

## Chapter 10

# Cage Culture of Walleye

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### Introduction

Cage culture can be defined as the raising of aquatic organisms in an enclosure within a larger body of water. Although cage culture of walleye is not a well-established practice, the four case studies included in this chapter demonstrate that walleye can survive in cages, can be trained (habituated) to accept artificial feed in cages, can be over-wintered in cages in temperate regions, and can grow to a size at which they are marketable as a food fish. The initial capital investment required to begin raising fish in cages in existing water bodies is much less than that required for construction of drainable ponds or an intensive culture system. Therefore, cage culture may very well contribute to the development of walleye as a commercial species.

### Advantages of cage culture

#### General concepts

There are a number of advantages to culturing fish in an enclosure. Cage culture of walleye does not require expensive tank or raceway facilities, and usually does not require continuous pumping of large quantities of water. The capital and overhead costs of walleye cage culture would therefore be somewhat less than for other types of walleye culture. Cages allow the use of existing water bodies that would otherwise not be suitable for aquaculture due to their size, bottom configuration, lack of drainability, or the presence of obstructions which make seining impractical. Cage culture may be the only practical aquaculture method in these waters. When existing water bodies are used, the initial cost of pond construction is avoided (Masser 1988a; Swann et al. 1994).

It is easier to monitor the health and growth of fish in a cage than in open ponds. Sampling and harvest are simpler and require less equipment. In some cases a

pond used for cage culture can be used to grow a second crop outside the cages, a form of polyculture, or for sport fishing or other recreational activities (Masser 1988a).

### Walleye culture in cages

There are several advantages to raising walleye in cages. Walleye generally do not respond to feed spread on an open pond as well as some other cultured species. When walleye are confined to cages, however, they can be habituated to a prepared diet, because the fish are concentrated near the feed.

In ponds, tanks, or cages, walleye will cannibalize smaller siblings when size differences are sufficiently great. Antagonistic behaviors (hierarchy and territorial defense) of some fish species break down in the close confinement of cages, but there is no evidence that cannibalism by walleye is decreased by crowding. However, cages allow fish to be observed and graded to maintain a uniform size and they facilitate hand-removal of cannibals.

Walleye possess several characteristics that make them an attractive choice as a culture animal. Walleye are highly regarded both as a sport fish and as a food fish. Market potential exists both for fingerlings for stocking to enhance sport fisheries, and for larger fish for human consumption. Additionally, walleye are a coolwater fish. In temperate regions they may be better suited for cage culture than warmwater species because they will feed and grow at cooler water temperatures. The growing season for walleye would therefore begin earlier in the spring and extend later in the fall than for warmwater species.

### Disadvantages of cage culture

#### General concepts

There are a number of disadvantages to raising fish in cages. Concentrating fish in a small area can lead to degraded water quality conditions in a localized area around the cage. Low dissolved oxygen or a high concentration of ammonia in the cage can cause stress or mortality even though the overall pond environment remains suitable for survival. When water quality deteriorates, caged fish are not free to seek areas where conditions are more favorable.

Considerable time and labor may be required to clean cages. Fish in a cage are dependent on the movement of water through the mesh to flush away waste and to replenish oxygen. Because biofouling of the mesh can restrict water movement through a cage, cages need to be cleaned regularly.

When fish are crowded into a small area the potential for disease increases. Fish that are crowded may become stressed and, therefore, vulnerable to infection. The close confinement of fish in cages can lead to the rapid spread of infectious diseases. Inappropriate cage materials or design can lead to abrasions or injury which in turn provide opportunities for infection. Treatment of fish in cages can be difficult.

Fish in cages may exhibit antagonistic or territorial behaviors which can interfere with feeding and uniform growth. Fighting or biting can cause injury which may lead to infection.

Caged fish have little opportunity to acquire natural forage. Therefore, a nutritionally complete diet must be provided in order to obtain good growth rates and healthy fish.

Finally, fish can be lost from a cage in several ways. A small hole in a cage may allow the fish to escape. Escaped fish may be lost if the water body cannot be harvested. Fish in cages are more vulnerable to poaching or vandalism than fish cultured in open ponds. Predation by birds or snakes may be serious if the cage is not properly covered.

### Walleye culture in cages

There are specific problems involved with raising walleye in cages. Pond-cultured walleye must be trained

to accept a prepared diet, which can be done in cages (Harder and Summerfelt 1996), or in tanks. However, considerable mortality from disease, starvation, or cannibalism can occur during training. Although feed-trained fingerlings may be purchased from private producers, reliable sources are not always nearby and they may be costly.

Walleye are sensitive to disturbance; they may be stressed by handling or activity related to cleaning or maintenance of the cage. When stressed or injured, they are very susceptible to disease, especially if the temperature exceeds 77°F (>25°C). Also, walleye must be graded to prevent cannibalism or competition and sampled to adjust feeding rates; therefore, there is a high probability of significant mortality due to handling stress and disease.

