth and the adequacy of the food supply. Microscopic examination of the fish can be done to determine gas bladder inflation, presence of food in the gut, and presence of parasites.

Stocking densify-fertility relationship

Fertilization strategies for ponds are the most central yet the most contentious of all management considerations. Fish culturists want to maximize survival and yield (i.e., lb/acre, kgha). It has long been known that a functional relationship exists between pond fertility and yield of walleye fingerlings (Smith and Moyle 1945; Dobie 1956). At the same stocking density, yield is linearly related to survival; i.e., the higher the survival the greater the yield (Summerfelt et al. 1993). Carrying capacity may be limited by stoclung density (density limited) or fertility limited, a distinction that must be resolved to determine whether an increase in fertilization is justified. For example, traditionally, ponds at the NPSFH were not fertilized and stocking density was 100,000 fry/acre (250,000/ha). When stocking density was increased to 150,000/ac (375,000/ha) without addition of fertilizers, yield was unaffected; it was 55.1 lb/acre (61.8 kg/ha) from ponds stocked at 100,000/acre and 54.7 lb/acre (61.3 kg/ha) from ponds stocked at 150,000/acre (Harding and Summerfelt 1993). Thus, the ponds were not density limited, and yield was not increased with additional stoclung density. When the ponds were stocked with 150,000/acre (375,000/ha), and fertilized with 756 lbs/acre (848 kgha) of alfalfa pellets, yield was 41.6% greater from fertilized ponds (72.2 lb/acre, 81.0 kg/ha) than the yield from unfertilized ponds (51.0 lb/acre, 57.2 kg/ha).

Walleye production can also be measured as number of fish harvested/acre (No./ha). In that case, an increase in stocking density may be desired even though yield may not increase, but typically, mean size, and probably condition, will decrease. For example, at NPSFH, an increase in stocking density from 100,000 fish/acre (250,000/ha) to 150,000 fish/acre (375,000/ha), did not adversely affect the survival (61.8% vs 61.3%) and there was only a small decrease in mean size 1.4 vs 1.3 in (36.2 vs 33.5 mm). **Fox** and Flowers (1990) reported a substantial decrease in mean lengths and weights of walleye fingerlings as stocking density was increased from 24,670/ac-ft to 74,000/ac-ft (20 to 60 fry/m^3: mean length declined from 48.9 to 41.3 and mean weight from 788 mg to 470 mg.

Stocking density and fertilization may be progressively ratcheted upwards to some finite limit when water quality becomes the limiting factor. **As** a generalization, when carrying capacity for a given level of fertility is reached, additional stoclung density will result in smaller fish and/or reduced survival.

Food of pond cultured fingerlings

The first food may be rotifers and copepod nauplii (Smith and Moyle 1945), cyclopoid copepods (Fox and Flowers 1990), or small soft-bodied cladocerans (Raisanen and Applegate 1983). As they grow, walleye progressively switch to larger cladocera (Raisanen and Applegate 1983; Fox and Flowers 1990) and to immature aquatic insects, typically chironomid larvae and pupae (Fox and Flowers 1990; Summerfelt et al. 1993). Fox et al. (1989) reported that zooplankton are less important after the second week of culture, and that chironomids become the dominant prey in walleye >0.8 in (>22 mm). Studies on stomach contents of walleye at hatcheries in North Dakota and Nebraska consistently demonstrated a sequence from copepod nauplii, copepods, small cladocerans, then larger cladocerans, and chironomid larvae and pupae. Walleye fry did not eat diatoms or rotifers, even though rotifers were always the most abundant zooplankton (Summerfelt et al. 1993). The smaller copepods and cladocerans were preferred early in the culture season, but food preference shifted to large cladocerans (up to 2.0 mm) and chironomids in the latter stages of the culture period. On the other hand, Jahn et al. (1989) reported that walleye fingerlings smaller than 1.1 in (28 mm) ate mainly rotifers; those 21.1 in ate primarily copepods; and fingerlings >1.25 in (32mm) ate chironomids as well as copepods and cladocerans.

Table 3. Comparison of kinds and amounts of organic fertilizers used in drainable ponds for culture of walleye fingerlings.

Type of fertilizer	Initial amount lbs/acre (kg/ha)	Total amount lbs/acre (kg/ha)	Reference
Alfalfa meal	133 (118.6)	1,064 (949)	Call (1996)
Alfalfa meal and	587 (524)	1,175 (1,048)	
Torula yeast	59 (53)	118 (105)	Wawronowicz and Allen (1996)
Alfalfa meal	100-200 (112-224)	1,500 (1338)	Raisanen (1996)
Alfalfa pellets	220 (246)	880 (984)	Johnson (1987)
Alfalfa pellets	240 (269)	719 (806)	
alfalfa hay and	240 (269)	719 (806)	
alfalfa meal	240 (269)	719 (806)	Clouse (1991)
Alfalfa pellets	466 (523)	1691 (1896)	
alfalfa hay and	466 (523)	1632 (1830)	
alfalfa meal	466 (523)	1340 (1569)	Clouse (1991)
Alfalfa pellets and	180 (202)	720 (808)	
soybean meal	67 (74)	268 (300)	Clouse (1991)
Alfalfa meal and	189 (212)	950 (848)	
soybean meal	78 (88)	394 (352)	Harding and Summetfelt (1993)
Soybean meal	392 (350)		Flowers (1996)
Urea	400 (357)	4000 (3568)	Wright (1996)

Fertilization

Whatever the lunds, amounts, or application frequency of fertilizer used, the goal of pond fertilization is to increase yield. Fertilization may be done with organic or inorganic fertilizers or both (Table 3). In limnological terms, fertilization by addition of organic matter is used to nourish a heterotrophic pathway for fish food production, with the basis of the food web being organic matter added to the pond (i.e., allochtonous origin). Those who advocate inorganic fertilizers are designing an autotrophic pathway for fish food production, in which inorganic fertilizers are used to promote algal growth as the starting point for the food web (i.e., autochothonous production of organic matter from within the pond). It is important to understand the basics of these two strategies to understand how they can be managed to increase production.

The heterotrophic strategy is a conceptual scheme based on decomposition of organic fertilizers by microorganisms, whch are consumed by infusoria and other detritus-feeding organisms (detritivores) and their predators. Zooplankton and aquatic insect larvae that are eaten by walleye are either detritivores (i.e., heterotrophic organisms that consume organic matter) or predators on detritivores. In the narrowest sense, the goal in promoting a heterotrophic pathway is not algae production. Most pond culturists would be delighted to produce walleye without algae. Blue-green algae are a nuisance at harvest and they are not preferred by zooplankton. **A** large algal biomass causes strong diurnal pulses in oxygen, pH, and carbon dioxide. Of course, bacterial decomposition of organic matter consumes oxygen, and organic matter functions like a slow release fertilizer, releasing inorganic nutrients (N and P) that eventually stimulates algal production. Organic fertilization does not require measurement of N:P ratios.

The heterotrophic strategy, using organic fertilizers, has been the traditional practice at northern hatcheries for pond culture of walleye (Dobie 1956; Buttner and Kirby 1986; Richard and Hynes, 1986; Fox et al. 1989; Jahn et al. 1989; Flowers 1993; Harding and Summerfelt 1993; Summerfelt et al. 1993; Call 1996). Organic fertilizers are preferred because algal populations are too slow to develop at the low water temperatures in the ponds and because of the short interval between pond filling and stocking. Organic fertilizers stimulate heterotrophic food chains, and the organic materials generate a large decomposer community which can be consumed by zooplankton and yet also provide a slow release of inorganic nutrients to algae (Geiger 1983; Barkoh and Rabeni 1990). Green manure (e.g., flooded rye grass), animal manures, and ground hay, alfalfa pellets, and alfalfa meal, soybean meal, and Torula yeast are examples of organic fertilizers (Table 3). The type and particle size of organic fertilizers is important because they affect both the rate of decomposition and the ability to stimulate development of microbial populations (Barkoh and Rabeni 1990). Alfalfa, for example, is used as ground hay, pellets, or meal, which vary in particle size from large to small.

At the White Lake Fish Culture Station in Ontario, the decomposition process is initiated in containers by mixing soybean meal with water for up to a week before it is used (Flowers 1996). Their pond fertilization is started at least two weeks before stocking with a large initial application (392 lbs/acre-ft; 140 g/m3), and weekly applications of 98 lbs/acre-ft (36 g/m3) thereafter.

A diverse complex of factors affect the abundance and composition of the zooplankton community in ways that are still unpredictable. The selection of specific types and particle sizes of organic fertilizers and application schedules to specifically regulate the abundance of particulate organic matter, its associated microbes, and zooplankton numbers and composition is a new direction in pond culture derived from experimental studies such as that done by Barkoh and Rabeni (1990).

The inorganic or autotrophic strategy has been used by Culver (1996) at the Hebron, Senecaville, and St. Mary's Fish Hatcheries in Ohio. They applied amounts and mixtures of fertilizers to achieve desired N:P ratios. After pond filling, the concentrations of N and P are raised to 600 mg N/L and 30 mg PO_4-P/L, and are maintained at those levels by weekly applications of liquid inorganic fertilizers to achieve a 20:1 N:P ratio. Inorganic fertilizers arc used to produce crops of small algae (diatoms, coccoid greens, flagellates) that are eaten by zooplankton.

This procedure requires precise analysis of the fertilizers; accurate measurements of ammonia, nitrate, and phosphate in pond water; and one-person day of effort each week per 30 ponds to conduct the analyses. The appeal of the technique is the potential for improved management of algal abundance and Community structure, as well as reduced cost when compared with organic fertilization. Culver et al. (1993) reduced the number of "bust" ponds (ponds with <10% survival) from 55% to 0% with this fertilization program.

Tice et al. (1996) reports a comparison of organic and inorganic fertilization strategies. They compared survival, yield, and mean size of walleye harvested from ponds fertilized organically (alfalfa meal and yeast) with ponds fertilized with liquid inorganic fertilizer. They did not find any difference in survival, or final mean lengths of the fish; however, mean fish weight was significantly lower in the inorganically fertilized ponds, and yield was higher in the organically fertilized ponds: 52.7 lb/acre (47 kg/ha) compared with 37 kg/ha in the inorganically fertilized ponds. Filamentous algae was not reduced by use of inorganic fertilizers; in fact, the only two ponds where it was a problem was in a pond fertilized with inorganic fertilizers.

Smith and Moyle (1945) found no correlation between total phosphorus and total nitrogen and yield of fingerlings in 66 Minnesota walleye culture ponds. They suggested that "... basic fertility is not converted into a crustacean crop early enough in the spring to be available when most needed by the small yellow pikeperch (i.e., walleye)." Walleye culture in northern latitudes with slowly warming water over the culture season may not benefit from inorganic fertilization as it does in the southern portion of the north central region. The contrasting results of Tice et al. (1996) and the studies by Culver (1991, 1996) and Culver et al. (1993) indicate that differences in success with inorganic fertilizers may be as variable as that previously reported in ponds fertilized with organic matter.

Zooplankton inoculation

Seeding walleye culture ponds with zooplankton inoculation may be an effective way to initiate a rapid increase in desirable zooplankton numbers. Zooplankton seeding serves a special need in walleye production in northern climates where the interval between pond filling and stocking is limited, water temperatures are low, and where there **is** little time to optimize zooplank-

Table 4. Stocking densities and harvest characteristics of phase I walleye fingerlings reported in the case studies on drainable and undrainable ponds.

	Stocking density (1,000's)	**Harvest characteristics**			
Pond type Reference	**Number/acre (Number/ha)**	**No. fish/lb (No. fish/kg)**	**Length inches (mm)**	**Survival (%)**	**Yield lbs/acre (kg/ha)**
Drainable					
Call (1996)	166–200 (410–484)	1,700 (3,744)	1.25 (32)	76	80 (89.7)
Wawronowicz and Allen (1996)	120 (300)	417–450 (917–990)	2.0 (51)	30–75	Not given
Culver (1996)	100–240’ (247–596)	1,410[2] (3,102)	1.2–1.6 (30–40)	64	61 (68)
Flowers (1996)[3]	120 (296)	792 (1,742)	1.8 (45)	69.2	112 (126)
Wright (1996)[4]	25 (62)				
Raisanen (1996)	75–150 (185–371)	417(917)[5]	2.0 (51)	46	119 (133)[6]
Undrainable					
Daily (1996)	3–5 (7–12)	25–30 (55–66)	5.1–4.8 (129–122)	3.2	Not given
Jorgensen (1996)	20 (49)	400–210 (881–462	2.0–2.5 (51–64)	6.8[7]	4.6 (5.2)[8]
Gustafson (1996)	30–75 (74–185)	983–212 (2,163–466)	1.5–2.5 (38–64)	30	7–33 (7.8–37)[6]
Gunderson et al. (1996)[9]	2.5–30 (6.2–74)		2.0–3.0 (51–76)		

’Given an average survival of 64% survival and a harvest of 86,000 fingerlings, the average stocking density would be 134,375 (86,000 fingerlings/acre ÷ 0.64).

*Estimated from data provided by author (i.e., 86,000 fingerlings/acre ÷ 61 lbs/acre).

[3] Flowers presented several data sets; these data are means of values from Table 3 of his report.

[4] Wright's report is for a phase II fingerling, harvested from early August to the end of October.

[5] Length was used to estimated number of fish/lb Table I–4 in Piper et al. (1982).

[6] Calculated from number harvested/acre ÷ number fish/lb = lbs/acre

[7] A partial harvest, an additional 9.6% of phase II fingerlings are harvested in October

[8] Only phase I fingerlings; the combined yield of phase I and II fingerlings is 106 lbs/acre (118 kg/ha)

[9] Most harvest is of phase II finglerlings in the fall; specifics for phase I fingerlings could not be identified.

ton populations. Geiger (1983) recommended zooplankton inoculation for pond production of fingerling striped bass and Richard and Hynes (1986) suggested using the procedure to culture walleye fingerlings. As previously noted, ponds filled with filtered water from surface water sources often contain populations of zooplankton which serve as an artificial inoculum. However, the kind and size of zooplankton differ substantially, and an inoculum of cladoceran species too large for first feeding larval walleye may reduce survival (Clouse 1991).

