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Chapter 6

Walleye Fingerling Culture in Undrainable Ponds

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Introduction

To obtain control over the pond production process and to facilitate harvest of walleyes, many agencies use drainable ponds, however, the natural resource agencies in Michigan and Minnesota still rely heavily on the use of undrainable ponds for walleye fingerling culture. Some pond management procedures, such as fertilization and control of predaceous insects and nuisance aquatic plants, are similar for both drainable and undrainable ponds. The major differences between the two culture systems is in harvest methods. In undrainable ponds, active seining or trap nets are used. Also, in undrainable ponds which do not winterkill, fish carryover is avoided by treatment with a piscicide (e.g., rotenone).

In the production phase from fry to fingerling, walleye first rely exclusively on zooplankton then benthc organisms, and finally they become piscivorous, at which time they must be harvested or provided with suitable prey (minnows). Fertilization and stocking rates cannot be defined to raise a specific sized fish. Walleye fingerling production is variable, and site-specific factors account for much of this variation. Summerfelt et al. (1993) reported that procedures to culture walleye fry to a desirable sized fingerling in earthen ponds have not been standardized, and culture methods are site specific. Factors such as soil type, water fertility, and stocking levels influence the abundance and composition of zooplankton populations in ways that are unpredictable.

Pond selection

The case studies on walleye culture in undrainable ponds show variability in criteria for pond selection. Gunderson et al. (1996) reported that commercial walleye producers in Minnesota use natural ponds that are 5–10 ft (1.5–3.0 m) deep, which are deep enough to prevent summerlull but shallow enough to winterlull. These ponds are typically 5–30 acres (2–12.1 ha) but can range from 1–100 acres (0.4–40.5 ha).

Daily (1996) indicated that Minnesota Department of Natural Resources prefers to use ponds larger than 50 acres (20.2 ha), but they also use ponds that are less than 5 acres (2 ha) and some that are larger than 100 acres (40.5 ha). They prefer ponds with depths up to 15 ft (4.6 m) to prevent summerkill. Low fertility ponds that do not winterkill and are less than 5 acres (2 ha) are usually avoided. Lilienthal (1987) reported that state-controlled walleye culture ponds in Minnesota averaged 58 acres (23.5 ha) while statewide cooperative walleye culture ponds averaged 27 acres (10.9 ha).

Michigan Department of Natural Resources Fisheries Division, uses walleye culture ponds (Figure 1) that

Figure 1. An undrainable walleye culture pond in Michigan.

range from 0.540 acres (0.2–16.2 ha) in size (Gustafson 1996). Laarman and Reynolds (1974) indicated that undrainable walleye culture ponds in Michigan should be a minimum of 5 acres (2 ha) with a maximum depth of 6–8 ft (1.8–2.4 m) and minimal shallow areas less than **3** ft (0.9 m) to discourage aquatic weed growth.

Table 1. Oils used to control predacious aquatic insects in walleye culture ponds.

	Application Rate		
Oil	**gal/acre**	**Uha**	**Reference**
Fuel Oil	3-5	28.2-46.7	Gunderson et al. (1996)
	3	28.2	Gustafson (1996), Laarman and Reynolds (1974)
	1-5	9.4-46.7	Buttner (1989)
	5.3-6.6	49.4-61.8	Richard and Hynes (1986)
Kerosene	10-12	93.4-112.4	Gunderson et al. (1996)
Fish Oil	3-5	28.2-46.7	Gunderson et al. (1996)
Vegetable Oil	1-5	9.4-46.7	Buttner (1989)

Water quality

Gunderson et al. (1996) reported that private walleye producers in Minnesota generally use ponds with alkalinities of 150–200ppm, but alkalinity ranges from 50–300 ppm. The pH in these ponds ranged from 6.5–9.0. The dissolved oxygen typically was 5–10 ppm. Gustafson (1996) indicated there was a large variation in alkalinity, pH, and productivity in walleye culture ponds used by the Michigan Department of Natural Resources.

Summerfelt et al. (1993) found that when dissolved oxygen levels in walleye culture ponds dropped below **3** ppm, the addtion of water and aeration should be used. Richard and Hynes (1986) and Laarman and Reynolds (1974) indicated that dissolved oxygen was the most important water quality parameter, and should be at least 5 pprn at dawn.

Alkalinity levels below 40 ppm and pH levels below 6.5 or above 9.0 are not suitable for walleye culture (Richard and Hynes 1986) They further indicated that the optimum temperature for walleye fingerlings is 69.8–71.6°F (21–22°C), although temperatures greater than 86°F (30°C) may be tolerated for a short period of time. Laarman and Reynolds (1974) indicated that temperatures above 85°F (29.5°C) are detrimental.

Buttner (1989) recommends that dissolved oxygen and temperature measurements be taken daily at dawn, and turbidity, pH, ammonia-nitrogen, nitrate-nitrogen, and phosphate be measured twice each week.

Aquatic pest control

Aquatic insect control

Predaceous aquatic insects are often controlled by oil application. **A** variety of oils have been used to control air-breathing aquatic insects in walleye culture ponds (Table 1). Gunderson (1996) suggested that these oil applications be made on the windward side of the pond under moderate wind conditions. Such applications should be avoided within 2 weeks prior to stocking walleye fry or within 3 weeks after stocking (Gustafson

Table 2. Rotenone applications to eradicate the fish populations in ponds. This is usually done in undrainable ponds to eliminate fish populations before walleye are stocked. Rotenone is a restricted use pesticide and applied only in accordance with state and federal guidelines. In many states this would require certification as an aquatic pesticide applicator. Contact State Department of Agriculture.

Rate	Reference
1 gal/acre-foot (3.8 Uacre-foot)	Daily (1996), Lilienthal (1989)
2 pprn (2.5% synergized liquid formulation)	Jorgensen (1996)
1-4 ppm	Buttner (1989)

1996). Summerfelt (personal communication) indicated that using oils to control insects within 2 weeks of stocking walleye fry or within 3 weeks after stocking may prevent gas bladder inflation. Before using any oil, the user should insure that any federal, state, or local laws do not restrict its use.

Fish contrul

To control unwanted fish in walleye culture ponds, a piscicide (e.g., rotenone) is applied; usually this is immediately after fall harvest (Table 2). Obtain a copy of the label before purchasing or using any commercial product to make sure the product is approved for its intended use. A number of restrictions may apply to use some compounds. Restricted-use products such as rotenone fish toxicants can be purchased only by a Certified Pesticide Applicator or under a certified applicator's direct supervision (Federal Joint Subcommittee on Aquaculture 1994). Look for the "restricted use pesticide" designation on the label to identify such products. Before using any chemical, the user should insure that any federal, state, or local laws do not restrict its use.

Temperature, light, oxygen, and alkalinity affect the breakdown rate of rotenone. Rotenone used in 80ºF water will detoxify in less than 4 days, while at 45°F the toxicity to fish may last for 33 days. In waters that are acidic, very soft, or deep and stratified detoxification of rotenone may take longer. At temperatures above 60°F, most waters treated with rotenone completely detoxify within 5 weeks of treatment. Other factors that influence the degradation rate of rotenone and reduce its toxic effect include the presence of organic debris, turbidity, pond shape and depth, and dilution by inflowing water. Ice and snow cover may prolong the toxic effect of rotenone.

Aquatic plant control

Specific chemicals have been used to control aquatic plants in walleye culture ponds (Table **3).** Caution should be used as concentrations of copper products can be toxic to fish, especially in soft water. Some of these chemicals can only be used if there is no discharge into public waters. It is the responsibility of the user to always refer to the product label for details on recommended or approved treatment rates and usages as well as for any restrictions on use.

Gustafson (1996) reported that mechanical harvesting of algae and macrophytes has been successful in clearing areas for fingerling harvesting, but it is labor intensive.

Table 3. Chemicals used to control aquatic plants in walleye culture ponds. Use of chemicals is regulated by the EPA and FDA. They may be used only in accordance with state and federal guidelines. Contact State Department of Agriculture. In many states this would require certification as an aquatic pesticide applicator.

Aquatic Plant	Chemical	Rate	Reference
Macrophytes	Aquazine™1	2 ppm	Jorgensen (1996)
Potamogeton	Copper sulfate	0.5 ppm	Summerfelt (1993)
	Aquazine™1	2.2 ppm	Summerfelt (1993)
Chara	Copper sulfate	0.5 ppm	Summerfelt (1993)
	Aquazine™1	2.2 ppm	Summerfelt (1993)
Hydrodicton	Copper sulfate	0.4 ppm	Summerfelt (1993)
	Copper sulfate	0.5 ppm (alkalinity >50 ppm)	Laarman and Reynolds (1974)
	Copper sulfate	0.25 ppm (alkalinity <50 ppm)	Laarman and Reynolds (1974)
	Aquazine™1	1.7 ppm	Summerfelt (1993)

[1] Not available, no longer registered for aquatic applications.