Stocking density

Fry stocking densities varying from 25,000/acre (62,000/ha) to 240,000/acre (596,000/ha) have been reported for drainable ponds (Table 4). In these ponds, harvest characteristics were not correlated with stocking density. Typically, at carrying capacity, fish size at harvest is inversely related to fish stocking density (Schroeder 1978), and mean weight inversely related to number of fish harvested per unit area. This has been reported in many experiments (Harding and Summerfelt 1993; Summerfelt et al. 1993).

Nevertheless, whatever the traditional stocking density at a hatchery, stocking density may be increased if a partial harvest of small fingerlings (1.0 in, <25 mm) can be made to reduce the density during production of phase I fingerlings. Because walleye are strongly attracted to light before they reach 1.25 in (32 mm) (Bulkowski and Meade 1983), fingerlings can be attracted to a floating light, surrounded with a soft, fine-mesh seine, and hauled to shore where the seine is cribbed and the fish carefully dipped out (Figure 8). This strategy permits increased stocking density because the partial harvest of the small fingerlings reduces the density to the carrying capacity of the pond for grow-out to the standard size.

Harvest from drainable ponds

Undrainable ponds must be harvested with traps or seines, but drainable ponds can be harvested by draining water into a catch basin. Wawronowicz and Allen (1996) described the use of fyke nets and a seine to harvest drainable ponds that were not equipped with catch basins. Drainable ponds may be partially harvested with seines or fyke nets, or seined during draining. Most state and federal production hatcheries drain the ponds to a catch basin and harvest the entire pond in one day. If desired, walleye may be partially harvested over several days by using traps, seines, night harvest with lights, or a drain-and-seine procedure.

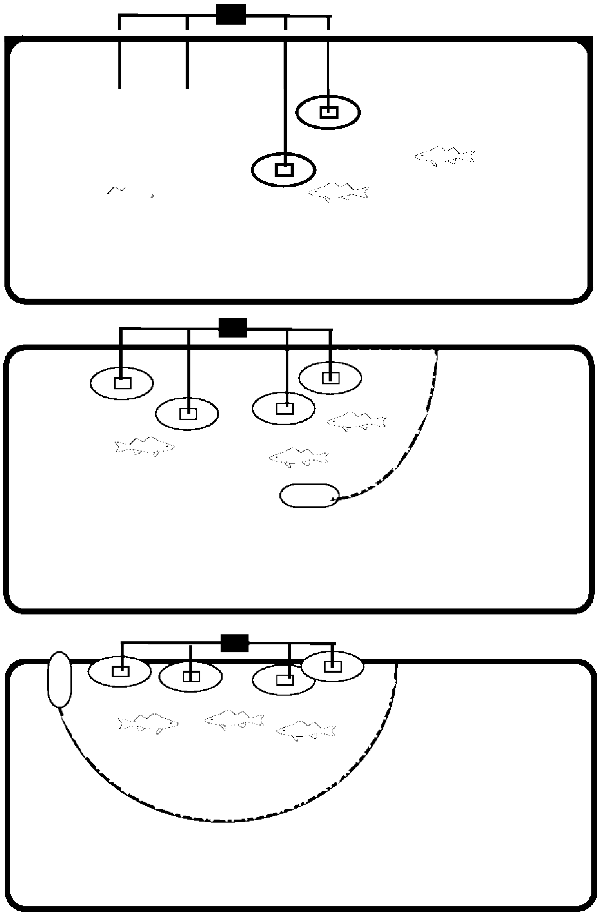

Figure 9. Technique used for partial harvest of small (<32 mm) walleye fingerlings that are strongly attracted to a night light. Submerged lights are attached to floats in the pond (upper). After fish are attracted to the light (middle), a boat is used to extend a seine and at the same time the lights are slowly pulled back to shore while the fish are surrounded by the seine (lower).

Harder (Tom Harder, Max McGraw Wildlife Foundation, personal communication) found that a night-harvest technique using floating lights was an effective method for harvesting walleye fingerlings (Figure 9). This system was a modification of procedures described by Manci et al. (1983) for harvesting yellow perch. **A** special advantage of the night harvesting technique was that fingerlings were captured without the usual abundance of tadpoles and salamander larvae, which were a nuisance with daylight pond seining. Bulkowski et al. (1983) reported that fingerlings are photopositive up to 1.25 in (32 mm) gradually becoming photonegative by 1.6 in (40 mm).

Yield

In the drainable ponds reported in the case studies in this chapter, yields range from 61 to 119 lbs/acre (68–133 kg/ha); the lowest yield and smallest fish size (no fish/lb) was from ponds fertilized with only inorganic fertilizers (Culver 1996).

Because of the complexity of pond ecosystems, survival, production, harvest, and mean size of fingerlings is variable (Mathias and Li 1982; Richard and Hynes 1986; McIntyre et al. 1987). Fox et al. (1989) reported survival ranging from 0.7 to 73% and a yield ranging from 1.8 to 26.1 g/m^3 in experimental ponds. Reducing this type of variability is dependent upon careful management, especially the fertility, prey population, and control of cannibalism (McIntyre et al. 1987).

Culture interval

The length of the culture interval for production of phase I fingerlings reported by case study authors is varied: 29 (Call 1996), 40 (Wawronowicz and Allen 1996), 42-56 (Flowers 1996). The 29 day interval reported by Call (1996) is exceptionally because the walleye are typically stocked after northern pike at the GDNFH, which results in a higher average temperature than typical of most walleye culture. There is an obvious inverse relationship between the length of the culture interval and mean water temperature: 68°F (20°C) water temperature for 24-29 day culture season at GDNFH; 62.6°F (17°C) water temperature and 39-52 day culture season at VCNFH; and 59°F (15°C) water temperature and 40-60 day culture season at North Platte State Fish Hatchery, North Platte, Nebraska (Summerfelt et al. 1993). There is also a relationship between average water temperature, size at harvest and length of the culture interval.

We have found a strong negative correlation between the length of the culture interval and survival (-0.77), and number of fingerlings harvested (-0.90). We have found equally strong positive correlations between length of the culture interval and yield (0.77–0.85), number of fingerlings/acre (0.90), and length (0.84–0.89), and weight (0.67–0.96) (Harding and Summerfelt 1993). These findings demonstrate that larger fish can be obtained by lengthening the culture season, but at a cost, which is lower survival. In research involving large numbers of ponds, differences in the length of the culture season of individual ponds can strongly bias the findmgs unless harvest dates are randomized among treatments or appropriate statistical methods (e.g., analysis of covariance) used to adjust for the length of the culture season.

Problem organisms

Weeds, invertebrate predators (both air-breathing and gill-breathing insects) and clam shrimp reduce survival and cause problems with harvest. It has been a common practice to control air breathing invertebrate insect predators in ponds by applying motor oil and diesel fuel to the water surface (Dupree and Huner 1984; see summary of methods used in undrainable ponds by Kinnunen 1996).

Net algae *(Hydrodicton)* has been reported to be a problem in walleye ponds in Ohio (Culver 1996) and VCNFH (Clouse 1991). In the past, copper sulfate and Aquazine™ have been used to control this problem at VCNFH.

Clam shrimp are small crustaceans that superficially resemble small clams (Figure 10). When abundant, clam shrimp are a nuisance in ponds used for production of fingerling fish because they clog screens during draining, and they are reported to cause a substantial reduction in fish production. When abundant, clam

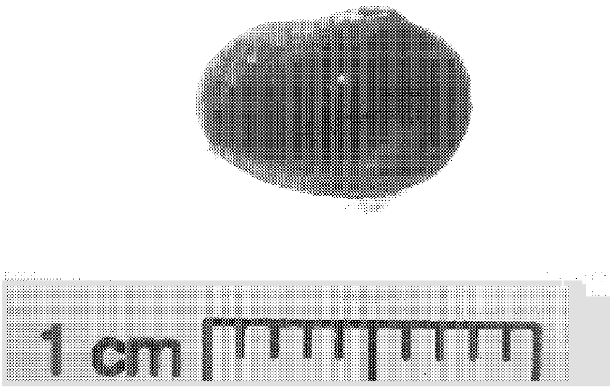

Figure 10. Photo of a clam shrimp, a nuisance organism in culture ponds because they clog the screens during draining.

shrimp have reduced the production of fingerling northern pike and goldfish (Dexter and McCarraher 1967). Clam shrimp also consume detritus, diatoms, and green algae (Strenth and Sisson 1975), competing for the same food resources used by copepods and cladocerans. Because clam shrimp lack predators, their populations continue to expand during the culture season; they can become so numerous that they clog the outlet screens in the kettle which may require frequent cleaning.

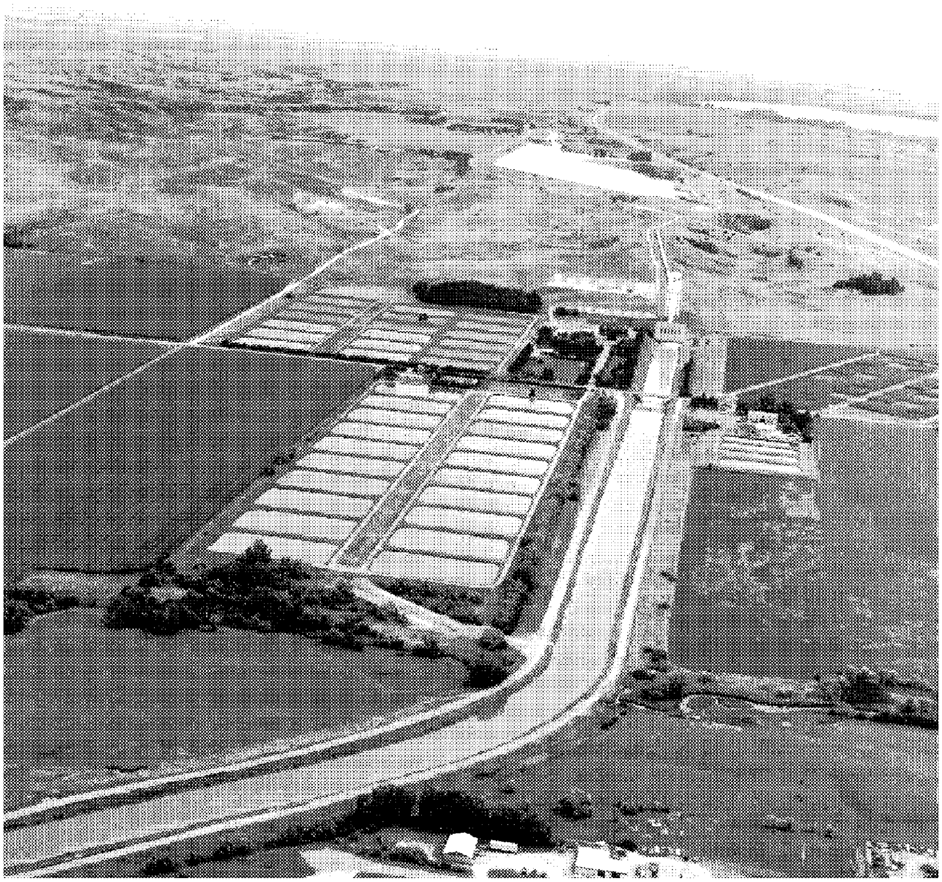

Figure 11. Aerial view of North Platte Fish Hatchery, North Platte, Nebraska, a facility of the Nebraska Game and Parks Commission. The 40 acres of ponds have been used for raising fingerlings of several species of coolwater (northern pike, walleye, muskie and tiger muskie, hybrid striped bass) and warmwater (channel catfish and grass carp fish). The block of 20, 1-acre (0.4 ha) ponds in the foreground are excellent for controlled experiments. Photo courtesy of Terrence B. Kayes.

Research needs

A driving force in pond management is the need to optimize capital costs for pond construction and to meet the increasing demand for fingerlings. Survival and growth of walleye at high densities (e.g., >100,000/acre, 250,000/ha) are dependent on pond management strategies that result in: (1) maintenance of good water quality (e.g., adequate dissolved oxygen); (2) development of large populations of desirable zooplankton and chironomids; and (3) minimization of undesirable animal and plant species that compete with the fish for food or which prey on fry.

Although pond production of walleye fingerlings in drainable ponds is commonplace by governmental agencies and is expanding in the private sector, site specific cultural procedures are used. Few experimental studies have been undertaken on many issues. Survival and yield of walleye in ponds is intimately associated with production of the right size and type of prey. Even though ponds are small, and the manager has control over fish stocking density and water and fertilizer inputs, ponds are complex ecosystems that defy precise control. Differences of opinion on the merits of inorganic and organic fertilizers means further studies to determine proper rates and types in relation to climate, water quality, and other site specific variables are needed. Although variation in yield among ponds is less than year-to-year variation, variability inherent in pond culture experiments requires many replicates to determine significant differences at conventional probability levels (Figure 11). Research also is needed to initiate feeding of phase I fingerlings on formulated feed before harvest, and for culture of a phase II fingerling in ponds on formulated feed rather than minnows.

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Pond Production of Fingerling Walleye at Garrison Dam National Fish Hatchery

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Introduction

The Garrison Dam National Fish Hatchery, located in central North Dakota, has been operated by the **U.S.** Fish and Wildlife Service since 1964 for the production of sport fishes. Up to 10 million walleye fingerlings are produced annually. Northern pike, hybrid walleye, largemouth bass, paddlefish, rainbow trout, and salmon are also cultured. The hatchery is situated below the dam of Lake Sakakawea, which serves as its primary water source (Figure 1). There are sixty-four 1.5-acre (0.61-ha) ponds. All ponds are equipped with outside kettles for fish harvest. This report describes contemporary procedures used at Garrison Dam National Fish Hatchery to produce walleye fingerlings.

Figure 1. One unit of 1.5 acre (0.61 ha) ponds at Garrison Dam National Fish Hatchery as viewed from dam.

Culture

walleye eggs are obtained from wild stocks at Devils Lake and Lake Sakakawea in mid-April. At this time of year, the hatchery water supply is approximately 35°F (2°C), and must be heated by boilers to provide more suitable water temperature for egg incubation. Manipulating water temperatures, however, enables us to control the length of egg incubation. Lengthening the walleye incubation interval to as much as 40 d allows us to double crop some rearing ponds, producing both northern pike and walleye fingerlings in tandem in the same rearing ponds, because northern pike spawn earlier in the year than walleye, and northern pike fingerlings require a relatively short rearing period. Extending the walleye egg incubation period allows us to raise a crop of northern pike fingerlings in a pond, drain and refill the pond, and then restock it with walleye fry. Although egg survival may be reduced for a 40 day incubation, the loss is a small price to pay for enabling us to double crop ponds.

Pond filling and egg hatching are coordinated by using a spreadsheet which predicts hatching dates based on cumulative temperature units. Pond filling begins approximately May 6, at which time the water temperature is near 50°F (10°C) and prolonged periods of cold weather are normally past.

Pond fertilization is based on information gathered by trial and error over 30 years. For many years alfalfa hay was chopped and added to the ponds. It performed well as a fertilizer, but was labor intensive to handle and spoiled quickly in storage when rained on. In 1992, we switched to alfalfa meal. The small particle size allows rapid decomposition and it does not plug screens during pond draining. Additionally, because it is stored in a bin, there is no spoilage. **A** grain box mounted on a trailer is used to transport the alfalfa meal to the ponds. The meal is broadcast onto the pond surface by an auger projecting out over the pond as the truck is slowly driven along the dike (Figure 2).

Fertilization begins immediately after pond filling using 133 lbs/acre (118.6 kg/ha) of alfalfa meal/application. Ponds are fertilized once every 3 d. Fertilization is discontinued 7 d before the anticipated draining date. Pond fertilization schedules are generated by a computer program. Dissolved oxygen levels are monitored closely. If dissolved oxygen levels fall below **5** mg/l at sunrise, when measured 1 ft (30 cm) above the pond

Figure 2. Alfalfa meal broadcast onto the pond surface at the Garrison National Dam Fish Hatchery.

bottom, fertilization ceases until oxygen levels recover. The maximum amount of organic fertilizer that can be safely used without oxygen depletion will be influenced by many factors, such as water temperature, natural soil fertility, cloud cover and the amount of phytoplankton present. However, no attempt is made to adjust fertilization based on plankton, pond color or other criteria. In 1995, cost of alfalfa meal for pond fertilization was about $75.00/acre ($185.00/ha)

Walleye fry, 1–2 d old, are stocked **9** d after the pond has started to fill with water. Fry are enumerated by water displacement (220/ml) and are transported to the pond in 5-gal (18.9-L) buckets which are equipped with a stone diffuser through which oxygen is bubbled during transport. Stocking rate varies from 166,000–200,000/acre (410,000–494,000/ha).

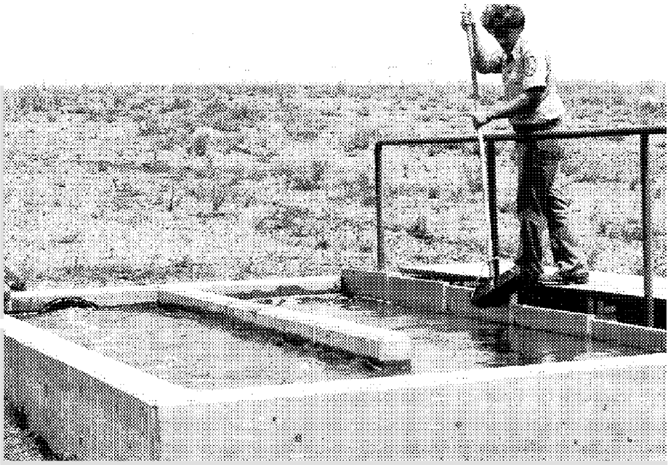

Figure **3.** Catch basin used at the Garrison National Dam Fish Hatchery for collecting walleye fingerlings discharged directly from 16 in (40 cm) pipe from the pond.

The culture period for walleye fingerlings is normally 29 d, but abnormal water temperatures can alter the culture period by as much as a week. **As** the anticipated draining time approaches, fish are sampled by seining every **3** d to determine fish size and condtion. When fish reach 1.25 inches (32 mm) total length, the pond is drained (Figures 3 and 4). However if sampling indicates that the fish have not grown, a food shortage probably exists, and the pond is drained before fish condition deteriorates further. We believe that survival after distribution is determined as much by fish con&tion as it is by fish size. Average production for the last 3 years has been 136,000/acre (336,000/ha) of 1,700/lb (3,744/kg) fingerlings. Average survival for the same period was 76%. **As** the pond bottom is exposed during the draining process, it is seeded with annual rye grass using a broadcast seeder at the rate of 33 lbs/acre (37 kg/ha). This is done to increase soil organic matter and to help control soil erosion.

Information gathered during the growing season is stored in a database. We have found this to be a convenient way to not only record information but to analyze the production data.

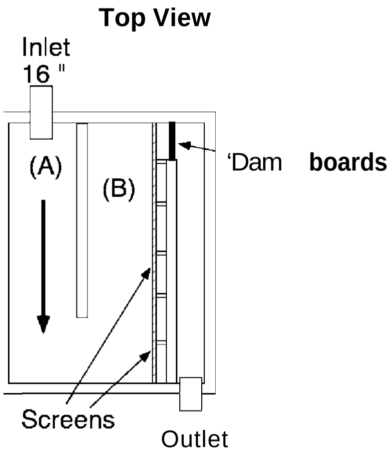

Figure 4. Schematic of catch basin shown in Figure **3.** Area A is the turbulent section which receives water from the pond. Area B is less turbulent and water leaves by passing through screens (Area B). Dam boards are used to set water depth in the kettle and may be removed for complete draining. For harvesting the fish, the inlet water is turned off and a crowder screen is used to force the fish out of A into B.

Wawronowicz, L. J., and W. G. Allen. 1996. Walleye fingerling production techniques in drainable ponds on the Lac du Flambeau Indian Reservation. Pages 111–113 *in* R. C. Summerfelt, editor. Walleye culture manual. NCRAC Culture Series 101. North Central Regional Aquaculture Center Publications Office, Iowa State University, Ames.

Walleye Fingerling Production Techniques in Drainable Ponds on the Lac du Flambeau Indian Reservation

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Introduction

Surface waters on the Lac du Flambeau Indian Reservation support a subsistence and sports fishery with walleye being the primary target species for harvest. Based on adult walleye population and recruitment estimates conducted during the spring and fall, the number, size, and lakes to be stocked with pond-reared walleye are determined. The purpose of the paper is to describe the techniques used by the Tribal Fish Culture Program for rearing walleye from fry to 1.75–2.25 in (44.5–57.2 mrn) fingerlings in drainable ponds. The reservation is located in north-central Wisconsin, approximately 80 miles (128 km) northwest of Wausau. The 92,000 acres (36,800 ha) of reservation land has 20,000 surface acres (8,000 ha) of water in 158 lakes and 34 miles (54.7 krn) of creeks, rivers, and streams.

Description of ponds

The ponds are 0.25–0.75 acres (0.1–0.3 ha) in size and are either lined with clay or HDPE plastic. The 12 ponds used in the program are 8.5 acres (3.4 ha) of which six, 0.5 acre (0.2 ha) ponds, are plastic lined. Average pond depth is 4.0 ft (1.2 rn) with 34 acre-ft (41,942 m^3) of water available for walleye production. Pond levee slopes are either 2:1 or 4:1 with 20 ft (6.1 m) levee crowns. The water supply is groundwater or lake water. The groundwater can be supplied to the pond at a rate of 1,000 gpm (3,790 Wmin) and lake water at 2,600 gpm (9,854 L/min). Lake water temperature ranges 40"–79°F (4.4"–26.1"C) during the production season and the groundwater is constantly 50°F (10°C). Both the groundwater and lake water have methyl orange alkalinity ranges from 20–70 ppm (mg/L) calcium carbonate, respectively. Soil associated with the watershed is Rubicon sand which has a pH ranging 4.5–6.0 and an organic matter content of 0.5–1.0%.

Pond preparation and fertilization

Pond preparation begins in the fall for the next production season. All ponds are left dry over winter. This consolidates the bottom, aides in disease control, and eliminates unwanted fish and plants. The earthen ponds are allowed to seep dry, rather than being rapidly drained, to simulate natural conditions that trigger cladocerans and copepods to produce resting eggs. The eggs survive the winter and contribute to the initial zooplankton present in the spring when the ponds are filled. Levees are repaired along with any plumbing problems and pond bottoms that are not plastic lined are planted with rye grass. The rye grass aides in erosion control and adds to the fertilization regime. In mid-April, the earthen ponds are disked to break down the rye grass and to aerate the soil. Rye grass is disked to breakup clumps of rye grass which may serve as starting sites for benthic algae. The ponds are partially filled about 4 weeks before walleye fry are stocked. Initially, the ponds are fertilized and filled to about one third the pond volume. This allows the water to warm faster which speeds up the establishment of zooplankton. Surface water from Pokegama Lake is used to fill the ponds, which is the same water source used to hatch the walleye eggs. We are able to observe the zooplankton in the unfiltered hatchery water, When the zooplankton are observed, water from Pokegama Lake is again pumped to the ponds to capitalize on the plankton in the lake water. An addtional one third of the pond is filled when we first see the plankton in the hatchery water and the final one third is added when the walleye eggs start to hatch.

Since 1980, many different fertilization programs were tried before it was decided that organic fertilization was the best alternative. The amount of fertilizer used largely depends on pond fertility, weather conditions, number and size of the fish, and the quality and quantity of the zooplankton population. Generally, we apply 1,175 lb/acre (1,335 kg/ha) of alfalfa meal and 118 lb/acre (134 kg/ha) of Torula yeast. The fertilization program usually begins by applying approximately ½ the total amount of fertilizer required when the pond is first filled, and subsequent applications are weekly, each about ⅛ of the total amount of fertilizer required during the production season (Table 1).

Table 1. Application rates lb/acre (kg/ha) of Alfalfa meal and Torulas yeast during the production season.

	1st	2nd	3rd	4th	5th	Total
Alfalfa meal [a]	587.5	146.88	146.88	146.88	146.88	1175.0
	(524.0)	(131.0)	(131.0)	(131.0)	(131.0)	(1048.0)
Torulas yeast	59.0	14.75	14.75	14.75	14.75	118.0
	(52.6)	(13.2)	(13.2)	(13.2)	(13.2)	(105.4)
Total	646.5	161.63	161.63	161.63	161.63	1293.0
	(576.7)	(144.2)	(144.2)	(144.2)	(144.2)	(1153.5)

[a] The initial application of alfalfa meal equals ½ of the total amount of fertilizer required, subsequent applications equal ⅛ of the total amount of alfalfa meal required. The same proportions are used for application of the Torulas yeast.

Alfalfa meal is broadcasted evenly around the pond with a scoop made from a one gallon milk container. Because Torulas yeast is a very fine powdery substance, it is applied as a slurry formed by mixing it in 50 gal (190 L) of water. The yeast and alfalfa meal are distributed evenly around the pond.

Monitoring of zooplankton

The ponds are monitored for zooplankton before and after the fry are stocked. Zooplankton are collected by using a 80 micron mesh net with a mouth diameter of 8 in (203 mm) and a length of 20 in (508 mm). The net is extended from a fiberglass pole and pulled through the pond for approximately 20 ft (6.1 m). Sampling areas of the pond will vary, but the windward side of the pond is usually sampled. The pond manager is responsible for determining the quantity and quality of the zooplankton populations before stocking and during the rearing season. Subsequently, the hatchery and pond managers make the decision when fry are stocked based on the age of the fry and the condition of the zooplankton population. We stock three-d-old fry, or fry that are strong enough to swim to a light located at the head end of a fry tank. Walleye fry are stocked at a rate of 120,000 fry/acre (300,000 fryha).

What constitutes a desirable zooplankton population? A subjective judgment, based on experience of the pond manager has been our guide. This is based on relative abundance, size, and species composition of the zooplankton determined by daily monitoring of the ponds. In general, at the time of stocking, copepods and rotifers of various sizes should be abundant, and only a moderate number of daphnids (water fleas). As the rearing season progresses, there should be more daphnids than copepods and chironomid larvae as well. The condtion of the zooplankton is also noted. The biologist looks for the presence of egg or embryos in the zooplankton and the relative size composition of the zooplankton. These observations provide the pond manager the information required to know if more fertilizer is necessary to maintain the zooplankton population. If, for example, the relative abundance of copepods is decreasing compared with previous samples, and there are no large-bodied cladocerans present, and the zooplankton that are present are not reproducing, the pond manager would fertilize if oxygen concentrations at sunrise are adequate (>5 mg/L). If oxygen concentrations are less than 4 ppm (mg/L), and the weather is predicted to be cloudy, hot, and with little or no wind, the ponds should not be fertilized because the additional fertilizer will result in decreased oxygen concentration when the fertilizer begins to decompose.

Monitoring oxygen and pH

We monitor oxygen concentrations at sunrise using an oxygen meter. Samples are usually collected at the deepest area of the pond at mid-depth. On occasion, all ponds will be sampled more thoroughly to determine if there is oxygen and temperature stratification. The most critical interval for low oxygen is from mid-June to July when the walleye are harvested. The rearing volume may be reduced by half when oxygen stratification occurs, with oxygen concentrations of <2 ppm (mg/L) from the pond bottom to mid-depth. If low oxygen concentration or stratification occurs, we draw-off the bottom water and replace it with aerated cooler lake water or cold groundwater.

Because our ground and lake water have low alkalinity (i.e., buffering capacity), the pH is monitored in the morning, afternoon, and after dark to spot pH changes occurring as a consequence of photosynthesis and respiration. Water samples for pH monitoring are collected at mid-depth and at the surface. Changes in pH were a preliminary concern when we lined the ponds with plastic liners because we thought that if the soil was covered, the buffering capacity of the water would be changed, however, we found that pH readings in the lined ponds were not substantially different from that of the clay lined ponds.

Monitoring fingerlings and aquatic insect control

We do not actively sample walleye to determine growth rates or condtion factors during the production season. Growth, condition, and density are casually observed and noted daily. Generally, walleye fingerlings can be observed near flowing water during the daylight hours, 14 d after stocking. At 14 d, the fingerlings are approximately 0.75 in (19.1 mm) and can be easily observed.