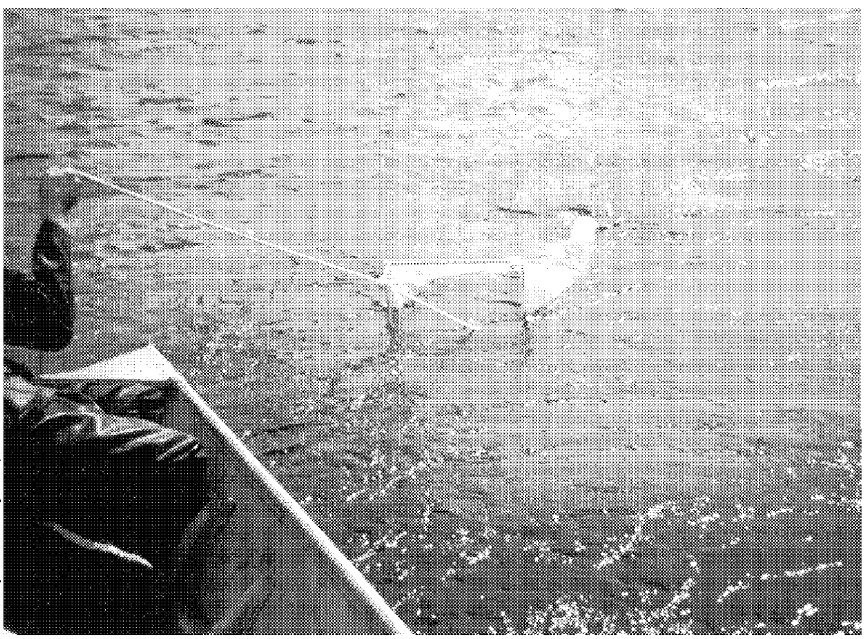
Fertilization and Zooplankton

Gunderson et al. (1996) reported that the use of fertilizers among Minnesota private walleye producers is a matter of experience and varies from pond to pond. Zooplankton are, at times, seeded before fry are stocked and later when a decline is detected. Zooplankton are monitored by towing a plankton net 50–100 ft (15.2–30.5 m) through the pond early in the morning or late evening.

Daily (1996) indicated that Minnesota Department of Natural Resources does not use artificial fertilization on their walleye culture ponds because it is not practical or economical for ponds of the size that they use (58 acre average). The productivity of each of their ponds is influenced by alkalinity, pH, depth, nutrient load, and fish species present. Large amphipod populations were found to be important, and if amphipods were not present they could be inoculated. Their policy is to rest the less fertile ponds on a regular basis, especially those under 30 acres (12.1 ha). No sampling or monitoring of their ponds is done throughout the summer.
Michigan Department of Natural Resources Fisheries Division uses an initial application of fertilizer two weeks prior to fry stocking, when ponds are fertilized. Fertilizers are then applied as needed. Fertilizers include grain by-products, animal manure, yeast, inorganic fertilizer, hay, or a combination of these. Monitoring of zooplankton abundance (Figure 2) and composition is initiated before fry are stocked and twice per week thereafter, and inoculation of zooplankton is done as needed (Gustafson 1996).

Buttner and Kirby (1986) found that walleyes ate mainly cladoceran, copepods, and chironomid larvae and pupae. When compared with their abundance in the zooplankton, rotifers were found in significantly lower and chironomids, cladocerans, and copepods in significantly greater proportions in walleye stomachs. Westers (1980) indicated that a key to successful pond culture of walleye is to maintain a 10:1 weight ratio of food organisms to fish.

Dobie (1956) was the first to note a relationship between fertility of pond substrate and walleye production. In ponds with less than 4% organic matter in the soil, aquatic insects are scarce and walleye fingerlings are often lost to cannibalism when a zooplankton shortage develops. Ponds with soils of a high organic content usually produce more fish in natural ponds than in drainable ponds where water is changed every year, The goals of pond culture are to produce large crops of microcrustaceans, such as cladocerans and copepods, in the spring to ensure good fry survival and microcrustaceans and insects, such as chironomids, to feed the fish in midsummer (Laarman and Reynolds 1974; Richard and Hynes 1986; Buttner 1989).



Courtesy of the Michigan Department of Natural Resources.

Figure 2. Zooplankton are monitored by towing a plankton net through the pond.

Enrichment of walleye culture ponds is attained by using organic or inorganic fertilizers. Richard and Hynes (1986) indicated that organic fertilizers play a greater role in benthic development than inorganic fertilizers, which have not been commonly used for walleye culture. Bacteria and protozoans growing in decomposing organic fertilizers are consumed **by** certain zooplankton.

Inorganic fertilizers appear to be more practical in ponds with soils of low fertility (Laarman and Reynolds 1974). However, chances for increased filamentous algae growth is greater using inorganic fertilizer as release of nutrients into water is more rapid when compared with organic fertilizer. Buttner (1989) reported that inorganic fertilizers have performed inconsistently, and frequently promote poor water quality and should be used cautiously. Such fertilizers should only be used if nitrogen and/or phosphorus is deficient.

Compared with inorganic fertilizers, the rate of release of nitrogen and phosphorus into the water is slower with organic fertilizers (Dobie 1971). Culver et al. (1993) stated that it was difficult to adjust the relative amounts of nitrogen and phosphorus added to ponds with organic fertilizers, such as alfalfa meal. They found that the addition of small amounts of inorganic fertilizer each week avoided the production of filamentous algae.

Inoculation of walleye culture ponds with zooplankton should occur immediately after ice melts and at least 2–3 weeks before fry are stocked (Buttner 1989). Richard and Hynes (1986) recommended inoculating the center of walleye culture ponds with zooplankton at 378–567 organisms/gal (100–150 organisms/L) at the beginning of the culture season or when zooplankton populations abruptly decline ("crash").

Monitoring zooplankton populations in walleye culture ponds should occur on a regular basis, and fertilizer application schedules can then be adjusted to encourage zooplankton blooms (Summerfelt 1993). Zooplankton monitoring can be accomplished through weekly plankton tows, using an 80 mm plankton net and separating the sample into Copepoda and Cladocera (Richard and Hynes 1986). Harding and Summerfelt (1993) collected zooplankton samples at night, using a flexible impeller pump and 80 mm plankton net, through which the pond water was filtered. Buttner (1989) determined zooplankton abundance 2–3 times per week, using a flashlight after sunset and collecting them as they congregated near the light. An undesirable situation would include few microcrustaceans and cladocerans with incubating ephippia (resting stages) rather than eggs/larvae.

If presunrise concentration of dissolved oxygen is less than 4 ppm, the midday pH is greater than 9, total ammonia is >1 ppm, then fertilization is excessive and should be reduced, and supplemental aeration or addition of water may be necessary (Buttner 1989). If zooplankton abundance is decreasing or if the composition is shifting to less desirable taxa (i.e., rotifers, which are poorly utilized by walleye) and water quality is acceptable, then the fertilization rate may be increased and the pond can be inoculated with additional zooplankton.

Walleye stocking densities, fertilization rates, and yield

The stochng density of walleye fry and the ultimate yield of walleye fingerlings will depend on basic pond fertility. Pond fertility can be controlled through intensive management with the use of fertilizers. Table 4 summarizes various management practices presented in the case studies.

Stocking

The stocking density of walleye fry will vary, depending on basic pond fertility and whether aeration is used. In Minnesota private walleye fingerling producers typically stock 2,500–10,000 fry/acre (6,180–24,710 fryha), but 20,000–30,000 fry/acre (49,420–74,130 fry/ha) are stocked if the pond or lake is aerated, more intensively managed, or known to be very productive (Gunderson et al. 1996).

Minnesota Department of Natural Resources walleye culture program found that early efforts to stock fry at 10,000–50,000 fry/acre (24,710–123,550 fryha) met with limited success. Typically, stocking densities now range from 3,000–10,000/acre (7,410–24,710/ha) (Daily 1996).

Michigan Department of Natural Resources determines walleye fry stocking rates on past pond performance, relative productivity, and harvest plans. Typically stocking rates are 30,000–75,000 fry/acre (74,130–185,325 fryha). To determine growth and survival, samples of fish are collected at night 3 and 6 d after stoclung using a light and fine-mesh aquarium net, thereafter, monitoring is every two weeks. Fingerlings are collected with a small-mesh seine (Gustafson 1996).

At Spirit Lake Fish Hatchery, Iowa, fry are stocked at 20,000 fry/acre (49,420 fry/ha). Fish are monitored weekly after they are 2–3 weeks old (Jorgensen 1996).

Attempts to define an ideal stocking density is pointless as water productivity levels, pond configuration, and organic soil content vary, ensuring carrying capacity will also vary (Richard and Hynes 1986). In drainable ponds, Harding and Summerfelt (1993) reported that

Table 4. Summary of stocking rate, fertilization, survival, and yield for the four case studies of walleye culture in undrainable ponds.

Stocking Rate (fry/acre)	Fertilization	Survival (%)	Fish size at harvest	Case Study Reference
2,500-10,000	Varies by pond	10–40	2-3 in (July) 4-8 in 15-25/lb (Sept/Oct)	Gunderson (1996)
20,000-30,000	Intensively managed	10–40	2-3 in (July) 4-8 in 15-25/lb (Sept/Oct)	
30,000-75,000	Intensively managed	30	1.5-2.5 in (4-8 wks)	Gustafson (1996)
10,000-50,000	None	Poor	—	Daily (1996)
3,000-10,000	None	10–50	25.6/lb	
20,000	None	—	2.0-2.5 in (first cropping) 5.0-6.0 in (second cropping with fathead minnows)	Jorgensen (1996)

stocking density ranged from 11,736–242,820/acre (29,000–600,000/ha).

Laarrnan and Reynolds (1974) recommend stoclung densities of 50,000–75,000/acre (123,550–185,325/ha). Richard and Hynes (1986) indicated that realistic stocking densities are 25,000–30,000 walleye fry/acre-ft, but higher densities can be used in extremely productive waters. They further found that stocking densities whch are too high can lead to competition for food resources which will stunt growth, while lower stoclung density can lead to less competition and maximize the quality of fish produced.

Summerfelt et al. (1993) stocked walleye fry at 101,175/acre (250,000/ha) in unfertilized, drainable ponds and noted that zooplankton such as copepods, cladocerans, and rotifers were present at densities of 500-2,500/L during the production period. Chironomid larvae were abundant in the pond substrate. Fertilized drainable ponds were stocked at 151,762-159,452/acre (375,000-394,000/ha).

Stocking 182,115 fry/acre (450,000 fry/ha) in ponds fertilized with inorganic fertilizer appeared appropriate for obtaining both the greatest total numbers and yield (Culver et al. 1993).

Fertilization

Buttner (1989) used grain by-products, such as finely ground wheat sorts, alfalfa meal, or soybean meal applied at 400–500 lbs/acre (450–560 kg/ha) with half applied immediately after ice-out, before fry are stocked. An application of 10–15 lbs/acre (11.2–16.8 kg/ha) is done every 7–10 d to maintain zooplankton. Fertilization with yeast at 80–125 lbs/acre (89.7–140.1 kg/ha) can be applied concurrently with the grain by-products.

Beyerle (1979) found that weekly applications of sheep or horse manure, plus Torula or brewer’s yeast, stimulated the production of *Daphnia* which was the first and main food of walleye. Applications of hay, sewage sludge, or sucrose as substitutes for the manure-yeast combination failed to stimulate adequate *Daphnia* populations. Peterson (1973) added 3.5 bales of hay/acre (8.6/ha) in unproductive borrow pits in Michigan in the fall prior to ice formation. The following spring, weekly applications of 30 lb/acre (33.6 kg/ha) of Torula yeast began two weeks prior to stoclung. After stoclung, yeast was applied bi-weekly. Successful walleye production in Minnesota was obtained by delaying the application of yeast about one month after stocking, especially in ponds with greater organic matter in bottom soils.

Richard and Hynes (1986) fertilized ponds with fermented soybean meal at 99 lb/acre-ft/week (45 kg/

acre-ftfweek) beginning two weeks prior to stocking. Application continued throughout the 6- to 8-week culture period and was terminated 1 week before harvest or if dissolved oxygen levels dropped or the amount of algae and macrophytes increase dramatically.

Dobie (1971) found that fertilization with dried sheep manure to provide 2.4 lb (1.1 kg) of nitrogen per 1,000 m^3 and weekly applications of brewer's yeast at 100 lb/acre (112 kg/ha) starting when cladoceran populations declined produced the best seasonal distribution of zooplankton and benthic organisms.

Summerfelt et at. (1993) fertilized drainable ponds with a total of 714 lb/acre (800 kg/ha) of alfalfa pellets applied in four weekly applications during the culture period. Fertilizer application was managed to prevent excessive algae blooms. Other drainable ponds were fertilized with 357 lb/acre (400 kg/ha) of ground alfalfa hay applied weekly during the culture period in four equal applications for a total of 1,428 lb/acre (1,600 kg/ha). Chironomids averaged nearly 3,000/m^2 in week one to nearly 8,000/m^2 in week four.

Culver et al. (1993) developed inorganic fertilizer regimens for drainable ponds in Ohio, that increased fingerling yield 4-fold. Optimal inorganic fertilization was identified as that needed to restore nutrient levels to 600 mg N/L (NH+ NO) and 30 mg P/L as PO^3 weekly. They found that alkalinity, pH, and temperature are factors that could potentially influence its adoption at other sites. Weekly chemical analysis and fertilization requires more time, but discontinuing the use of alfalfa hay and meal has, in turn, decreased labor and material costs.

Yield

Generally, Minnesota farmers obtain a 10–15% survival to fingerling stage, but it may reach 30–40%. Some of the fingerlings are harvested in early July when they are 2–3 in (50–76 mm); most are harvested in September and October when they are 4–8 in (100–200 mm) or 15–25/lb (33–55/kg). Conservative estimates are that 600,000 walleye fingerlings were produced in 1992 by Minnesota fish farmers (Gunderson et al. 1996).

There is a negative relationship between average harvest size at harvest and stochng density when stocking rates exceed 5,000/acre (12,350/ha). In 1993, Minnesota Department of Natural Resources had an average statewide production of 2.4 million walleye fingerlings from over 240 natural ponds. These ponds produced 218 fingerlings/acre (540 fingerlings/ha) and survival averaged over 3.2%. In other years it ranged from 10–50%. Between 1982 and 1986, the average yearly production was 3.6 million fingerlings, which was 25.6 fish/lb (56 fish/kg) (Daily 1996).

Michigan Department of Natural Resources operates over 100 walleye culture ponds statewide, and in 1990 over 5.7 million fingerlings were produced. The production season lasts 4–8 weeks and fish are harvested before the zooplankton crashes when they are 1.5–2.5 in (38–63 mm). Production averaged 7,000 walleye fingerlings/acre (17,300/ha); survival was 30% (Gustafson 1996).

The Iowa Department of Natural Resosurces uses two harvests from Welch Lake. The first cropping occurs at a rate of 1,370 fingerlings/acre (3,385 fingerlings/ha) when fingerlings reach 2–2.5 in (50–64 mm). Fathead minnow are then stocked and the walleye are harvested in September when they reach 5–6 in (127–152 mm); at that time harvest rates are 1,930 fish/acre (4,770 fish/ha) (Jorgensen 1996).

Beyerle (1979) used a stocking density of 3.5 fry/m^3 which produced fish that averaged 50 mm in 6–7 weeks; survival rates were >90%. Lilienthal (1989) found that stockmg rates of 5,000/acre (12,350/ha) in unfertilized non-drainable productive ponds have the capability of producing 10 lb/acre (11.2 kg/ha), with survival of 5–7.5%. Larger ponds produced larger fingerlings. There was a negative relationship between the average harvest size when stocking rates exceeded 5,000/acre (12,350/ha). Therefore, walleye stocking rates should not be less than 3,000/acre (7,410/ha) or more than 10,000/acre (24,710/ha) (Lilienthal 1987).

Laarman and Reynolds (1974) indicated that production goals should be 6,000–10,000 of 2.5–3.0-in (6.3–7.6 cm) fingerlings/acre (40–50 lbs, 18.2–22.7 kg). Buttner (1989) developed walleye culture methods that averaged 50% survival of fry stocked at 20,000/acre (49,420/ha).

Fingerlings reached 1.6–2.4 in (40–60 mm) 40–60 d after stochng in unfertilized drainable ponds (Summerfelt et al. 1993). Fingerlings reached 1.3 in (32 mm) 39–52 d after stocking, and yield was 36.3–44.7

lb/acre (40.7–50.1 kgha); survival ranged from 42–71% in fertilized drainable ponds (Summerfelt et al. 1993j. In other drainable fertilized ponds fingerling yield averaged 34.1–51.4 lb/acre (38.2–57.6 kg/ha) and survival ranged from 49.8–51%.

Harding and Summerfelt (1993) stocked drainable ponds at 101,175/acre (250,000/ha); ponds were either unfertilized or fertilized with four weekly applications of either alfalfa pellets at 189 lb/acre (212 kg/ha) for a total of 757 lb/acre (848 kg/ha) or soybean meal at 79 lb/acre (88 kg/ha) for a total of 314 lb/acre (352 kg/ha). No significant dfference in yield, number of fingerlings harvested, mean length, and mean weight were observed. They then stocked fry at 101,175 and 151,762/acre (250,000 and 375,000/ha) into ponds which were either unfertilized or fertilized with alfalfa pellets at 126 lb/acre (141 kgha) applied in six weekly applications for a total of 757 lb/acre (848 kg/ha). Yield was greater in fertilized ponds at both stocking densities. Fingerlings with the largest average weight were raised in fertilized ponds stocked at 101,175/acre (250,000/ha), while the smallest fingerlings were from unfertilized ponds stocked at 151,762/acre (375,000/ha). Survival averaged 64.7% and did not differ between density treatments.

NCRAC (1994) research in drainable ponds in Nebraska demonstrated that the number of walleye fingerlings that can be produced per acre can be increased 2–3 times above present levels without affecting survival and with only a small reduction in size. The success of this approach depended on harvesting fingerlings when they were 1.3–1.7 in (34–44 mm) and before the forage base collapsed and water temperatures became a problem. In one experiment, survival (71–81%) and fish size at harvest (1.5–1.7 in, 37-44 mm) was similar for ponds stocked at 163,904 and 245,653 fry/acre (405,000 and 607,000 fry/ha) and fertilized weekly with 134 or 201 lb/acre (150 or 225 kg/ha) of alfalfa pellets supplemented with phosphoric acid. In a second experiment, ponds were stocked at 163,904, 245,855 and 324,003 fry/acre (405,000, 607,500 and *800,600* fry/ha), but all ponds received the same weekly application of alfalfa pellets (303 lb/acre, 340 kg/ha) and liquid phosphoric acid. At harvest, the fish stocked at the lower density were significantly longer and heavier than those stocked at the higher densities. However, neither stoclung rate nor aeration had an affect on survival (69–79%) or yield 112–148 lb/acre (126–166 kgha).