When necessary, to control air-breathing piscivorous aquatic insects, a portion of a mixture of **3** gal (11.4 L) of fuel oil and 1 qt (0.95 L) of 30-weight motor oil is applied to the surface of the pond. Ponds should not be treated until fish are at least 12–14 d old, which avoids affecting swirnbladder inflation.

Harvest methods

Five fyke nets and a seine are used to harvest fingerlings from the ponds. The fyke nets are made of ⅛ in (3.2 mm) mesh, with 4 ft gates (1.2 m), and **3** ft (0.9 m) diameter hoops; they are used with a 25 ft (23 m) lead. The seine has ⅛ in (3.2 mm) mesh, it is 300 ft (275 m) long x **8** ft (7.3 m) deep. Fingerlings are crowded toward the water supply line by seining ½ to ¾ of the pond. Fyke nets are set in the un-seined portion of the pond. The pond is slowly drained while fresh water is added. Seining and setting of the nets occur in the morning and the nets are checked every **3** h. Two floating boxes are used to place the walleye fingerlings in when removed from the nets. The boxes, which look like a jon boat with two bows, are approximately 3 x 4 x 1 ft (0.9 x 1.2 x 0.3 m) and are constructed so the bottom and the 3 ft (0.9 m) sides are screened to allow for water exchange. Water is exchanged by simply moving the boxes through the water. When all nets are harvested, the boxes are floated to a pond side site where the length, number of fish/lb, and total weight of the fish harvested are determined. The fish are transferred to a hauling truck and transported in a 1.0% saline solution to reduce physiological stress. Because the tribal government does not allow the use of herbicides and the ponds do not have catch basins, our harvest method was initially designed to harvest walleye in ponds that had aquatic vegetation problems. The method proved to be so effective and easy on the fish under poor harvest conditions, we now use this method all the time.

Yield

Typically we raise walleye to 2 in (51 mm) in 40 d. Given a size of 7 mm at hatching, the growth rate is about 0.043 in/d (1.10 mm/d). The fingerlings range 417–450 fish/lb (917–990 fish/kg) at harvest. Annual survival to 2.0 in (51 mm) is variable; it ranges from 30–75%.

Culver, D. A. 1996. Fertilization procedures for pond culture of walleye and saugeye. Pages 115–122 *in* R. C. Summerfelt, editor. Walleye culture manual. NCRAC Culture Series 101. North Central Regional Aquaculture Center Publications Office, Iowa State University, Ames.

Fertilization Procedures for Pond Culture of Walleye and Saugeye

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Introduction

Our research on fertilization and stocking strategies for walleye production ponds was stimulated by the unacceptable variation in the survival and growth of walleye fry to stockable-sized fingerlings in the ponds. Some of this variability is the result of low dissolved oxygen and/or high ammonia and pH. In many cases, the fish ponds developed a blue-green phytoplankton bloom with little or none of the edible and most useful algae for zooplankton, particularly if low N:P ratio fertilizers are used (Helal and Culver 1991). The zooplankton on which the fish depend also has been shown to vary profoundly in abundance, with an abrupt decline often occurring after a clear-water period 4 or 5 weeks after the ponds are filled, forces fish to switch to feeding on chironomids. An additional problem is that large mats of filamentous algae often float to the surface just before ponds are scheduled to be drained. As water levels drop during draining, fish often hide under these mats and are smothered. Mats also collect in the kettle areas where fingerlings are being netted out of the ponds and are difficult to separate from the fish. Clearly, research on suitable fertilizers must be directed toward the water quality and the algae and zooplankton produced, not simply correlated with fish production results.

While different abiotic (e.g., light, temperature) and biotic factors (e.g., food availability, competition, predation) have been found to regulate zooplankton abundance and thus fish growth in ponds, the most convenient variables to manipulate in managing hatchery ponds are: 1) amounts, timing and types of fertilizer inputs; 2) stocking schedules relative to pond filling times; and 3) the number of fish stocked. In determining the best strategies to use in Ohio hatchery ponds for culturing walleye and saugeye we have thus concentrated on these variables. Our approach has been to apply the results of research on lakes to suggest how plankton production might be optimized for fingerling production rather than to simply associate fish yield with various fertilization and stocking regimens. For example, when we tested various N:P ratios by fertilization with a combination of inorganic and organic fertilizers (Qin et al. 1995), and varied the number of days between the time when ponds were filled and the fry are stocked, we measured nutrient concentrations, phytoplankton composition and abundance, zooplankton composition and abundance, and fish diets from stomach content analysis throughout the production season in replicated pond treatments. We then interpreted the results in light of published results of eutrophication and trophic dynamics research in lakes.

Findings from limnological research involving different trophic levels that are applicable to problems in managing fish ponds include the following:

1) Small algae, most easily eaten by crustacean zooplankton, grow best when the inorganic nitrogen to reactive phosphate (N:P) ratio in the pond is above 7:1 by weight.
2) Algae favor ammonia over nitrate as a N source.
3) N:P ratios < 7:1 often favor nitrogen-fixing blue-green algae (Helal and Culver 1991), many of which are filamentous (inedible by many zooplankton) and/or may produce toxins harmful to fish and zooplankton.
4) Under low phosphate concentrations, small algae species (edible) are competitively favored relative to large green and blue-green filamentous species. Many large algae also store phosphorus in times of abundance in polyphosphate granules and then can supply daughter colonies for weeks.
5) Cladoceran production is enhanced by a high abundance of edible algae but these algae are overgrazed when cladocerans persist in high densities causing clearwater periods (Qin and Culver 1995a,b).

6) In the absence of fish predation, *Daphnia* suppresses copepods and smaller cladocerans such as *Bosmina* through competition for food (Culver et al. 1984).

7) Planktivorous stages of walleye and saugeye preferentially select large crustaceans, with copepods being preferred over cladocerans.

8) Under lower edible algal availability during clearwater periods, crustacean zooplankton reproduction rates decline, making them numerically more susceptible to fish predation (Wu and Culver 1994).

A number of Ohio hatchery production problems have been addressed using limnological strategies. We highlight five of these problems below, along with the means for their solution.

1) Maintaining an adequate abundance of copepods and cladocerans for fish growth and survival: We encouraged growth of small algae (diatoms, coccoid greens, flagellates) for growth using liquid inorganic fertilizers once per week to achieve an inorganic N:P ratio of 20:1 by weight, with no more than 30 µg phosphate-P/L. The ratio began changing immedately upon fertilization, but we restored it to 20:1 once per week. We stocked fish at 4–5 **d** of age and filled ponds at the same time using reservoir water. High densities (over 50/l) of zooplankton were not necessary to provide adequate food for fry at stocking. Walleye consumption per day per fish was very low initially and increased exponentially with time (Madon and Culver 1993). The zooplankton bloom grew along with the walleye's appetite, and we avoided overgrazing by *Daphnia* by stocking sufficient fish to prevent overabundance of *Daphnia* in week *4* or *5* (Culver et al. 1984).

2) Avoiding high ammonia concentrations in the ponds, especially during the clearwater phase during week 4 or 5*:* We measured nutrients in ponds once a week and fertilized up to a target inorganic P concentration and N:P ratio, rather than using one fixed fertilizer amount.

3) Avoiding low oxygen concentrations: We used no organic fertilizers. For each unit of photosynthetically-produced biomass, one unit of oxygen is released to the water; for each unit of heterotrophically produced biomass, one unit of oxygen is consumed.

4) Avoiding large filamentous green and blue-green algae: We maintained a low phosphate concentration, favoring those algae (mostly small species) whose phosphate uptake mechanisms become saturated at low concentrations. Addition of large amounts of fertilizer at one time, especially when ponds are filled, favored large filamentous phosphorus storers, so we fertilized often with small amounts of N and P. We restored the N:P ratio in the pond to 20:1 once per week to minimize growth of nitrogen-fixing filamentous blue-greens. Also, we found many filamentous greens and blue-greens grew heterotrophically on the bottom of the pond, especially in those ponds to which organic fertilizers such as alfalfa meal had been added. When ponds cleared up, these algae were still rich with phosphorus from the sediments and were able to photosynthesize sufficiently to produce oxygen bubbles which caused them to float up to surface just when we wanted to harvest fish. Another genus, *Hydrodictyon*, did not float up, but it acted as a mini-gill net, killing fry and even fingerlings. Heavy fertilization at the clearwater period would also favor this species. After a suitable fertilization regimen was identified, we adjusted the density of stocked fish to obtain the optimum trade-off among zooplankton abundance, fish size, and numbers produced.

Application to hatchery ponds in Ohio

walleye and saugeye production research was performed at the Hebron, Senecaville, and St. Mary's state fish hatcheries (total of 80 drainable ponds) in Ohio. All three hatcheries draw water from mesotrophic or eutrophic reservoirs, with significant agricultural activity in the watersheds. Depending upon weather, there can be tremendous differences in the nutrient concentrations in the water used to fill the ponds, from essentially no inorganic nitrogen or reactive phosphate to as much as 0.25 mg N/L as ammonia and 1.2 mg N/L as nitrate. In this last case, rainfall occurred at St. Mary's, OH, just after many farmers had fertilized their fields. Water sources for all three hatcheries have total alkalinity values of 80–111 mg/L as $CaCO_3$. Reservoirs usually have spring blooms of phytoplankton and diverse populations of zooplankton at the time ponds are filled.

Pond sizes and shapes differ among the hatcheries, with Hebron and Senecaville having primarily individually fillable and drainable 1 acre (0.4 ha) rectangular ponds averaging 3 ft (1 m) deep, whereas St. Mary's ponds vary from 0.1–7 acres (0.04–2.8 ha) in size, and many are arranged as groups of three ponds served by a single fill valve with two ponds fillable only by sequential overflow from the pond with the fill valve. All three are in turn drained by underground pipes feeding a single concrete harvesting kettle. Ponds at St. Mary's are currently under renovation to make them more uniform in size and to provide individual control of filling and draining.

Filling is delayed until just before fry are ready to be stocked so that the abrupt plankton decline that occurs 4-5 weeks after ponds are filled will occur as late into the production season as possible. Lake water is passed through a filter, either a 0.01 in (0.25 mm) mesh metal microstrainer (Hebron), a sand filter (Senecaville), or 0.01 in (0.25 mm) mesh screens in each pond (St. Mary's) to remove eggs of fish such as gizzard shad or common carp as the ponds are filled. Previously, saran sack filters (0.02–0.03 in, 0.5–0.7 mm mesh size) were fastened over inlet pipes for each pond. In order to maintain known nutrient inputs, no additional water is added after the ponds are filled except to make up for evaporation losses.

Brood stock and fry production

Fry stocked in the ponds are produced in jar hatcheries managed cooperatively among the three hatcheries to optimize use of spawning runs of walleye in Salt Fork and Senecaville Lakes (early, 1 April) and the Maumee River and reefs of Lake Erie (later, 17–18 April) and water temperatures available for running the jar hatcheries and for filling the ponds. Hebron warms up first, followed by Senecaville, and then St. Mary's. Numbers of fry that are stocked are estimated by counting a measured volume of settled fry in a cylinder, and by then generating estimates of volumes of fry needed to obtain the desired stoclung densities in the ponds, typically 180,000/acre (445,000/ha). Increasing attention is being given to avoiding introduction of zebra mussels into the hatchery with eggs and milt from Lake Erie. Zebra mussels may someday become established in the hatcheries due to introduction from fishing boats trailered between sites such as Lake Erie and the reservoirs that are used to fill the ponds, so the hatcheries are being monitored for zebra mussel adults, veligers, and settling juveniles.

Fertilization of the ponds

We use liquid nitrogen and phosphorus fertilizers from agricultural suppliers exclusively. For nitrogen fertilization, we use 28:0:0 which is a combination of urea and ammonium nitrate. All hatcheries now use phosphoric acid (0:54:0) as a phosphorus source. We cannot infer the N:P ratio of a *dry* fertilizer directly by the N:P:K ratio, since in this notation the N is percent weight as N, the P is as P_2O_5, and the K is as K_2O. For liquid fertilizers, one needs not only the percent N and P per weight of fertilizer but also the specific gravity (weight per volume) of the fertilizer to determine the expected N and P content per volume. Furthermore, none of the agricultural fertilizers we have purchased contained exactly the amounts of N and P expected. Nevertheless, for planning purposes, 28:0:0 fertilizer has about 4 lb N/gal (480 g N/L) (half as urea), and phosphoric acid is about 3.3 lb P/gal (396 g P/L). A typical 1–1.2 acre (0.4–0.5 ha) pond with no inorganic nitrogen or reactive phosphate will receive 1.3–1.6 gal (5–6 L) of the former and 10 fl oz (300 ml) of the latter. We have also used 10:34:0 liquid fertilizer (ammonium phosphate) plus 28:0:0 to obtain the desired additions, but the calculations are simpler using phosphoric acid and 28:0:0. Hatchery staff have reported no difficulties working with concentrated phosphoric acid, provided care is exercised, and they appreciate the much smaller volumes that need to be used. Measurements must be accurate: there is a big difference between the response of the algae to 30 µg (i.e., 10 fl oz/ac, 750 ml/ha) and 60 µg/L of phosphate (i.e., 20 fl oz/ac, 1500 ml/ha).

We analyzed each batch of all fertilizers, since we commonly find contamination, as well as variation in strength. For example, one batch of 28:0:0 had 0.24 lb P/gal (29 g P/L) as a contaminant, which not only complicated the computations, but would have resulted in adding 2.2 times the intended phosphorus dose had 1.3 gal (5 L) of it been added. To measure the ammonia and nitrate concentration of the 28:0:0 and phosphorus fertilizers, we first diluted them to 1:200,000 or 1:300,000 with ammonia-free (run through a cation exchange column) double-distilled water and then analyzed the diluted solution with ion-specific electrodes for ammonia and nitrate respectively (see below). Urea content is typically analyzed by measurement as ammonia after treatment with urease, a procedure used by all hospitals to measure blood and urine for urea-N content. This test can measure urea accurately over the range of 0.01–2 g/L urea N, so we only dilute fertilizer samples 1:1,000 before submitting them to local hospitals, who either perform the analyses free or for a small fee. Note that they report urea as mg N/dl (deciliter or 100 ml), not liter. We dilute phosphoric acid to 1:2, 1:3, and 1:4 million with double distilled water before analysis to test for consistent results in the range for which the ammonium molybdate method is accurate.