Culver et al. (1993j found that doubling the initial stocking density increased harvest from 60,705–121,410 fish/acre (150,000–300,000 fish/ha) and increased yield from 40–89 lb/acre (45–100 kg/ha) when using inorganic fertilizer in drainable ponds.

Forage fish introductions

Private producers in Minnesota often stock fathead minnows <1.5 in (<38 mm) as forage fish when walleye reach 2–3 in (50–76 mm) (Gunderson et al. 1996). In contrast, Minnesota Department of Natural Resources discourages this practice because of the extra labor and expense to purchase minnows (Daily 1996). To produce 3–6 in (75–150 mm) fingerlings, the Michigan Department of Natural Resources Fisheries Division thin walleye densities and then stock fathead minnows (Gustafson 1996). At the Welch Lake production site of the Spirit Lake Fish Hatchery, Iowa, the population of walleye fingerlings is partially harvested with seines when the fish reach 2–2.5 in (50–63 mm), then the lake is stocked with 2,816 fathead minnows/acre (6,958/ha) on a weekly schedule thereafter (28,016/acre or 69,230/ha total) until harvest of fall fingerlings 5–6 in (12.7–15.5 cm) (Jorgensen 1996).

Laarman and Reynolds (1974) question the value of addmg forage fish. Adult fathead minnow and brook stickleback have been responsible for low survival of walleyes because of interspecific competition (Beyerle 1979j. Ponds with dense fathead minnow populations severely depress zooplankton densities and adversely affect walleye survival (Lilienthal 1989; Daily 1996).

Cannibalism

Richard and Hynes (1986) reported that cannibalism can occur within a 6–8 week culture period if zooplankton populations collapse. They suggested that maximum walleye fingerling production may be attained by periodically removing the larger cannibalistic fingerlings. Smith and Moyle (1945) observed that fingerlings may become cannibalistic at 1 in (25 mm); however, when there is an abundance of zooplankton, fingerlings were 3–3.5 in (76–89 mm) before switching to a fish diet. After walleye fingerlings reach 1.57 in (4.0 cm) survival diminishes quickly because of cannibalism, unless there is an abundance of large-size zooplankters (Westers 1980). A decision must be made about whether greater mortality will occur from cannibalism or from increased handling of the fish during thinning operations. Some culturists think that adding forage fish prevents cannibalism, while others offer reasons to suggest that once walleye begin a piscivorous lifestyle, cannibalism will increase.


Courtesy of the Michigan Department of Natural Resources.

Figure 3. Seining walleye in an undrainable pond.

Harvest techniques

Although some fingerlings are harvested in early July when they are 2-3 in (50-76 mm), most commercial walleye producers in Minnesota harvest fish when they are 4–8 in (10.2–20.3 cm) or 15–25/lb (33–35/kg) in September and October when water temperatures are <60°F (<15.6°C) (Gunderson et al. 1996). Seining is used when conditions permit (Figure 3), but in most undrainable ponds trap netting is the only practical method for harvest. In the early 1970's, switching from seining to trap netting with the use of copper sulfate in natural ponds helped remove limitations on the use of large ponds (Lilienthal 1989). Trap nets are set along the shoreline at intervals of 150–200 yd (137–183 m).

Michigan Department of Natural Resources harvests fingerlings 4–8 weeks after stocking, when fish reach 1.5–2.5 in (38–63 mm). Fingerlings are harvested with the use of 1/8–1/4-in (3–6-mm) mesh fyke nets (Figure 4) which are 4 × 4 ft (1.2 x 1.2 m) and 6 ft (1.8 m); lead lengths depend on the pond (Gustafson **1996).** Copper sulfate (0.15–0.30 ppm) is used to stimulate fish movement in the pond to increase trapping rates. Fingerlings trapped using this technique were usually in excellent condition.

Culturists at Spirit Lake Fish Hatchery, Iowa, use seines to harvest fingerlings (Jorgensen 1996). Seines 1,000 ft (305 m) long with 1/4-in (6-mm) mesh are used to remove 2–2.5-in (50–63-mm) fingerlings, while seines 2,800 ft (853 m) long with 1/2-in (12-mm) mesh are

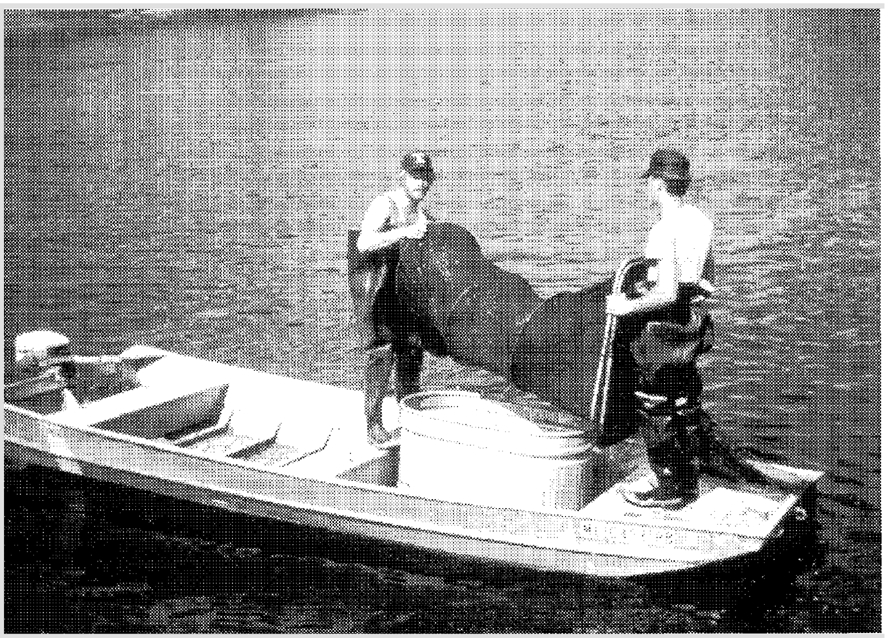

Courtesy of the Michigan Department of Natural Resources.

Figure 4. Fyke nets like these are used to harvest walleye fingerlings in undrainable ponds.

used to remove 5–6-in (127–155-mm) walleye. Gunderson et al. (1996) reported that large ponds are difficult to harvest, so the returns are less when compared with smaller ponds.

If fingerlings are uniform in size, fyke nets 3/8-in (9-mm) mesh can be used to harvest fish that weigh 45/lb (99/kg). Lilienthal (1987, 1989) recommended applying copper sulfate at no less than 0.5 lb/acre-foot (0.56 kg/ha-foot) in ponds with a pH <6.5. In ponds with total alkalinity >150 ppm and water temperatures >48°F (>9°C) copper sulfate should be applied at 1 lb/acre-foot (0.37 ppm). Applications occur when few fish are netted after the first lift or after catches have declined. Richard and Hynes (1986) recommended using 6 mini-fyke nets/surface acre (15 mini-fyke nets/ha) with green or red colored mesh to harvest walleye fingerlings. Copper sulfate was added at a rate of 4–6 lb/surface acre (4.4–6.7 kg/ha) to irritate fish and which encouraged them to swim more actively. It should be noted that although copper sulfate is an EPA-registered algicide, it is not registered as a fish irritant to increase the movement of fish.

Richard and Hynes (1986) reported that improper harvesting methods can kill fingerlings, especially when the water temperature is >77°F (>25°C). Harvest usually occurs when fingerlings reach 2–2.4 in (50–60 mm), when zooplankton populations diminish, or when cannibalism or emaciation of fish occurs.

Seines usually have 0.25-in (6-mm) mesh for fish between 1.5 and 2.5 in (38 to 63 mm), but larger mesh (0.5 in, 12 mm) is used for 5 to 6 in (127–155 mm) walleye. Seining continues until the number of remaining fish is negligible. Peterson (1973) used 0.25-in (6-mm) mesh nylon seines 150 ft (46 m) long and 12 ft (3.6 m) deep. Buttner (1989) recommended seining early in the morning to harvest 1.4–2.6-in (35–65-mm) fingerlings.

Climate influence on pond culture

Cold and cloudy weather during the first 2–3 weeks of culture, can prevent an adequate zooplankton bloom which will cause massive mortality as fish have no source of food (Richard and Hynes 1986). Periods of unusually cold weather temporarily inhibit zooplankton production and reduce walleye growth and survival (Beyerle 1979; Westers 1980). Summerfelt et al. (1993) found greater year-to-year variations in yield and survival than pond-to-pond variation within years which suggests climatic factors strongly influence production. They also noted that differences in the mean water temperature affected the length of the culture period, with higher mean temperatures resulting in shorter culture periods to grow fish to the same size.