Immediately after the pond fills, we raise the inorganic concentration to 600 μg/N/L and P to 30 μg PO_4-P/L, and then maintain this concentration each week thereafter using the appropriate volumes of nitrogen and phosphorus fertilizers. This requires first measuring the ammonia, nitrate, and phosphate concentrations in each pond. We use ion-specific electrodes for ammonia and nitrate and the acid molybdate/stannous chloride method for phosphate (APHA et al. 1980). The ammonia method requires a digital pH meter that can be read in millivolts, an ion-specific ammonia electrode (e.g., ORION 951201), a magnetic mixer, dilute standards of 50–1,000 μg NH_3-N/L made fresh each week in distilled, ammonia-free deionized water, an alkaline ionic strength adjusting solution (e.g., ORION 951211), and the solution for filling the electrode. Nitrate requires the same meter, a nitrate electrode (e.g., ORION 930700), a reference electrode (e.g., ORION 900200 plus solutions), standards, and an ionic strength solution called Nitrate Suppressor Solution (e.g., ORION 930710). The suppressor solution is both a pH buffer and a solution to remove interfering ions. For example, it contains silver sulfate to precipitate chloride ion, sulfamic acid to remove nitrite, a buffer at pH 3.00 to remove bicarbonate and carbonate, and alum to complex organic acids. Instead of using the recommended 10 ml suppressor solution plus 10 ml sample or standard, we use 5 ml of suppressor and 15 ml of sample or standard (or even 2 ml + 20 ml) as this gives a greater millivolt response per mg nitrate.

Phosphate is measured using acid molybdate and either stannous chloride or ascorbic acid methods (APHA et al. 1980) using a spectrophotometer or colorimeter. We prefer the stannous chloride method because it is more sensitive and allows for correction for turbidity. We have found a Klett-Summerson colorimeter with a 4-cm light path to be less expensive than a spectrophotometer, but quite effective.

Complete equipment, glassware, stock solutions, and supplies for these analyses are available from scientific supply houses such as VWR and Fisher Scientific, and cost about $5,000. Some effort was required to find a source of distilled water low enough in phosphate to give low blanks and accurate standards. Analyses for 30 ponds requires one person-day, although our staff usually divides up the tasks of sample collection, and nitrogen and phosphorus analyses among three persons.

Once the N and P concentrations of fertilizer and ponds are known, we use them and the volume of each pond at the current water level to calculate the amounts of N and P fertilizers to add to each pond that week to restore phosphate to 30 μg/L and inorganic N to 600 μg/L using the following formulas:

$$\mathbf{1.\ Vpf = \frac{(30\text{-}Pp)\ Vp}{Pf \times 1000}}$$

where: Vpf = volume of phosphorus fertilizer needed (L); Pp = phosphorus concentration measured in pond (pg P/L); Vp = volume of water in the fish pond (m^3); Pf = phosphorus concentration of fertilizer (g P/L); and 1,000 is the combined conversion factors between L and m^3 and between μg and g.

$$\mathbf{2.\ Na = \frac{(30\text{-}Pp)\ Nf}{Pf}}$$

where: Na = nitrogen added by ammonium phosphate fertilizer (pg N/L); Pp = phosphate concentration measured in the pond (pg P/L); Nf = nitrogen concentration of ammonium phosphate fertilizer (g N/L); and Pf = phosphate concentration of ammonium phosphate fertilizer (g P/L). If phosphoric acid is used as the phosphorus source, this calculation is not required.

$$\mathbf{3.\ Vnf = \frac{(600\text{-}Np\text{-}Na)\ Vp}{Nf \times 1000}}$$

where Vnf = volume of nitrogen fertilizer needed (L); Np = inorganic nitrogen concentration (NO_3^-+NH_4^+) in the pond (μg N/L); Na = nitrogen added to the pond by P fertilizer from equation 2 (μg N/L); Vp = volume of the pond (m^3); Nf = nitrogen concentration of fertilizer (ammonia plus nitrate plus urea (g as N/L)); and 1,000 again is the combined conversion factors between L and m^3 and between μg and g. The calculations of nitrogen and phosphorus fertilizer to be added are made assuming that either phosphoric acid or ammonium phosphate (10:34:0) is the P fertilizer form and that neither is the phosphoric acid contaminated with nitrogen, nor is the nitrogen fertilizer (28:0:0) contaminated with phosphorus.

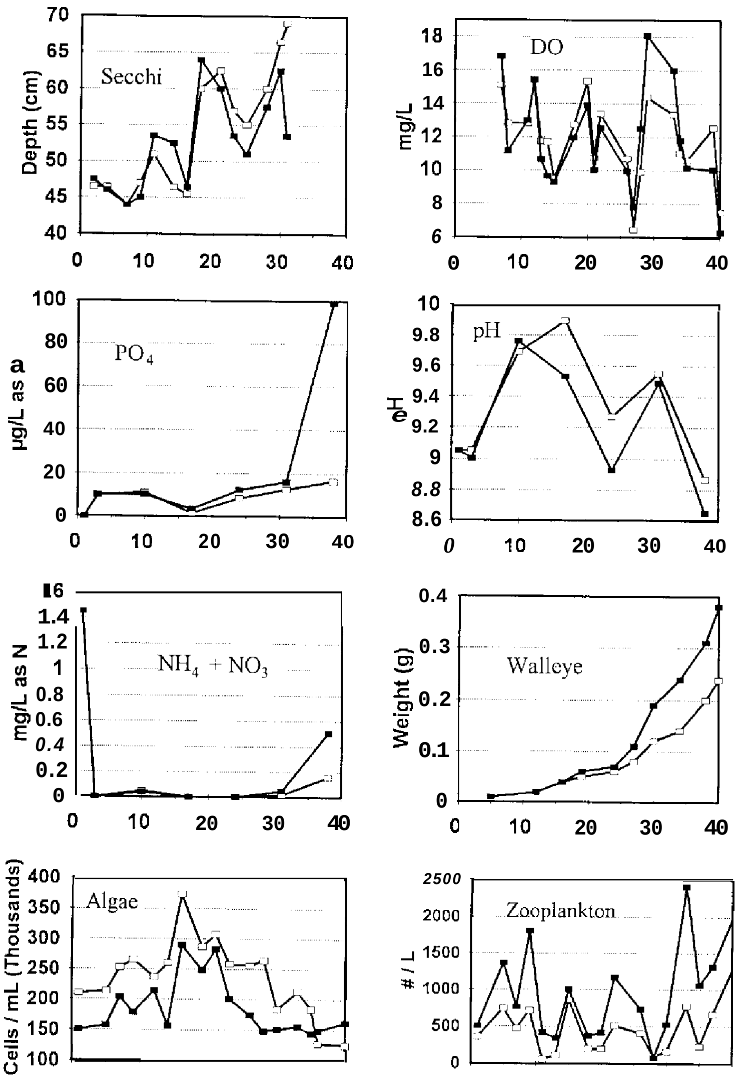
As noted above, we only use liquid inorganic fertilizer. Not only does organic fertilizer contribute to oxygen problems (Qin and Culver 1992, 1995b; Qin et al. 1995), but it is also not possible to alter the relative amounts of N and P in organic fertilizer (Culver 1991), nor is it possible to know with certainty when or where the N and P contained in organic fertilizer will be released into the pond. Inorganic fertilizers are also less expensive than organic fertilizers. In 1993, phosphoric acid cost $412/metric ton, and $90 purchased sufficient fertilizer to supply all three hatcheries for the season. Nitrogen fertilizer (28:0:0) cost $150 per metric ton, or about $400 for the season for all three hatcheries. Adding 90 lbs (40 kg) alfalfa meal to a single 1 acre (0.4 ha) pond (equivalent to adding 10 mg/L) for each of 6 weeks cost $69 for the season. Inorganic fertilizer cost an average of $490/80 = $6.13/pond for the season.

Liquid fertilizer is added to the tank of an agricultural sprayer that is attached to a tractor and diluted with 50 gal (200 L) of pond water, and the solution is sprayed over the surface of the pond as the tractor travels along the dam. Some practice is required to time tractor speed to spray the entire contents of the tank in one pass. Measuring out the fertilizer went quickly using carboys with spigots for dispensing the phosphoric acid and larger polyethylene tanks with valves for the nitrogen fertilizer. In practice, the N and P are depleted by the next week in most ponds. More than half of our ponds needed the full 600 µg/L N or 30 µg/L P. **If** pond concentrations of N (or P) exceeded the target of 600 (or 30) µg/L, no fertilizer of that form was added until the concentration dropped below the target level.

Biological monitoring

The progress of the seasonal bloom of algae was followed with weekly algal counts or more frequent measurements with a Secchi disk (Figure 1). The data in Figure 1 are from St. Mary's hatchery in 1990 from a group of ponds stocked at two different fish densities. Secchi transparency can be seen to decrease and then

Figure 1. Comparison of high and low fish stocking density effects on various parameters in inorganically-fertilized ponds (2 per treatment) at the St. Mary's State Fish Hatchery, 1990.



Hollow squares = high fish density (216,000/acre, 540,000/ha), Filled squares = low fish density (104,000/acre, 260,000/ha). Secchi disc transparencies after day 32 were to the bottom of the pond, or about 1 m. Walleye biomass is shown as mean individual wet weights from twice-weekly samples of 10 or more fish seined from each pond.

increase as imperfect evidence of an algal bloom that builds and declines as a result of a zooplankton bloom that occurred in the ponds. The dynamics of the algae and zooplankton can also be followed by their indirect effects on water chemistry. For example, oxygen declined throughout the season as the algae declined. Lower algae abundance resulted in lower photosynthesis, resulting in lower oxygen concentration. The pH tends to be high when photosynthesis is high and declines later in the season. Measurements of N and P are shown for the initial conditions and for subsequent weeks, 6 d after each fertilizer addition. When algal abundance becomes low, added nitrate, ammonia, and phosphate will be left over the next week when analyses are performed (e.g., day 38), since there are insufficient algae to assimilate what we add plus what is released by decomposition and animal excretion (Qin et al. 1995). Here, analysis of N and P in the ponds is particularly important, since hatchery managers may see an increase in Secchi transparency, assume that addtional fertilizer was required, and then overfertilize the ponds.

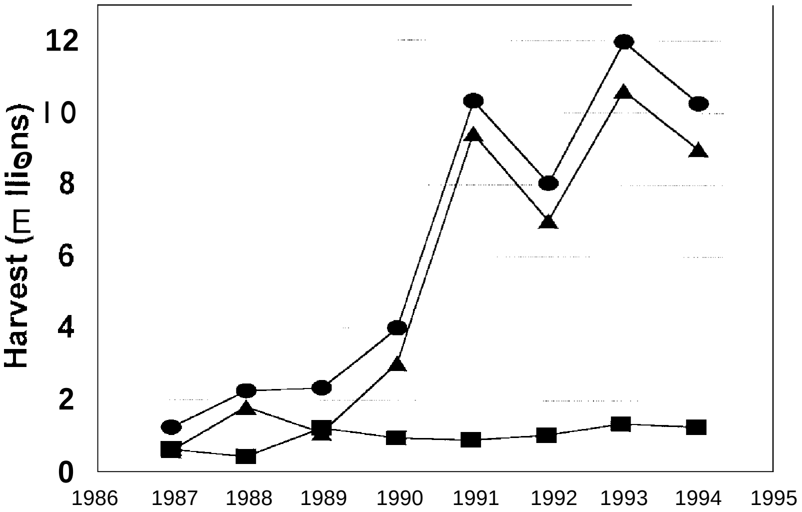
Fish growth is monitored weekly, and the pond draining is influenced by whether growth exceeds 1 mm/d, apparent condtion of the fish, and whether they are > 25 mm. Fish are usually harvested when they are 30–40 mm; larger fish are easier to harvest, as they are less likely to be pressed against the screens on the kettle by the draining currents. Growth is affected by stocking density, but it is difficult to follow this through the season, since survival is not 100% and one cannot know with certainty when mortality occurred. If we assume that most mortality occurs the first week after stocking, however, we can compare growth of fish living at different densities using their abundance at harvest. Walleye and saugeye attained larger size at harvest densities below 32,000/acre (80,000/ha). Above that density, however, fish size at harvest stays constant (at about 0.3 g wet weight) up through at least 144,000/acre (360,000/ha). A constant fish size at harvest with increasing harvest numbers implies that greater yield occurred at higher harvest numbers, which was indeed the case, We found walleye yield (kg/ha) = 24.2 + 0.0002 HD, where HD is the harvest density in number of fish/ha (Culver et al. 1993). A similar regression for saugeye was Yield = 12.6+ 0.0003 HD.

Improving survival was a major goal of our project, and this has been achieved: The percent of ponds at the Hebron hatchery with < 10% survival declined from 55% to 0%. For ponds at the St. Mary's hatchery, which were used to illustrate results in this paper, survival varied from 46–86%, and the mean was 63%, over a range of stoclung densities from 100,000–240,000 fry/acre (248,000–596,000 fry/ha). Average survival across all ponds among the three hatcheries in 1991 was 64%, with a yield of 86,000 fingerlings/acre (215,000/ha), and a wet weight of 61 lbs/acre (68 kg/ha) (Culver et al. 1993).

These improvements in survival and yield have been reflected in both walleye and saugeye culture. Since 1986, the greatest demand for stocking in state waters has been for saugeye, so the increase in overall production due to the adoption of our fertilization, filling, and stocking regimen is reflected primarily in the production of saugeye (Figure 2). The same pond management protocol has been used for both taxa, and their growth and survival rates did not differ (Culver et al. 1993, Qin et al. 1994).

Our filling, stocking, and fertilization regimen has resulted in a 10-fold increase in total production of percids by the Ohio

Figure 2. Total harvest of percid fingerlings from St. Mary's, Hebron, and Senecaville Hatcheries, OH, 1987-1994.



Rectangles = walleye. Triangles = saugeye. Circles = total percids.

state hatchery system since 1987 (Figure 2) without an increase in personnel. The actual increase in fish produced per acre (hectare) is about 5-fold, since some of the increase represents the use of more ponds. Weekly chemical analyses and fertilization require more time than previous regimens, but more reliable water quality has decreased the need for intervention during low oxygen occurrences. Discontinuing the use of alfalfa hay and meal has, in turn, decreased labor and material costs, while increasing survival of fish. More reliable production has decreased the number of ponds needed to meet production goals.

These techniques may need to be adjusted for other locations where lower or higher inorganic carbon content (alkalinity), warmer or colder water temperatures (ours ranged from 52–73°F, 11–23°C), or differently-shaped ponds might alter the dynamics of the system. For example, we use lower phosphorus additions in our deep ponds and in lakes. Still, chemical and biological monitoring of the production season and high stocking density have successfully decreased the variability among ponds, while increasing the number and weight of fish produced per acre.

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Fingerling Production in Drainable Ponds at White Lake Fish Culture Station

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Introduction

White Lake Fish Culture Station (hereafter referred to as White Lake) is operated by the Ontario Ministry of Natural Resources (OMNR) and is presently the only government hatchery in the Province that raises walleye. In 1982, a new Provincial initiative established a Community Fisheries Involvement Program (CFIP). Under this program many walleye culture projects were begun as partnerships between community groups and local OMNR districts. Most of the walleye stocked in Ontario during the last 10 years have come from community operated ponds.

In recent years, a considerable amount of research and experimentation has been devoted to pond culture at White Lake. Walleye have been stocked at different densities in culture ponds to examine its effects on prey density and on walleye growth and survival. Other studies have compared various fertilization regimens using organic and inorganic fertilizers and examined their effects on pond dynamics and walleye growth. These studies have helped government and CFIP hatcheries manage ponds more effectively for fingerling production.

In Ontario, pond culture begins in May when fry are stocked into fertilized ponds. Fry feed on zooplankton and insect larvae for 6 to **8** weeks and grow to 1.6–2.4 in (40–60 mm) by early July. At that time, they are usually harvested and stocked in local lakes, or brought indoors for further intensive culture using artificial feeds. Some CFIP groups have been quite successful supplementing ponds with minnows to extend the growing season and produce larger fingerlings.

This case study describes pond management techniques used at White Lake that have evolved from traditional culture methods used in Ontario and from research findings at White Lake and elsewhere.

Pond management techniques

White Lake has ten small ponds for walleye production that have a combined total surface area of 2.6 acres (1.05 ha). Six ponds were designed as replicates for experimental work, each has a surface area of 0.1 acre (0.04 ha), mean depth of 3 ft (0.91 m) and a volume of 0.28 acre-ft (345.4 m^3). The remaining four ponds are designated production ponds (Figure 1). They have larger surface areas (0.4–0.6 acres, 0.16–0.24 ha) and are more variable in shape and depth (mean depth 2.5–3.4 ft, 0.76–1.04 m). Although pond stocking and fertilization rates are often based on surface area, at White Lake, these parameters are based on pond

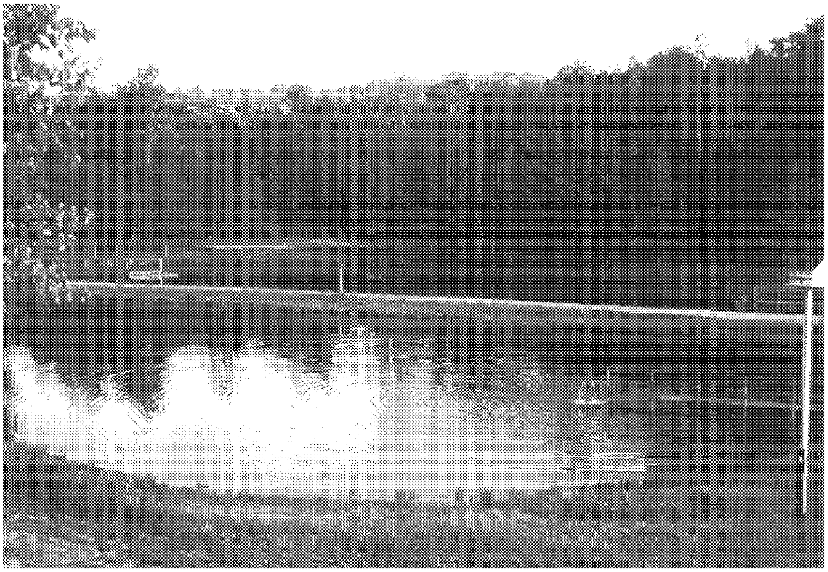

Figure 1. Production ponds at White Lake.

volume using acre-ft (volume of water covering 1 acre (0.4 ha) to the depth of 1 ft (0.3 m)) as the standard unit of measure. Pond volume should be considered when determining how many walleye can be stocked in a pond, especially when using small ponds having similar surface areas, but significantly different volumes. Studies at White Lake have used surveyed pond volume measurements to more accurately determine stocking rates for ponds of different sizes (i.e., for fish density studies) and to help standardize fertilization rates and phosphorus inputs between ponds.

There are many factors that affect annual variation in pond production. Variability in water quality and uncontrollable parameters, such as the weather, cause problems when trying to maintain adequate zooplankton populations. In addition, cohort competition and cannibalism will limit the consistency in fingerling size and numbers produced from ponds. While there is little we can do to compensate for poor weather, good pond management practices are essential to consistent fingerling production.

Pond preparation

Many of the ponds at White Lake are used to raise salmonids over the winter, however, they are completely drained in the spring and left dry for at least 10 d before refilling. Drying stabilizes the pond substrate, reduces aquatic vegetation growth and facilitates the oxidation of accumulated fecal matter and excess feed. The water source for the ponds at White Lake is from a natural mesotrophic lake. The inflow to each pond is fitted with a retaining screen to prevent the entrance of undesirable fish during initial filling. Ponds are filled at least 2 weeks prior to walleye introductions to ensure adequate time for zooplankton development. Inflows are usually shut off during the culture period to prevent dilution of nutrients, but minimal flows may be used to offset evaporation and seepage.

Initial pond stocking densities

The stocking rate for White Lake ponds has traditionally been 50,000 fry/acre-ft (40.5 fry/m^3). In 1988 ponds were stocked at 3 densities (24,670, 49,340 and 74,010 fry/acre-ft; 20, 40 and 60 fry/m^3), to study the effects on walleye growth and survival. In 1988, survival from stocking to harvest during a 6-week culture period was not affected by stocking density, however, size at harvest was density-dependent (i.e., fish were smaller in ponds stocked at the higher densities). Growth differences began to appear after week 3 (Figure 2) and at 6 weeks fingerlings harvested from low density ponds weighed 40% more than fingerlings from high density ponds (Table 1).This study suggests that at high fish densities competition for space and food would limit walleye growth and will ultimately lead to significant cannibalism and density-dependent mortality.

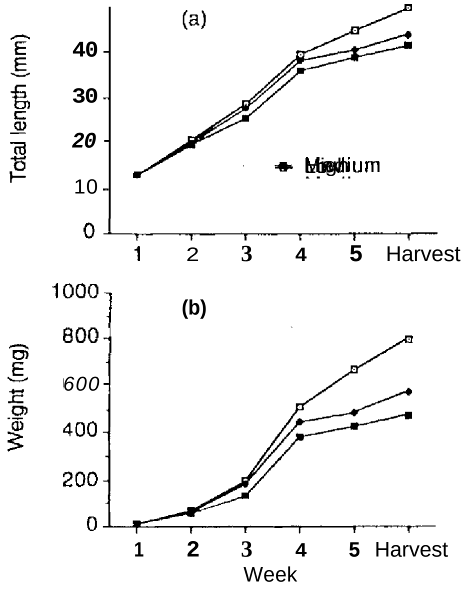

Figure 2.Weekly changes in (a) mean total lengths and (b) mean weights of walleyes in ponds stocked with low (20 fish/m^3), medium (40fish/m^3) and high(60 fish/m^3) densities of larval walleyes. From Fox, M.G. and D.D. Flowers. 1990. Effects of fish density on growth, survival and food consumption by juvenile walleyes in rearing ponds.Transactions of the American Fisheries Society 119:112-121.

Fertilization

Traditional pond fertilization methods in Ontario have centered on the use of organic fertilizers such as soybean meal (solid content - 7.7% N, 0.7% P, 2.0% K) for extensive pond culture. White Lake ponds are fertilized at least 2 weeks prior to stocking fry to ensure adequate time for zooplankton development. They receive a large initial application of dry soybean meal (applied to the pond bottom immediately before filling) at a rate equivalent to 4 times the weekly rate

Table 1. - Summary of measurements (means with ranges in parentheses) of juvenile walleyes harvested from ponds stocked at low (20 larvae/m^3), medium (40 larvae/m^3), and high (60 larvae/m^3) densities at the White Lake Fish Culture Station Ontario, in 1988.[c]

	Stocking Density		
Measurement	**Low**	**Medium**	**High**
Total length (mm)[a]	48.9	43.0	41.3
	(47.8-49.6)	(40.3-45.8)	(39.0-43.0)
Weight (mg)[a]	788	565	470
	(711-832)	(447-683)	(397-518)
Final Density	14.4	31.5	41.4
(number/m^3)	(10.5-15.7)	(27.9-35.1)	(39.4-42.7)
Percent Survival	71.8	78.7	69.0
	(62.3-78.3)	(69.7-87.7)	(65.7-71.1)
Biomass (g/m^3)	11.3	18.2	19.7
	(8.3-13.4)	(15.7-20.6)	(15.6-22.6)
Condition factor[b]	0.637	0.630	0.650
	(0.62-0.65)	(0.62-0.64)	(0.61-0.70)
Number of ponds	3	2	3

[a] Standardized for 44-d-old fish; fish were harvested over a 3-d period when they were 44-46 d old.

[b] Condition Factor = 10^5 (weight,g)/(length,mm)^3.

(i.e., about 392 lbs/acre-ft, 140 g/m^3). The standard weekly application rate is 98 lbs/acre-ft (36 g/m^3), equivalent to 2.8 mg N/L and 0.25 mg P/L. During the culture period soybean meal is pre-weighed for each pond, mixed with water and then placed in large containers near the culture ponds to ferment. When spread along the shallow, near-shore areas of the pond this fertilizer helps stimulate the production of chironomids and larger invertebrates. It is an excellent soil conditioner. Soybean fertilization rates are reduced to 73 lbs/acre-ft (27 g/m^3) when inorganic supplements are used (to be discussed). Any ponds that held salmonids during the previous winter are not given a large initial application of fertilizer because of the accumulated nutrients from fecal matter and excess feed. Instead, these ponds are fertilized using the standard weekly application rate during the culture period. All pond fertilization is terminated one week prior to fish harvest.

Soybean meal fertilization increases chironomid production which are one of the most important prey items for pond fingerlings, but soybean meal alone has not always been effective in production of zooplankton populations. Inorganics, with high phosphate levels, have proven effective supplements to our standard fertilization practices. They stimulate the production of phytoplankton, which, in turn, increases densities of zooplankton species that are preyed upon by walleye. Present production targets for White Lake require summer fingerlings that average 908–454/lb (2,000–1,000/kg). To consistently achieve this target size with good survival rates it is often necessary to use inorganic fertilizers. Experimental studies at White Lake have shown that using a combination of soybean meal and inorganic fertilizer has helped increase walleye growth and production from culture ponds. Table 2 summarizes the results of a fertilization experiment at White Lake in 1990. Walleye in ponds given inorganic supplements grew faster and were almost twice the weight of those in the control ponds (soybean meal only) at harvest. Improved fingerling growth was apparently due to higher production of *Daphnia* which persisted longer in ponds given inorganics.

Table 2 - Juvenile walleye harvest from a fertilization experiment at White Lake in 1990 (standard deviation in parentheses)?

	Treatment Mean	
Variable	**Soybean Only (n=3)**	**Soybean + Inorganic Supplement (n=3)**
Mean length (mm)	42.9 (3.0)	51.5 (2.1)
Mean weight (mg)	486 (64)	933 (122)
Production (g/m^3)	7.2 (0.8)	10.2 (3.8)
Survival (%)	49.3 (3.3)	35.9 (21.1)
Condition factor (K)	0.63 (0.06)	0.68 (0.07)

[a] Modified from Fox et al 1992

A commercially formulated granular fertilizer (8% N, 32% P_2O_5, 16% K_2O) is applied at 23.6 lbs/acre-ft (8.7 g/m^3), which is equivalent to 0.7 mg N/L and 2.8 mg P/L per week. Inorganic fertilizer is placed in large, screened floating trays in the middle of the pond where it dissolves quickly.

Problems in using inorganic fertilizers, include midday oxygen supersaturation, and high pH (>9.0) readings. High phosphorus levels in pond water discharge may also exceed environmental guidelines for hatchery effluent. Oxygen deficiencies associated with over-fertilization and cloudy weather account for most of the problems encountered in our ponds.

General pond maintenance and monitoring

Pond culture programs have often been developed using a trial-and-error approach. Successful, fish production depends on calculated and planned pond management strategies. Production programs should have predictable results, when based on accurate record keeping and diligent monitoring procedures.

Water quality sampling. Alkalinity and pH are determined before stocking fry and once a week thereafter, usually in the early afternoon. White Lake ponds have an approximate alkalinity of 100–120 mg/L and the normal range for pH is from 7.5–8.5. Oxygen and temperature readings are taken near the outflow of each pond before sunrise. These measurements are recorded at least twice weekly for all ponds. Pond temperatures range from 57°F (14°C) when fry are stocked, to 77°F (25°C) by early July when ponds are harvested. The average pond temperature throughout the culture period is 68°F (20°C). If oxygen levels drop below 4 mg/L inflows are increased and/or fertilization rates reduced. Supplemental aeration systems are used to prevent critically low oxygen levels and help improve nutrient cycling within ponds (Figure 3).