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Pond Culture of Fingerlings in Undrainable Ponds

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Introduction

walleye is one of the most desired sport fishes by Minnesota anglers. The Minnesota Department of Natural Resources (DNR) has stocked walleye fry and fingerlings in lakes that have insufficient recruitment to sustain a walleye fishery. To meet the demand for fingerlings, artificial propagation has been practiced in this state for almost 60 years in both drainable and natural ponds. Early efforts in drainable ponds consisted primarily of evaluating fry stocking densities, but results with stocking fry at 10,000to 50,000 fry/acre (24,710–123,550/ha) were inconsistent. This problem led to research to provide guidelines that would enable consistent levels of fish harvest. Experience indicated that stocking ponds with 3,000–5,000 fry/acre (7,413–12,355/ha) would be sufficient stocking densities when the goal was to obtain a fall-fingerling that would weigh 30/lb (66/kg) or larger. Large fall fingerlings were needed to avoid high mortality of stocked fish. Evaluation of the contribution of stocked walleye to walleye populations in state lakes indicates that stocked fish only contribute to year-class strength in a lake when the stocked fish are of a size to compete successfully with the resident population of walleye for the young-of-the-year yellow perch, their preferred prey.

In 1993, the DNR operated 13 seasonal hatcheries which are located from the southwest **part** to the northeast. These hatcheries obtain most of their walleye eggs from broodstock collected from natural river-runs of walleye. Most collection sites are located in the northwest and central parts of the state. In 1993 over 2.4 million fingerlings were stocked into state waters. Over 240 natural ponds are operated by state personnel. Since 1990, production levels have been decreasing by deleting stocking from lakes where stocking was not needed or ineffective.

Pond selection

During the 1960's, many DNR area managers began using natural ponds and small lakes that winterkilled on an annual or semiannual basis. Most ponds were on pubic lands, some were leased from private land owners, and other ponds were also available under a cooperative program with various sportsmen groups and local lake associations. In the early years of walleye culture, there was a lack of information about proper pond size, and depth, watershed factors, and management strategies. Ponds ranged in size from less than five acres to more than one hundred acres. The major constraint was an inability to harvest fingerlings using seines. Seining was not effective in ponds with tree stumps or heavy stands of submergent vegetation. In the early 1970's, the major harvest method changed from seining to trap netting which allowed the use of ponds that could not be seined. Because of the large geographic range of the ponds over the state of Minnesota, there was a large variation in alkalinity, pH, depth, nutrient load, fish fauna, and yield. In the 1980s, fish managers learned more about proper pond management and the impact of chemical and biological condtions.

Today ponds are only used when they meet the following criteria:

1. There must be an annual winterkill of all the fish.
2. Water depth (up to 15 ft, 4.5 m) should be sufficient to avoid summerkill and to have a temperature strata that allows the young walleye to avoid high summer temperatures.
3. Ponds in forested areas are avoided because of natural low fertility.
4. Ponds must be >5 acres (>12.4 ha) but less than 100 acres (247 ha), a range of 50 to 100 acres (124–247 ha) is better, and the ideal size is >50 acres (124 ha).
5. The pond should be accessible to trucks and have a suitable site to launch a boat from which nets can be set and fish harvested.

Other factors considered in pond selection are potential conflict among user groups, wildlife concerns, and bait producers. It seems that walleye production triggers considerable public interest and controversy because of perceived conflicts in DNR Wildlife management areas, Federal Waterfowl production areas (WPAs), or when there will be competition with private aquaculture.

Production data

Ponds are classified as cooperation ponds and state-controlled ponds. Cooperative ponds represent about 15% of the pond acreage and 25% of the ponds by number. In 1984, the average size of these ponds were 27 acres (66.72 ha) compared to 58 acres (143.3 ha) for state-controlled ponds. Between 1982 and 1986 the average statewide production averaged 3,634,000 fingerlings/year, with an average size of 25.6 fish/lb (56.4 fish /kg).

Pond management

It is important to have a hydrographic map for each pond. Water chemistry should be monitored. Dissolved oxygen, pH, and total alkalinity are the most essential variables. In February and early March oxygen levels will determine whether winterkill was effective to prevent carryover of fish. Carryover of walleye fingerlings will result in a diminished production capability for the coming year. Ponds can be sampled with trap nets with 0.25-in (6.4-mm) mesh nets a few weeks after ice-out to determine if any fish survived. Plankton populations should be assessed along with bottom soil types and shoreline depths. Ponds with large stands of emergent vegetation are avoided because they will make fish harvest difficult. Amphipod ("scuds") populations *Gammarus lacustris* (up to 22 mm) and *Hyalella azteca* (up to 8 mm) should be assessed, as they provide important forage for the fish. *Gammarus* is the largest and most important of these scuds; they only survive in waters with a total alkalinity over 80 ppm. A pond that lacks *Gummarus*, but meets the alkalinity criteria can be inoculated with *Gammarus* by adding at least a 0.5 lbs/acre
(0.56 kg/ha).

Fertility appears to be a variable that greatly effects production, but artificial fertilization is not considered practical. Yield declines sharply in the third year of continued production. For this reason, some less fertile ponds are "rested" on a regular basis, especially so when they are <30 acres (74 ha). Numerous pond checks during the summer are not usually required, but a check prior to harvest helps determine the mesh size needed for the trap net, and harvest priority can be set, generally, ponds with larger fish are first to give ponds with smaller fish an opportunity to grow. To provide consistency in pond production detailed records should be kept.

Pond stocking

Fry stocking rates should not exceed more than 5,000/ acre (12,355/ha) to obtain fall fingerlings that will average 25–30/lb (55–66/kg). There seems to be a negative (inverse) relationship between average size of walleye fingerling harvested and stochng density. Stocking rates in excess of 5,000 per surface acre (12,355/ha) will not produce fingerling fish that reach the desired size. When fry are planted at (<5,000 fry/ surface acre, (12,355/ha) can usually produce a quality size fingerling (larger than 30/lb, 66/kg) in small ponds (larger than 50 acres, 123.5 ha) for lake stoclung.

Pond reclamation

Pond reclamation (i.e., treatment with rotenone to kill all fish) may be needed in natural ponds, but this is prohibited for ponds >100 acres, (247 ha). Reclamation is done only on an exceptional basis on ponds less than 100 acres (247 ha), when large numbers of black bullheads and common carp are present. Abundant populations of fathead minnows, dace, and or stickle-backs can reduce fry survival even though such populations would be desirable forage for larger fish. Typically, walleye culture in ponds that have other fish present are usually a failure. Restricted-use products such as rotenone fish toxicants can be purchased only by a Certified Pesticide Applicator or under a certified applicator's direct supervision (Federal Joint Subcommittee on Aquaculture 1994). Look for the "restricted use pesticide" designation on the label to identify such products. Before using any chemical, the user should insure that any federal, state, or local laws do not restrict its use. Rotenone treatments are best done in the late fall rather than in the spring. When treated in the fall the zooplankton has time to recover, and become abundant the following spring before fry are stocked. Ponds that are free of competitors and predators greatly improve harvest and lowers the handling stress on walleye fingerlings. Inoculation with preferred zooplankton and scuds in the spring is also desirable. In the past, minnows have been stocked as forage, but present studies indicate that this practice is inefficient and is a costly method to increase average size. Fathead minnows can compete with larval walleye for food .

Conclusion

The Minnesota Department of Natural Resources walleye culture program has produced fingerlings for stocking reclaimed lakes, maintenance stocking, and introduction to waters without walleye (e.g. winterkill lakes and bass-panfish lakes). Minnesota has around 1 million acres of walleye water to manage. This program of extensive production in natural ponds began in the 1930s. Ponds used for walleye culture are found throughout the state and are managed by 6 regional offices and 22 of 28 area stations. An average of all ponds in statewide production produced 218 fingerlings/surface acre (538/ha) in 1993 with a fingerling average return of 3.2%. Generally ponds have averaged from 10 to as high as 50% return from fry stocked. There is great diversity in physical, chemical, and geographical characteristics of these ponds. Each pond must be managed on an individual basis thus there is no single recipe for success. Nutrient levels, nuisance plants, predatory insect populations, and established fish populations all provide some limitations as to production success. Harvest methods have been modified to accommodate pond types by bottom content, size, and available work force. The method of harvest are practiced on a pond by pond basis. Even with the best possible management scheme the harvest success is largely dependent on weather.

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Extensive Culture of Walleye Fingerlings

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Introduction

The information presented in this case study describes the methods used at Spirit Lake State Fish Hatchery to raise fingerling walleye in Welch Lake, a shallow winterkill lake located in northwestern Iowa (Figure 1). Culture in other nursery lakes is quite similar to this lake. Two harvest are made from Welch lake, first 2 to 2.5 in (5.1 to 6.4 cm) fingerlings are harvested in June to thin the population to obtain fish for tank culture and for stocking, This harvest reduces population density and fathead minnows are added to provide forage to raise the remaining fingerlings to about 6-in (15.2 cm).

Methods

Welch Lake is a 57-acre (23 ha) glacial lake with an average depth of 5.1 ft (1.6 m). Total alkalinity averages 176 ppm. Daytime pH ranges from 8.2 to 9.0. Because carryover of walleye from one season to the next would result in predation by yearling fish on the newly stocked fry, in late October the lake is treated with 2 ppm rotenone to kill all fish. In the past, the pond was treated in early spring with Aquazine at 2 ppm to prevent a vegetation problem in June when the first harvest is made.