Prey monitoring and fish sampling. Zooplankton are carried into White Lake ponds during initial filling, which is from a mesotrophic lake. These zooplankton provide a seed stock for future development. Visual observations during the day or at night, can easily confirm presence or absence of adequate zooplankton numbers without elaborate routine sampling. Stomach analysis of pond-raised walleye at White Lake have shown that chironomids are a very important component of the diet. Final emergence of chironomids from ponds late in the culture period often causes prey shortages and predictable growth reductions for fingerlings.

A reduction in abundance of zooplankton or benthic invertebrates often reduces walleye condition. Routine weekly fish sampling is essential to assess fish condition and to help forecast potential harvest dates. Walleye condition at White Lake is assessed weekly beginning at week 3. **A** small number of fingerlings (20–40) are seined from each pond, measured and weighed. If collected fish appear emaciated or if large numbers of cannibals appear, an early harvest is considered. If walleye continue to grow and if there is weight gain from week to week then pond culture continues. No weight gain for more than 2 consecutive weeks often indicates low prey abundance. Under these conditions walleye become more cannibalistic and ponds should be harvested quickly to ensure reasonable survival.

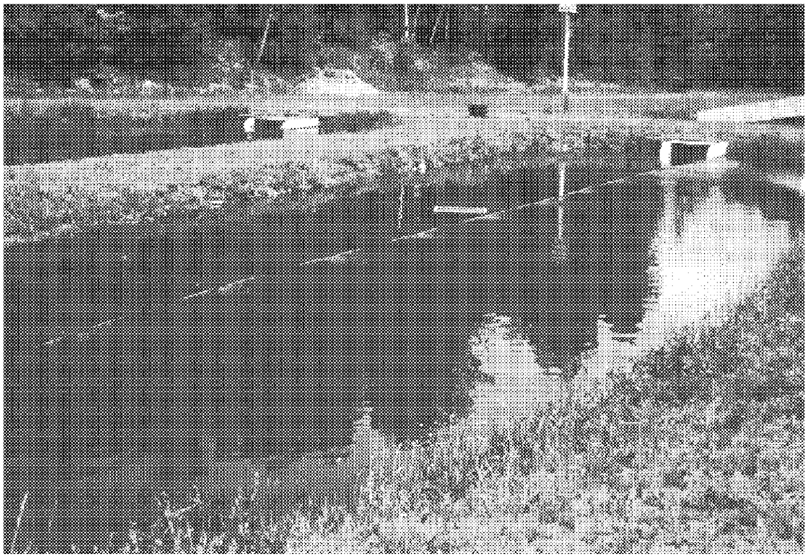

Figure 3. Experimental ponds at White Lake with supplemental aeration. Granular inorganic fertilizers are placed in floating trays in the middle of the pond and soybean meal is spread in the shallow water along the shoreline. The black steel drum at the rear of the picture holds fermenting soybean meal.

Aquatic vegetation and insect control. Chemicals are not used to control aquatic vegetation at White Lake and applying gas or oil to pond surfaces, to control predacious aquatic insects, is prohibited at this facility. Floating, filamentous algae are usually raked from the ponds during drawdown procedures. Regular draining with long fallow periods helps reduce the growth of rooted aquatic vegetation and prevents major insect problems.

Fingerling harvest and handling procedures

All ponds at White Lake have a partial concrete bottom that is exposed when water levels are reduced. This makes it easier for staff to walk on the bottom of the ponds and effectively use seines to harvest fingerlings. Final harvest occurs **6** to **8** weeks after stocking. After harvest, fingerlings are placed in large tanks where they are separated from aquatic insects, tadpoles, algae and other organic matter. To reduce fingerling stress during

Table 3 - Summary of production results for ponds at White Lake Fish Culture Station, Ontario. Values represent mean data for the period 1991-1994 (ranges in parentheses).

Pond	Pond size		Number stocked	Days in pond	Survival (%)	Harvest			Survey years[a]
	(acres)	(acre-ft)				W (g)	L (mm)	Production (lbs)	
2a	0.1	0.28	10,200	36.5	73.9 (61.8-86.1)	0.31	35.4	5.3 (4.2-6.5)	91,93
2b	0.1	0.28	10,200	43.0	90.5	0.64	44.8	12.9	93
5a	0.1	0.28	10,200	40.7	60.1 (26.1-86.5)	0.61	44.6	7.8 (3.8-10.6)	91-93
5b	0.1	0.28	10,200	40.7	88.7 (86.0-91.2)	0.70	47.9	13.9 (11.2-17.8)	91-93
5c	0.1	0.28	10,200	40.7	87.5 (81.8-96.9)	1.19	59.5	22.7 (9.7-37.3)	91-93
5d	0.1	0.28	10,200	40.7	89.8 (84.1-100)	0.58	46.0	12.0 (11.2-12.7)	91-93
3	0.4	1.37	67,560	47.0	53.9 (20.6-75.3)	0.56	43.2	47.0 (15.4-71.4)	91-93
4	0.5	1.23	60,640	48.0	57.6 (28.0-80.4)	0.57	43.8	51.9 (13.2-100.2)	91-94
6	0.5	1.61	79,480	44.0	60.0 (43.8-76.5)	0.51	39.0	57.1 (23.7-130.0)	91-94
7	0.6	1.71	84,560	47.0	29.8 (5.0-64.0)	0.66	48.5	26.0 (12.6-54.7)	91,92,94

[a] Production data is reported only for those years where consistent stocking rates were used in the ponds; i.e.. 37,000 fry/acre-ft (30/m^3) for experimental ponds (0.1 acres, 0.04 ha) and 49,340 fry/acre-ft (40/m^3) for production ponds (0.4–0.6 acres, 0.16–0.24 ha).

clean up, tank water temperatures are adjusted below ambient conditions and light levels are reduced. We have found that walleye held for 24 h after seining are in much better shape for transport and stocking, than walleye harvested and stocked on the same day.

Summary

White Lake ponds are intensively managed for production of fingerling walleyes. Fertilization rates and initial stock densities arc high and supplemental aeration systems are used to improve nutrient cycling and prevent oxygen problems. Research studies at this facility have shown that stocking densities can be adjusted to maximize numbers or size of fish produced from ponds. Other studies have provided insight into use of inorganic fertilizers and organic fertilizers to improve production. During the period 1991–1994, the mean survival from fry to fingerlings in White Lake ponds was >60% (Table 3) and the total annual production was about 200,000 summer fingerlings that average 908–454/lb (2,000–1,000/kg).

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Walleye Culture in a 100-acre Drainable Pond in Northern Michigan

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Introduction

The Chippewa/Ottawa Treaty Fishery Management Authority stocks about 350,000 fingerling walleyes into the three upper Great Lakes (Huron, Michigan, and Superior) annually to create a commercial fishery for walleye in an area where no significant walleye populations existed in the past. About 250,000, 2-inch (5.1-cm), fingerlings are stocked in late June to early July, and from late September to early November, about 100,000 advanced fingerlings, 6–7 in (15.2–17.8 cm), are stocked. Because survival of the small fingerling has been poor, increased effort is now given to rearing and stocking more advanced fingerlings. This case study describes procedures used at Nunns Creek Fishery Enhancement Facility to raise advanced fingerling walleye.

The pond

Advanced fingerlings are raised in a 100-acre (40.5-ha) drainable pond. The pond was built about 30 years ago by constructing a 2,000-ft (610-m) earthen dam across a small intermittent stream. The pond is filled each year with runoff from spring rains and snow melt. The pond bottom is primarily clay with little organic material. Nearly 40% of the pond has standing or floating timber. The pond has a maximum depth of 12 ft (3.7 m), and about 75% is 4–6 ft (1.2–1.8 m) deep. The surrounding watershed is a mix of maple forest wood lots and hay fields.

Stocking

Fry are stocked by the third week of May when water temperature is about 52°F (11°C). About three million fry are stocked annually (25,000 fry/acre, 61,775 fry/ha). Predation from brook sticklebacks, are regarded as the major cause of fry mortality. By mid June, walleye are about 1.0–1.2-in (25–30-mm) in length. Walleye fry feed primary on zooplankton until mid-July. The pond has zooplankton densities that range from 71 to 3,312/qt (75–3,500/L). Daphnia populations range from 4.7 to 237/qt (5-25OL). By the second week of July, however, walleye begin to forage on fish, which is mainly small stickleback, but other prey include fathead minnow, finescale dace, pearl dace, golden shiner, leeches, and crayfish.

Fertilization

Inorganic fertilizer (urea) is applied throughout the culture period to develop phytoplankton needed to sustain the zooplankton populations. The pond is fertilized with urea (46:0:0). Urea is applied by placing perforated 50-lb (22.7-kg) bags on floating cribs that are distributed throughout the pond. About 10 bags are placed on the cribs every other week. A total of 4,000 lbs (3568 kg) of fertilizer (i.e., 400 lbs/acre, 357 kg/ha) is applied during the growing season.

Harvest

Pond draining begins in early August and, depending in the local precipitation, it usually is completed by the end of October. In the first **part** of the harvest interval, the fish range in size from 3–5 in (7.6–12.7 cm), the larger fish are not harvested until the final draw down, and then they are usually harvested at night.

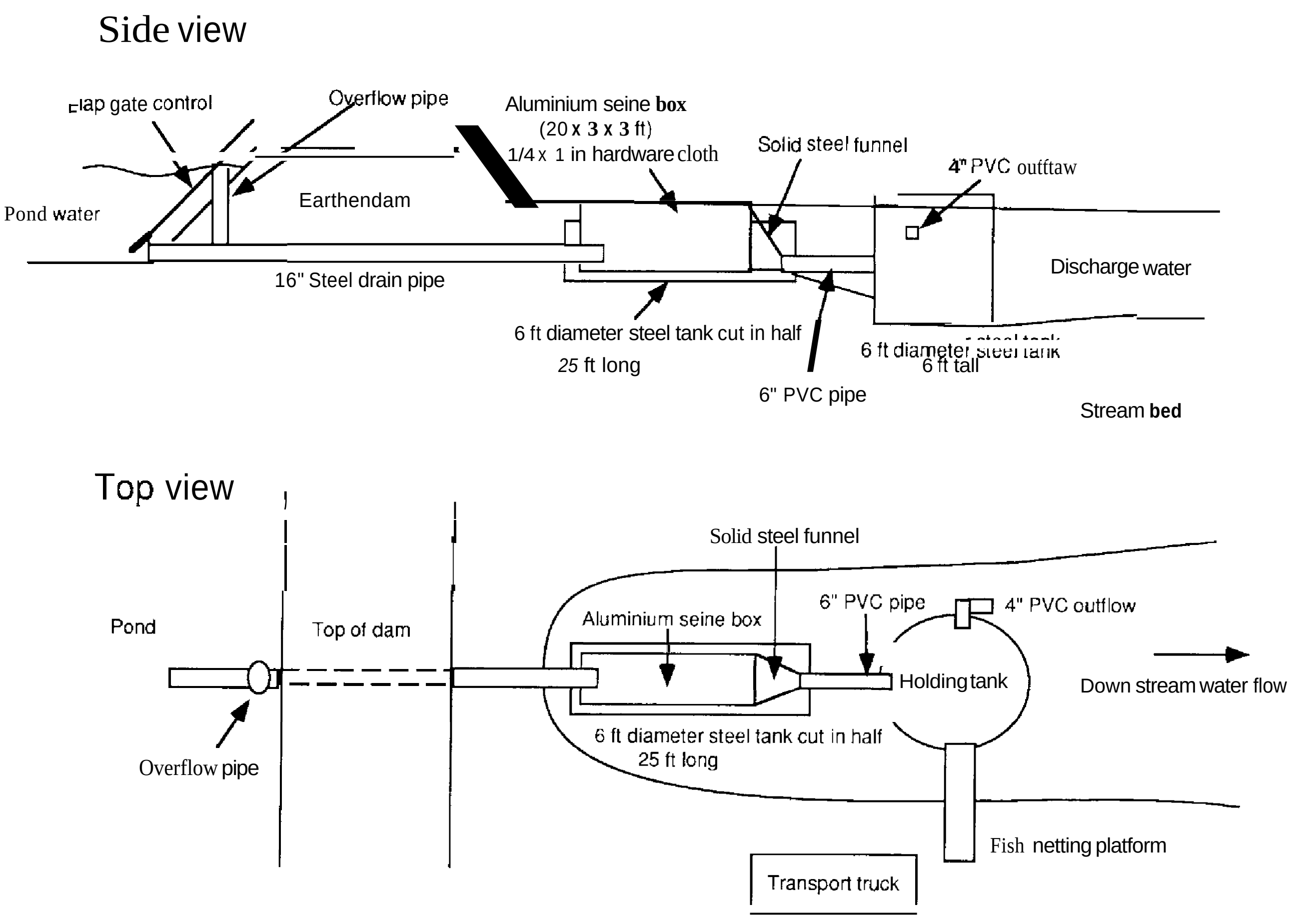
During draining, water and fish flow through a 16-in (40.6-cm) pipe into a seine box and finally into a holding/harvesting tank (Figure 1). Most water flowing into the seine box drains off, but fish are deflected into a 6-ft (1.8-m) diameter holding/harvesting tank. This system is currently being upgraded with a perforated aluminum seine box and much larger harvesting tank.

When the pond drains down to the bottom, the water quality is poor because of high suspended solids, and low dissolved oxygen. However, in 1994, a 4-in (10.2-mm) well was installed to help maintain water quality in the holding/harvesting tank. The well water is passed through a packed column to degas and oxygenate before entering the harvesting tank. The addition of cold, well-oxygenated water has helped reduce the stress on the fish.

Summary

This pond culture system produces 100,000 (1,000/acre), 6–7-in (15.2–17.8-cm) walleye with minimal inputs for fertilizer and little labor. The fallen and standing timber seems to facilitate fish production. The major liability of this culture system is the heavy predation by brook stickleback on newly stocked walleye fry. To eliminate this problem, in 1995, a 10 acre (4.1 ha) nursery pond was constructed. The nursery pond is located up stream of the production pond. The nursery pond will be stocked with fry and they will be raised to about 1-in (25-mm), then the pond and fish will be drained into the larger pond.

Figure 1. Schematic diagram of connection between the pond and the external seine box where walleye are harvested.



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Culture of Advanced Fingerling Walleye in Minnesota Ponds

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Introduction

Traditionally, fingerling walleyes are raised by stocking fry (1–3 days posthatch) into fertilized ponds from which fingerlings are harvested 25–45 d later when they reach about 2-in (5.0-cm) long. Most fingerlings are stocked into lakes and reservoirs for population enhancement. This method of production is currently being used by both state and federal agencies across the country. Because the survival rate of 2-in (5.0-cm) fingerlings that are stocked in natural and artificial lakes is highly variable, in the 1960s, the Minnesota Department of Natural Resources (MNDNR) recognized the need for the stocking of larger fingerlings, 4–9-in (10.2–22.9-cm), especially when they are stocked into waters with larger predator populations. There is also a market for larger fingerlings by lake associations and angler clubs and the private sector is currently producing fish to meet this need.

To produce larger fingerlings, pond-cultured walleye must be provided forage fish, or they can be moved from ponds to tanks where they can be trained (habituated) to eat formulated feed. Governmental and private hatcheries that raise advanced fingerlings in drainable ponds usually harvest the 2-in (5.0-cm) fish and then transfer a known number back into ponds at a lower stocking rate, 10,000-15,000/acre (24,700–37,050 ha), and feed the fish fathead minnows until they are harvested in the fall. Although this method is successful in the production of advanced fingerling fish, it may be cost prohibitive in the private sector. The price for forage fish (usually fathead minnows) range from $0.50 to $3.00/lb wholesale which means there is a production cost of $2.00 to $12.00/lb ($0.90–$5.45/kg) of fingerlings produced if a 4:1 food conversion ratio is obtained. The cost for minnows to raise a 5–in (12.7–cm) fingerling will range from $0.08 to $0.48 per fingerling. When the cost of pond construction, pond filling, management, harvesting, and fry is added, the current market value of fingerlings would be less than production costs.

In west-central Minnesota there are numerous winterkill ponds that are 5–150 acres (2–60 ha) which have mean depths of 4–12 ft (1.2–3.7-m). Because they winterkill, these ponds do not have a persistent sportfish population, and they are used for the production of baitfish and leeches by the private sector. Most are highly productive, yields of baitfish are as high as 1,000 lbs/acre (1,121 kg/ha); however, typical rates are closer to 250 lbs/acre (280 kg/ha).

For the past 30 years, the MNDNR has used winterkill ponds to produce advanced walleye fingerlings. The ponds are usually stocked with fry at a rate of 5,000/acre (12,355/ha) in the spring and then harvested in the fall when water temperatures drop below 60°F (15.5°C). Survival of walleye fingerlings ranges from 0–30% but average 3.5%. The target yield is 5–10 lbs fingerlings/acre (5.6–11.2 kg/ha) (MNDNR personal communication). The harvest of fingerlings is dependent upon survival and also on the percentage of the population that can be harvested. Survival is influenced by zooplankton populations, temperature, predator populations (other fish, birds, mammals, amphibians), forage fish populations, and water quality.

In the private sector, the price of fry ranges from $0.01–0.02 each, thus, the extensive method of fingerling production as practiced by the Minnesota DNR would not be profitable because a survival rate of 3.5% means the production costs for a 5-in (12.7 cm) fingerling is $0.28 to 0.57 each just for the fry used for stocking. Production costs would be much higher when labor, transportation, and forage are included. Moreover, the loss of baitfish production when the ponds are stocked with walleye fry has to be regarded as a production cost, because the reduced baitfish harvest is a real loss of income.

During the past three years at Alexandria Technical College we have been evaluating a two-step protocol where a combination of drainable and undrainable ponds are used to produce advanced walleye fingerlings. In this 2-step protocol we take advantage of the high fry survival in drainable ponds and the high forage production of the undrainable ponds. We are interested in evaluating the success of rearing walleyes in drainable ponds from fry to 2 in (50.8 mm) fingerlings, and then transferring known numbers of fish at desired densities to natural ponds for final rearing to advanced fingerlings. Specifically, we were interested in determining the percentage of stocked fingerlings that can be harvested, how the growth rate of fingerlings is influenced by stocking density, and the influence of pond size on these factors.

Methods

walleye fingerlings were raised during the summers of 1992, 1993, and 1994. Two drainable ponds were utilized. Pond 9 is 2 acres (0.81 ha) and pond 10 is 1 acre (0.40 ha). The ponds were filled 10 d before stoclung. After filling, the ponds were fertilized with alfalfa meal twice-weekly at a rate of 100–200 lbs/acre (112–224 kg/ha) per application. Fertilizer was added unless dissolved oxygen fell below 3 ppm in the morning. Total fertilizer added annually averaged 1,500 lbs/acre (1,338 kg/ha). Fry were stocked at 150,000 fry/acre (370,500/ha) in the one acre (0.40 ha) pond and 75,000 fry/acre (185,250/ha) in the two acre (0.81 ha) pond. Zooplankton was monitored bi-weekly by making a 20 ft (6.1 m) zooplankton net tow in three locations and pooling the three samples. Three sub-samples were counted using a circular plankton counting chamber. Zooplankton were identified and classified as rotifers, cladocerans, and copepods. Estimates of zooplankton density were calculated from these samples.

Ponds were drained and the fish were harvested 30–40 d after stocking. Fingerlings were netted, enumerated, and placed in a 0.5% salt solution in a hauling tank. Fingerlings were then transferred to the natural ponds for further culture. Five different natural ponds were used during the 3 years. Ponds utilized during the study had been leased by three different private fish growers in the Alexandria, MN area. Ponds were checked for fish populations prior to stocking using fyke nets. If adequate minnow populations were present, no additional stocking of forage was done. If test nets showed poor minnow populations present, the ponds were stocked with adult fathead minnows in the spring at the rate of 2 gal/acre (7.6 L/ha)

Ponds were stocked with 400 to 3,800 fingerling walleyes/acre (988–9,390/ha). Stoclung rate varied dependmg on pond size and the number of 2-in (5-cm) fingerlings available. Advanced fingerlings were harvested beginning the first week in October. Fyke nets (2–4 ft [0.61–1.2 m] diameter hoops, and one lead) were set perpendicular to the shoreline. Nets were set at a rate of at least 1 net/4 acres (1 net/1.6 ha) of water. Nets were checked at least every other day, depending upon the catch rate. If the harvest rate was low, copper sulfate was applied at a rate of 0.5 ppm to stimulate fish movement, a common practice for capturing fish in undrainable ponds in Minnesota. Harvest normally was accomplished in a 2 week period. Fingerlings were transported in a 0.5% salt solution to a holdmg facility were they were counted, measured, and graded.

Results and discussion

Survival from fry to fingerlings in drainable ponds ranged from 21–75% (Table 1). Mean length at harvest was 2-in (5.0 cm) and ranged from 1.7–2.3in (4.3–5.8 cm). Although differences in survival and mean length at harvest between years could not be actually evaluated because of the variation in culture conditions between years, length of the culture period and zooplankton densities seem to be the most important factors. In 1992 and 1993, the fish were harvested after 30 d while in 1994 the fish were harvested after 45 d (Figures 1 and 2). Higher zooplankton populations in 1992 compared with 1994 may also have contributed to higher survival in 1992 than in 1994 (Figures 3 and 4). Cladoceran populations peaked right after stochng the fry in 1992 and stayed at 500/L until harvest. In 1994, cladoceran populations never reached as high a density and fell to low levels a week before harvest. This may be due to the high copepod population that was present in the pond during 1994.

The harvest of 2-in to 5-in (50 to 127-mm) fingerlings grown in natural ponds ranged from 27–55% with a mean of 42% (Table 2). Pond E had a return rate of 52%, even though the pond has a high population of black bullheads. Mean length at harvest appears to be inversely related to the initial stocking rate, less than

1,200/acre stocking rate, produced the larger fingerlings. Although water temperatures were not taken, the mean air temperature was warmer in 1994 than the other two seasons.

Table 1. Walleye fingerling production in Ponds 9 (2 acres, 0.81 ha) and 10 (1 acre, 0.40 ha) at Alexandria Technical College.

Year	Pond number	Number stocked	Number harvested	Survival	Fish length (in)	Culture days
1992	9	150,000	83,000	55	1.8	35
	10	150,000	112,600	75	1.7	30
1993	10	150,000	85,000	57	1.5	28
1994	9	150,000	35,300	24	2.0	45
	10	150,000	31,443	21	2.3	40
Totals		750,000	347,343	46	2.0	36

Total harvest from fry to advanced fingerling ranged from 10–23% with a mean of 19%. Fry purchased at $0.01/fry but actual cost of fry was $0.053 ($53/1,000) per advanced fingerling produced. Mean return was lower during the 1994 season because of the low fingerling survival in the drainable ponds. Perhaps survival would have been greater if the fish had been harvested sooner. If a mean survival rate of 60% can be obtained from fry to 2-in (5.0-cm) in drainable ponds and a harvest rate of advanced fingerlings average 42% of the stocked 2-in (5.0-cm) fingerlings, an overall return rate of 25% could be expected. This would result in fry cost of $0.04/advanced fingerling produced compared with $0.28/advanced fingerlings when fry are stocked directly into undrainable ponds.

The two-step protocol allows the producer to take advantage of the high survival in the drainable ponds and the high productivity of the undrainable ponds. This results in lower fry and forage costs which may make the growing of advanced fingerling walleye more profitable.

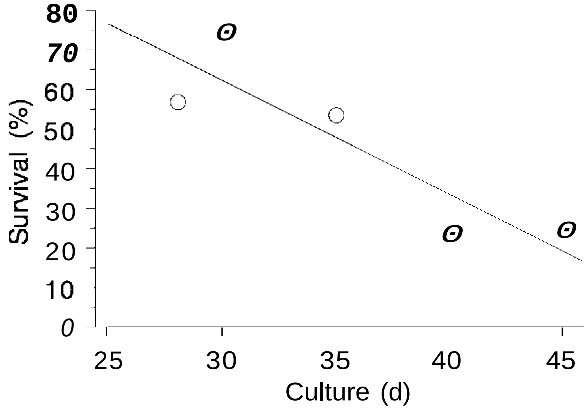

Figure 1. Survival of walleye from fry to 2-in (5.0 mm) fingerlings in relation to the number of culture days at Alexandria Technical College. Data are from ponds 9 and 10,1992–1994(See Table 1).

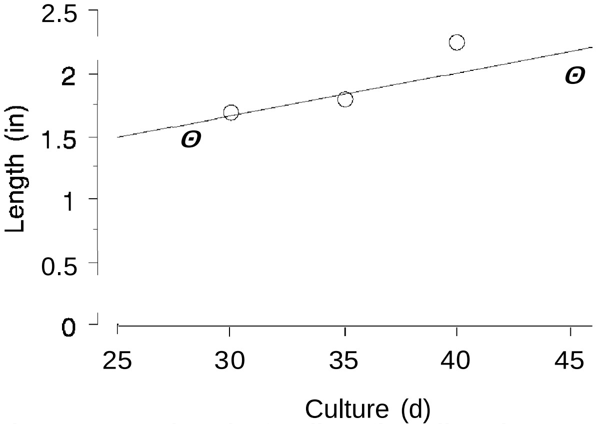

Figure 2. Mean length of walleye fingerlings harvested versus the number of culture days, Alexandria Technical College. Data are from ponds 9 and 10,1992–1994 (See Table 1)

Table 2. Production of advanced fingerling walleye in natural ponds near Alexandria, MN, 1992-1994.

Year	Pond	Size (acres)	Number stocked	Stocking rate[a]	Number harvested	Percent harvested	Fish length (in)
1992	A	7	22,000	3,140	10,200	45	4.2
	B	10	38,640	3,860	12,264	31	4.8
1993	B	10	32,000	3,200	8,656	27	4.0
	C	40	42,000	1,050	23,088	55	5.1
1994	D	52	26,170	500	9,986	38	8.5
	E	80	31,443	400	16,344	52	5.5
Totals			192,253	2,025	80,538	42	5.4

[a] N/acre

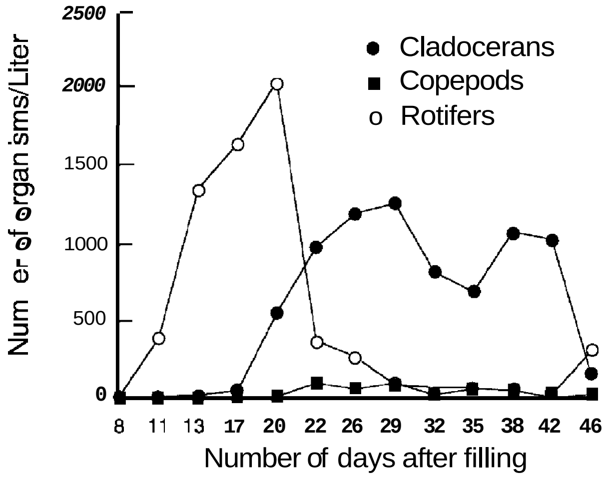

Figure 3. The number of zooplankton per liter (May–June 1992) in pond 10 with a stocking rate of 150,000 walleye fry.

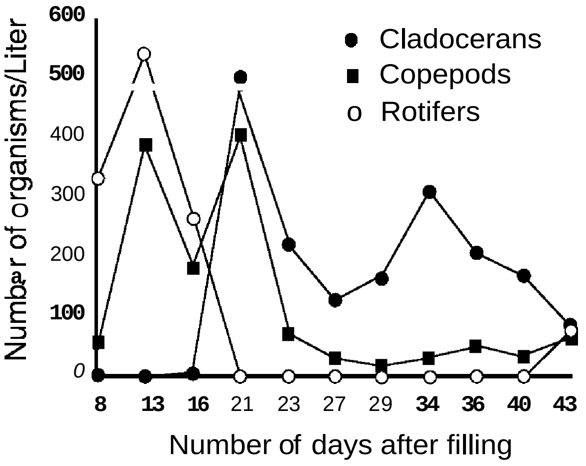

Figure 4. The number of zooplankton per liter (May-June 1994) in pond 10 with an initial stocking of 150,000 walleye fry.