Counting fry

The lake is stocked with 2-day old fry at about 20,000/acre (49,420/ha). Fry for stocking are estimated by the visual comparison method whereby an unknown fry density is compared with a counted sample. Fry density in a plastic bag with a known quantity of water is compared to a counted population of fry in the same volume of water. A periodic check is made to confirm that the comparison method is giving a reasonable estimate. Although the accuracy of this procedure has not been compared with other methods to enumerate fry, we find it expedient for stocking large numbers of walleye fry. We subtract the number of fry removed from the catch tanks against the number of eyed eggs remaining in the incubators to maintain our inventory of eyed-eggs.

Zooplankton (cladoceran and copepod) populations in Welch Lake are monitored using a fine mesh plankton net. A heavy planktonic bloom usually occurs during the first week in May at about the time fry are stocked.

First harvest

Weekly sampling of fish is started when fish are 2-3 weeks old to gain awareness of fry survival and growth rate. The first harvest is started when fish have reached a size of 2 to 2.5 in (5.1–6.4 cm) total length (400 to 210/lb, 881–462/kg). Fish are captured with a 1,000ft, ¼-in (6.3 mm) mesh seine. At this time, about 78,000 fish are seined and transported to the hatchery for training to formulated feed and for stocking. Fish are

Figure 1. Welch Lake (foreground), a shallow winterkill lake in northwest Iowa that is used by the Iowa Department of Natural Resources to raise walleye fingerlings.

transported from the lake to the hatchery building in a tank truck using pure oxygen to maintain oxygen levels. **A** saline solution is added to the water to reduce physiological stress. The saline solution is composed of 4.3 lb (1.95 kg) sodium chloride, 0.17 lbs (80 g) potassium chloride, 0.1 1 lb (50 g) monopotassium phosphate, **and** 0.09 lb (40 g) magnesium sulfate per 100 gal (378 L) water.

Addition of forage fish

After the first harvest, population monitoring is continued weekly. When walleye reach 185 fish/lb (407/kg) about 1,600 lbs (726 **kg)** of fathead minnow are introduced as forage (28 lb/acre, 31.4 kg/ha). Thereafter, fathead minnows are stocked weekly (18 lb to 25 lb/acre, 20.2 to 28 kg/ha), depending on walleye growth and abundance of forage. We typically use about 16,000 lb (727 kg) of minnows for the growing season (281 lbs/acre, 315 kg/ha), which represents about 3 lb (1.4 kg) of minnows for each pound (0.45 kg) of advanced fingerlings that are harvested. However, to avoid overstoclung minnows, forage stoclung is adjusted to the abundance of walleye fingerlings.

Second harvest

The second harvest occurs in early October when fingerlings are about 5 to 6 in (12.7–15.2 cm). Fingerlings are harvested using **a** 1/2-in (12.7 mm) bar measure mesh drag seine, 2,800 ft (853 m) long. With one or two hauls per day, it takes 5–6 d to harvest most of the fingerlings. Fish are transported as described earlier.

Production costs

Expenses for manpower, chemicals and vehicle uses are similar each year, consequently, variation in production numbers affect fingerling costs each year. Production may range from less than 110,000 to 350,000 walleyes annually. **A** normal production year would yield 78,000 (260 Ib) of 2 to 2.5 in (5–6.4 cm) and 110,000 (5,789 lb) 5 to 6 in (12.7–15.2 cm) fingerlings. The total harvest (188,000 fingerlings) is 16.5% of the fry stocked. Yield is 106 lbs/acre (118.8 kg/ha). Production costs are about $51.00/thousand (5.1¢) for 2.5 in (6.3 cm) fish and $253.00/thousand (25.3¢) for 5 to **6** in (12.7–15.2 cm) fingerlings.

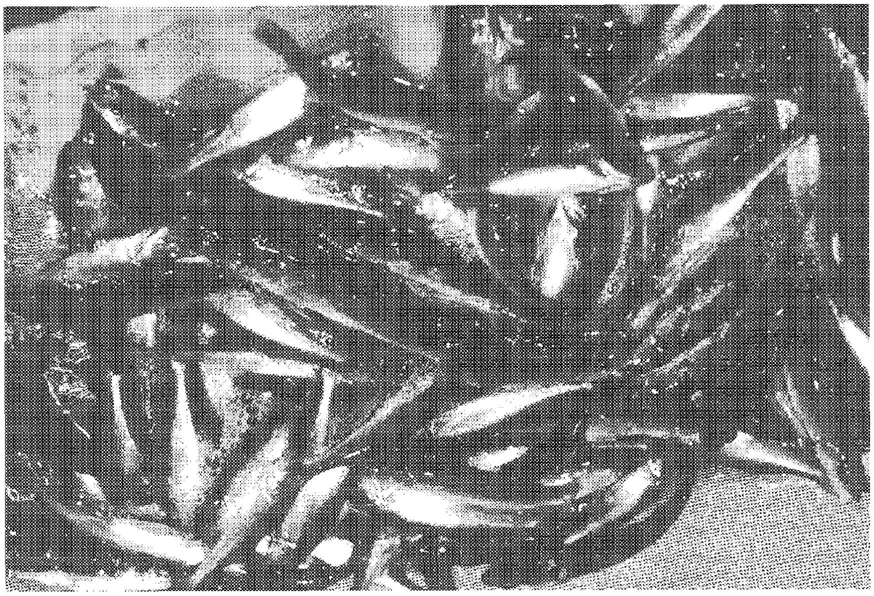

Figure 2. Five to six in (12.7 to 15.4 cm) walleye fingerlings obtained from the second (fall) interval.

In most years extensive lake culture is a satisfactory way to produce fingerlings, however, one of the major drawbacks is the unpredictable number of fish that can be produced. Fry must be stocked within 5-days posthatch, but cold weather and other factors may reduce zooplankton populations causing a sharp reduction in survival.

Gustafson, C. 1996. Pond culture of walleye in Michigan: fry to advanced fingerling. Pages 153–155 *in* R. C. Summerfelt, editor. Walleye culture manual. NCRAC Culture Series 101. North Central Regional Aquaculture Center Publications Office, Iowa State University, Ames.

Pond Culture of Walleye in Michigan: Fry to Advanced Fingerling

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Introduction

This paper describes walleye pond management practices used by the Michigan Department of Natural Resources to produce walleye fingerlings. In Michigan, artificial propagation of walleye has been practiced for more than 100 years. Early stocking efforts, which consisted primarily of stocking fry, met with limited success. The period 1940–1975 saw the historically strong Great Lakes walleye fisheries collapse. In 1970, pond culture of walleye fingerlings was undertaken to enable the Michigan Department of Natural Resources Fisheries Division to reestablish fisheries in Little Bay deNoc and at Muskegon in Lake Michigan and in Lake Huron's Saginaw Bay. Other fisheries in the lakes continue to expand. Expansion of the walleye fingerling program to inland waters has created new and supplemental opportunities for the state's anglers.

The walleye fingerling program has developed from trial-and-error and shared experiences with other hatchery managers in Michigan, as well as those from other states and Canada. The program has evolved by combining these experiences with research and new innovations.

Michigan has 13 fisheries management districts, and each operates its own walleye culture program. Eggs obtained from wild populations in Little Bay deNoc and the Muskegon River are hatched, and the fry are distributed by the division's hatchery section to all 13 districts. Over 100 ponds are operated state-wide. In the program's first year (1970), 45,500 fingerlings were produced. In 1990, over 5.7 million fingerlings were stocked into state waters. Between 1970 and 1990, production levels increased annually but have now leveled off. In 1990, average production was 7,000 fingerlings/acre (17,297/ha), with a fry to fingerling survival rate of 30%.

There is no typical pond that is used to culture walleye. They are distributed throughout the state and cover a wide range of geographical, physical, and chemical characteristics. Some of the ponds are drainable; others are borrow pits and sewage facilities; some are small ponds and lakes. Many ponds are under state or federal ownership, while others are private or leased. Pond size ranges from 0.5–40 acres (0.2–16.2 ha). There is a large variation in alkalinity, pH, and productivity. A growing number of ponds are being managed cooperatively with sporting groups, local organizations, and the **U.S.** Forest Service. Each pond is unique and must be custom-managed; as such, a "typical" management scheme is difficult to define.

Methods

In drainable ponds, the culture process begins in late summer. The pond bottom is planted with rye. Planting can be done with hand seeders, by tractor, or, in large wet situations, by aircraft. The ponds are left dry over winter. After flooding, the decomposition of the organic matter enhances zooplankton production. The cover also protects the pond bottom from the erosive effects of rain.

As soon after "ice out" as possible, the drainable ponds are filled, but before ponds are filled, any water in the pond, pools and puddles of water are treated with rotenone to lull any fish that might be present. Ponds are filled by runoff from creeks or springs, by pumping well water, and by pumping lake or river water. When using lake or river water, the inflow is screened to prevent the introduction of unwanted fish. Rotenone use in the spring is not desirable on full ponds, as it can adversely affect zooplankton production and then can remain toxic, delaying fry introduction.

Before fry are stocked, ponds are checked for zooplankton abundance, predaceous insect populations, and aquatic weed and algae growth. Ideally, the ponds should be monitored at least twice **a** week. Frequent monitoring allows problems to be corrected before they become unmanageable.

Not all ponds are fertilized, but when fertilization is done, an initial application of fertilizer is applied 2 weeks prior to stocking in ponds. **As** the culture season progresses, additional fertilizer applications are made as needed. Grain by-products, animal manure, yeast, inorganic fertilizer, hay or combinations of these fertilizers are used. The primary goal of a fertilization program is to produce a zooplankton population composed of desirable species. Daphnid cladocerans and cydopoid copepods are preferred by young walleye. If these species are present in adequate numbers, the chances of good fingerling production are excellent. The second consideration is to supply nutrients and substrate to encourage a favorable benthic environment that contains a good chironomid larvae population. This becomes increasingly important as the fingerlings reach a larger size. Some ponds must be heavily fertilized to meet these goals, whereas others need little or no fertilization.

If the monitoring shows a lack of desirable zooplankton, inoculation with the proper species is sometimes done. Sources of zooplankton include shallow ponds or lakes that support good populations. Collection can be made with plankton nets, and the zooplankton are then transported in tanks with oxygen bubbled into the water.

Piscivorous, air-breathing insects need to be controlled. Back swimmers (Notonectidae), giant water bugs (Belostomatidae), and predaceous diving beetles (Dytiscidae) are the major predators. The standard treatment that has been employed is to apply fuel oil at a rate of 3 gal/ acre (28 L/ha). Insect treatments are avoided 2 weeks prior and 3 weeks after fry are stocked to avoid interference with swim bladder inflation. Predaceous insect control treatments are used as needed. Environmental concerns about the use of fuel oil in water has prompted experimentation with vegetable oil. Preliminary results are encouraging, although it is more expensive.

Aquatic weed control is rarely necessary before stocking; however, as the water warms, aquatic weed control becomes more important. Excessive plant growth not only changes the productivity and dissolved oxygen levels in the pond, but also makes fingerling harvest more difficult. Several commercial herbicides are used to control aquatic weeds; label directions must be carefully followed and a check of state regulations is advisable. Filamentous algae growth often begins along the shoreline. Effective treatment of filamentous algae was obtained by dragging a burlap bag containing copper sulfate crystals through the vegetated area. This treatment was usually repeated during the culture season. Cutrine™, a copper sulfate product, can also be used. Care must be practiced while using copper products, as excessive concentrations can be toxic to fish, especially in soft water. In the past, Aquazine™ (simazine) was effective in controlling algae and macrophytes; however, its use is restricted to situations where there is no discharge to public waters.

Mechanical harvesting of algae and macrophytes is often employed. Although labor intensive and usually temporary, it is often the best choice to clear areas for netting or around water discharges during fingerling harvest.

Stochng of common carp into the ponds has been used experimentally in southern Michigan as a natural form of weed control. Common carp increase the pond turbidity which, in turn, retards weed growth. Early evaluation of this technique shows some promise, though further evaluation needs to be done.

Tadpoles compete with fish for food, and they are a major concern at harvest because they must be separated from walleye. Sorting requires extra work and causes additional fish mortality. An abundant tadpole population has developed in one of our better drainable ponds during the past few years. We are attempting to control tadpoles in this pond by preventing migration of frogs into the pond during the spring mating season by encircling the pond with 0.034 in x 1 x 4 ft (0.87mm x 0.3 x 1.22 m) rigid plastic fencing.

Fry are stocked in late April-early May. The normal production season lasts from 4–8 weeks and spans May, June, and July, depending on pond location. Due to the different spring temperatures from north to south, both egg collection and pond readiness vary. Fry are stocked **1–3** d after hatching. They are shipped from the hatchery in water-filled plastic bags supplemented with pure oxygen. Fry are transported to the ponds and stocked at 30,000–75,000/acre (74,130–185,325/ha). The variation in stocking rates results from past pond performance, relative productivity, and harvest plans. If the pond is to be used for fall fingerling production, higher rates are used and the population is thinned in the spring.

A fish sample is taken at night 3–6 d after the fry are stocked to see if the fry survived the first critical days. This sampling is done with a "crappie light'' and fine mesh aquarium net. Fry and zooplankton are attracted by the light and are usually easy to find. If survival is poor, more fish are ordered, and the pond is restocked. Fish are sampled bi-weekly. **As** the fish grow beyond the fry stage, they can be visually observed and collected with a small mesh seine. Length and condition are determined and signs of cannibalism are monitored.

Fish are normally harvested when they are 1.5–2.5 in (38–63 mm). The key to maximum yield is to harvest the fish before the food supply is depleted. **A** sudden depletion ("crash") of the zooplankton population will trigger cannibalism. Changes in the zooplankton population, includmg a lack of female cladocerans carrying young and the appearance of ephippia (the resting egg chamber) indicate that the population is about to decline. **As** the zooplankton becomes depleted, the fingerlings become emaciated, and their heads seem out of proportion. Also at this time, schools of fingerlings can be seen cruising in the shallows. If the zooplankton decline can be predicted, it can sometimes be delayed by the addition of fertilizer, an inoculation of zooplankton, or a combination of the two. Harvest must be initiated if the zooplankton population cannot be revived.

Harvest is accomplished using two methods. Small mesh (0.125–0.25 in, 3.17–6.35mm) fyke nets are used in combination with copper sulfate to capture fingerings. Copper sulfate crystals are added to the water to achieve a concentration of 0.15–0.30 ppm. The chemical irritates the walleye, which increases their movements, and thereby drives them into the nets. The fyke nets used are 4 x 4 ft (1.22 x 1.22m) and 6 ft (1.83 m) long; lead lengths vary among ponds. The condition of fish captured in these nets is usually excellent. Drainable ponds enable fingerlings to be captured in a screened **box** or with a seine at the spillway. We usually employ the netting method prior to draw down, as it results in fish in better condition and with less mortality.

Occasionally, we raise fingerlings to **3–6** in (75–150 mm). To successfully produce these fish and still get an acceptable harvest, the fish need to be provided with a food source to limit cannibalism. There are two ways we have successfully done this, and both utilize fathead minnow. In pretreatment, fathead minnow are captured in either fyke nets or seined from brood ponds and transported to culture ponds where they are released. Walleye in these ponds are usually thinned with the use of nets to reduce competition before the fathead minnow are added. Spawning structures for the fathead minnow are often placed in the ponds; cement blocks or wooden planks work well. In the second treatment, a known number of fingerling walleyes are stocked into a pond that has an established fathead minnow population. Good results have been realized using both methods. The latter method is easier to assess because stochng density is known. The former method, however, is used more often because it is easier. Larger fingerlings are harvested in late summer and in the fall.

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Walleye Fingerling Culture in Undrainable, Natural Ponds

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Introduction

Commercial walleye fingerling producers in Minnesota were interviewed in November 1994 on cultural practices used to raise walleye fingerlings in undrainable, natural ponds. Although they gave information freely, to protect the proprietary nature of the information not all of the subtle variations of their techniques are presented. Because natural ponds are highly variable in size, depth, water quality, and fertility cultural practices are not standard and experienced growers encounter substantial variation in survival, yield (lbs/acre, kg/ha) and size at harvest. What follows is a description of the general practices used to produce walleye fingerlings in Minnesota.

1992 survey

A 1992 survey (Minnesota Aquaculture Report, 1993) of commercial aquaculture producers in Minnesota indicated that 53 of 79 (69%) producers used natural waters for some of their production. About 1,206 natural ponds, totaling 39,291 acres (15,900 ha) (mean was 33 acres, 13.4 ha) were used to raise bait fish, such as suckers and fathead minnows, and to produce walleye fingerlings for stoclung. The survey reported that over 600,000 walleye fingerlings, valued at $328,000 ($0.54/fingerling), were sold by private growers in 1992. Data were not obtained from all producers in 1992, so actual production was probably higher. Minnesota producers are able to produce more fingerling walleyes than the existing market can bear in most years. Expanded markets in Minnesota and other states could significantly benefit producers.

Natural pond selection

Ponds vary considerably in size, depth, fertility, and many other features. Finding an available pond that is appropriate for fish culture can be difficult. Typically in Minnesota, commercial producers lease ponds from a farmer or farmers with riparian lands. The most productive ponds for aquaculture purposes are in west-central Minnesota. Competition for water in this area of the state can be high.

As a rule, ponds used to raise walleye fingerlings must not have other fish present or at least nothing other than minnows. Other fish in the pond may be predators or competitors, and they may greatly reduce walleye production. The preferred depth is five to ten feet. Shallower ponds are at risk of summerlull and they often develop heavy growths of aquatic plants which hamper harvest efforts. Deeper ponds can be difficult to harvest and may allow overwinter survival of walleye or other fish. A carryover of walleye will severely limit the following year's production because the carryover walleye will prey on newly stocked fry. Thus, the best fingerling culture ponds winterkill every year. The process which eliminates oxygen from the water and causes winterkill can vary from one year to the next, so a pond that has a complete kill one year may only have a partial kill another. Checking dissolved oxygen levels in late winter will help predict the extent of winterkill in a pond.

The size of the winterlull ponds that are used for walleye culture can range from 1–100 acres (0.4–40.5 ha), but the typical pond ranges from 5–30 acres (2–12 ha). Although ponds approaching 100 acre (40.5 ha), can be productive, it is often very difficult to harvest a high percentage of the fish from large ponds. Higher percentages of available walleyes can be harvested from small ponds.

Physical and chemical characteristics of ponds also varies. Bottom type may be sand, clay or muck, but harder bottoms are preferred because harvest is easier.

Brush, logs, heavy vegetation and rocks make harvest more difficult. Total alkalinities of around 150–200 ppm are typical, but alkalinities may range from 50–300 ppm. The typical pH of the waters used ranges from 6.5–9.0; however, pH varies in a daily cycle, with highest values at mid-afternoon and lowest values before sunrise. Presunrise dissolved oxygen levels should not drop below 5 ppm. It is the opinion of producers that ponds in good farm country are often more productive than ponds in wooded areas, and ponds with embayments are usually more productive than circular ponds.

Fingerling culture and pond management

Controlling insects

Ponds should be checked before fry are stocked to assess the numbers of predatory invertebrates such as beetle larvae and backswimmers. One practice is to lull predatory air breathing aquatic insects by covering the pond with a thin film of oil. According to Dobie (1956) kerosene, fish oil, No.2 fuel oil, and cod liver oil can be used for this purpose. Recommendations include using 3–5 gallons of fuel oil/acre (4.5–7.7L/ha), 10–12 gallons of kerosene per acre (15.4–18.2L/ha), or 4–5 gallons of fish oil per acre(6–7.7 L/ha). The oil is applied along the windward side of the pond when it is windy enough to spread the oil over the pond surface, but not so windy that it all blows to one shore. One producer used soybean oil mixed with kerosene, but he has since stopped the practice of oiling his ponds. Although the producer thinks an oil treatment improves survival, he has halted the practice because of costs for the oil and labor and to maintain landowner relations which could be strained by perceived negative environmental impacts. Another producer uses vegetable oil without kerosene mixed in.

Monitoring zooplankton densities

Many producers check zooplankton densities with a plankton net before walleye fry are stocked and one experienced grower stated that a plankton net is essential for walleye pond management. Zooplankton are sampled with a plankton net towed 50–100 ft (15–30 m) through the pond early in the morning or in the evening when zooplankton are higher in the water column. Experience is generally used to determine if fry should be stocked rather than specific zooplankton counts. If sufficient numbers of rotifers, daphnia, and copepods are not found, fry should not be stocked because survival will be low. If zooplankton numbers are low, then organic fertilizers can be added prior to stocking to stimulate a zooplankton production, however, results of pond fertilization are highly variable and are not immediate. Zooplankton populations must be surveyed far enough in advance of stocking to allow zooplankton time to respond to fertilization. Most producers do not fertilize large ponds. Many ponds in the row-crop area of west-central Minnesota receive sufficient fertilizers from runoff of adjacent farming operations. Fertilization may also be warranted after stochng if zooplankton numbers start to decline. The use of water clarity (Secchi disk-transparency) to determine when and how to fertilize (as recommended for southern **U.S.)** is not recommended by experienced growers in Minnesota. Better results are achieved by examining zooplankton numbers and composition than by looking at water clarity. Zooplankton can also be trapped from enriched ponds and stocked before fry are stocked or when zooplankton numbers decline (at least until the walleye reach 1.5–2 in [3.8–5.1 cm] when they become piscivorous).

Sources and stocking of fry

In Minnesota, walleye fry are purchased from the Department of Natural Resources or from private producers. Although the number of commercial sources are limited, the number of fish farmers building facilities for holdmg brood fish is increasing. Producers pay around $7 to $9 per thousand for walleye fry. Prices vary from place to place and by the size of the order. Walleye fry are transported in plastic bags with a small amount of water and a large volume of oxygen. The bags are usually placed in a cooler to reduce temperature increases. When the fry reach the pond it is important that they be acclimated to both the temperature and chemistry of the water. The plastic bags are typically floated in the pond until the transport water temperature equilibrates to the pond water temperature, then the bags are opened and pond water allowed to slowly enter the bag. Once the pond and transport water have mixed, the fry are slowly released into the pond. If pH of the pond water differs substantially from the transport water, additional acclimation procedures may be warranted. Some producers allow fry to escape slowly into the pond on their own from an acclimation chamber; others spread the fry throughout the middle of the pond to reduce predation by any minnows and aquatic invertebrates that may be present.

Stocking density

Most producers stock 2,500–10,000 walleye fry per surface acre (6,200–25,000/ha). Stocking rates of 20,000–30,000/acre (49,000–74,000/ha) or higher are used if the pond is known to be very productive, artificial aeration is used, and it is more intensively managed. Usually, when higher stocking densities are used, fingerlings are harvested or thinned in early July.

Pond aeration

It is a general practice to aerate small fertile ponds if there is access to electrical power. The risk of catastrophic loss is greatly reduced, and some producers think that aeration increases production. Because many of the ponds are large, they are not fully aerated to the manufacturer's recommendations because the expense would be too great. The most common type of aeration is an air compressor with a bottom diffuser.

Feeding

For production of advanced fingerlings, that is, fish larger than 2 in (5 cm), many producers feed fathead minnows to their walleyes once they reach 2–3 in (5–7.6 cm). Appropriate sized fathead minnows are less then 1.5 in (3.8 cm) and they pass through a 16 to 17 grader. Fatheads are added to the pond on a regular basis to maintain an adequate food resource. Without minnows, walleye can become quite cannibalistic. **An** indicator of cannibalism is a wide range of fingerling sizes; cannibalistic walleye grow faster than other walleyes. Some producers stock fathead minnow broodstock into ponds after stocking walleye fry. Fathead reproduction through the season is then a food source for the walleyes. Fatheads will, however, compete with or prey upon walleye fry, so care should be taken not to stock them before walleye fry are stocked.

Bird predation

Bird predation is regarded by the fish farmer as a significant cause of mortality in natural ponds. Fish farmers have said that cormorants and pelicans can wipe out an entire pond very quickly. Flocks of 100–200 have been seen on some production ponds. The stomach of one cormorant contained 42 four-inch (10.2 cm) walleye. Retail value of that one meal was about $42. While larger ponds seem to be at greater **risk** to bird predation, even smaller ponds are not safe. One experienced fish farmer claimed that if he had known how much of a problem birds can be, he never would have gotten into the walleye fingerling business. For more information about bird predation problems and solutions, the Southern Regional Aquaculture Center publications, numbers 400, 401, and 402 are useful. They can be obtained from your state aquaculture extension specialist or from the state **USDA, APHIS,** Animal Damage Control office, or the Regional Office of **APHIS** in Nashville, TN.

Harvest

Some walleye fingerlings may be harvested in early July when they are 2–3 in (5–7.6 cm), but most are harvested during September and October when water temperatures cool to below 60°F (16°C). Fingerlings harvested from warmer water can be stressed and are difficult to hold and transport. High and even total mortality can occur when fingerlings are captured in trap nets when the water temperature exceeds 70°F (21°C). If catches are small, walleye have been successfully trapped in warmer waters, but **risk** of loss is still high. The disadvantage of waiting for cooler water temperature is that there is less time to harvest the fingerlings before ice-up, resulting in reduced harvest rates, Walleye fingerlings can range in size from 3–10 in (7.6–25.4 cm) in September, although they are generally 4–8 inches (10.2–20.3 cm) long and 15–25/lb (7–11/ **kg).**

Walleye fingerlings are usually captured in trap nets, but may be seined if pond conditions permit. Traps are set along the shoreline at intervals of 150–200 yd (137–183 m). Catch rates vary daily. It can be very frustrating to realize that the fish are in the pond but are simply not moving enough to encounter the nets. It is speculated that when food is abundant, fish move less. Therefore, feeding is usually discontinued prior to harvest. Various methods to induce fish movement have been tried with variable success. Development of more effective harvest methods would be very beneficial.

The yield of stocked fry varies considerably among ponds and years, but it generally ranges from 10–15%. In any given year there are ponds in which harvest may be zero, while other ponds may produce up to a 30–40% or greater return. Prices for walleye fingerlings vary, but a general rule of thumb is that walleye fingerlings less than 8 in (20.3 cm) sell for around $0.10/in ($0.04/cm) wholesale and about $0.15–$0.30/in ($0.06–$0.12/cm) retail. The wholesale price for fingerlings greater than 8 in (20.3 cm) is about $0.12–$0.15/in ($0.05–$0.06/cm) and retail price are about $0.18–$0.40/in ($0.07–$0.16/cm). Walleye longer than 12 in (30.5 cm) are generally sold for around $3–$4.50/lb ($1.36–$2.04/kg) round weight.

Summary

Successful producers of walleye fingerlings in undrainable, natural ponds are experienced. Their advice is “get to know your ponds” and do not stock walleye fry in ponds if fish have survived the winter or if zooplankton populations are not sufficient in density and composition. Another recommendation from experienced fish farmers is to clean boats and equipment thoroughly before moving to another pond. This will help prevent introducing unwanted aquatic vegetation (e.g. Eurasian water milfoil) from one pond to another.

Experienced producers are moving towards exerting more management control over the production of walleyes in undrainable, natural ponds, but it remains an extensive type of aquaculture with inherent **risks.** Bird predation and weather are important factors that are difficult to manage. Manuals and case studies like this one provide insights and guidelines on culture techniques for the beginning fish farmer, however, experience is required to appropriately apply the information to each specific set of environmental conditions.

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