### Site selection

walleye have been raised in cages in many types of water bodies including strip pits (Stevens 1996; Harder and Summerfelt 1996), borrow pits, lakes (Blazek 1996), and farm ponds (Anderson and Budiselich 1991; Bushman 1996). There are a number of site selection criteria that should be met before cage culture is attempted (Masser 1988a; Selock 1990; Swann et al. 1994):

1. The pond should be large enough to support the number of fish in the cage. Biological processes in the pond environment break down metabolic wastes and produce oxygen. Most ponds can support only about 1,000-1,500lbs/acre (1136-1704 kg/ha) without supplemental aeration or water flow. Confining fish in cages does not increase the carrying capacity of the pond. Waste feed, feces, and ammonia excretion will add a nutrient load to the pond. This may increase algae, macrophytes, and potential for oxygen depletion.
2. The pond should not have a large biomass of fish outside of the cage. These fish must be included in the total carrying capacity of the pond.
3. The pond should not be located in a watershed where the pond will receive agricultural runoff, livestock waste, or pesticide contamination. Nutrients from agricultural runoff or livestock waste can increase biological oxygen demand (BOD) resulting in low dissolved oxygen, and nutrients can cause excessive phytoplankton

blooms leading to drastic swings in oxygen concentrations (Anderson and Budiselich 1991). Pesticides can kill fish directly or contaminate their flesh.

4. The site for the cage should be deep enough to allow waste materials to be swept away from the cage. At least 1-2 ft (0.3 to 0.6 m) of water should be kept between the cage bottom and the pond bottom (Selock 1990). The water level in the pond should not fluctuate significantly. The pond should be exposed to wind action to aid in water circulation through the cage.
5. The pond must be accessible. Cage culture requires regular maintenance and feeding, so easy access to the cage is important. If aeration is to be used, access to a power source is important. It is desirable for the pond to be in a controlled or secure area to minimize poaching.

### Types of walleye cage culture

There are four types of end products of walleye cage culture. They are:

1. Small fingerlings, 1.5-2.5 in (38-64 mm), for stoclung.
2. Feed-trained fingerlings, 2.5-3.5 in (64-89 mm), for sale to other producers.
3. Advanced fingerlings >6 in (>152mm) for stocking.
4. Food fish 14 to 16 in and larger (356-406+ mm).

The type of cage and methods used will depend on the desired end product.

Procedures for producing small fingerlings in ponds are well established (Buttner 1989; Harding et al. 1992; Summerfelt et al. 1994), and large numbers are produced annually at state and federal hatcheries. However, some work has been done culturing fry to the small fingerling stage in enclosures within a larger water body. Brugge and McQueen (1991) constructed large circular enclosures of polyvinyl-coated nylon. Their structure did not allow any water exchange between the enclosure and the surrounding water body. They were managed like small ponds, including fertilization to induce a high standing crop of zooplankton. The enclosures were stocked at rates ranging from 8,000 to 32,000 fry per 35,300 ft<sup>3</sup> (1,000 m<sup>3</sup>) enclosure. Survival at 50 d ranged from 25.4% to 45.3%, and mean fork length was 28.9 to 33.7 mm. The fingerlings could be released into the surrounding water body by simply

lifting the sides of the enclosure. With these methods, small fingerlings could be produced within a lake that was to be stocked while avoiding the stress and mortalities often associated with harvesting, transporting and stocking of fingerlings produced in hatchery ponds.

Feed-trained fingerlings produced in cages may be raised to produce either advanced fingerlings or food fish in cages. However, feed-trained fingerlings raised in cages could be marketed for grow out in other types of culture facilities.

Advanced fingerlings (> 6 inches) can be produced in cages by the end of the first growing season for stocking recreational fishing lakes (Blazek 1996). There also may be a market for advanced fingerlings that have been over-wintered in cages. An advanced fingerling stocked in the spring would avoid heavy mortalities often associated with the first winter in the wild.

The production of food fish in cages currently requires 2 to 2.5 growing seasons (Stevens 1996). Improved walleye diets and culture techniques will probably allow this production time to be reduced in the near future.

### Cage design

Criteria for cage design include size, number of cages, shape, mesh size, flotation, and means of access.

Cages can range in size from the 1000-m<sup>3</sup> enclosures used to raise fry to small fingerlings (Brugge and McQueen 1991) to about 1 m<sup>3</sup>. Cage size should be determined by the anticipated number of fish and desired size when the cage is harvested. Stocking densities can range from >3,600/m<sup>3</sup> for training small pond-raised fingerlings to formulated feed to as few as 17/m<sup>3</sup> for raising advanced fingerlings to food-size fish (Table 1). A large cage is more cost effective in terms of cost per unit cage volume, but larger cages are more difficult to handle and harvest. Several small cages allow walleye to be graded and divided as they grow.

The number of cages in a pond should be determined by the capacity of the pond and the size and capacity of the cages. If the intent is to grow advanced fingerlings for stoclung, grading and dividing may not be necessary, and a single large cage may be suitable. Food-size walleye will require at least two growing seasons to

**Table 1 Stocking density, growth and survival of walleye stocked into cages by case study authors.**

Cage volume (m <sup>3</sup> )	Cage shape*	Number stocked	Initial density (No./m <sup>±</sup> )	Initial length inches (mm)	Final length inches	Mesh inches (mm)	Survival (%)
Blazek (1996)							
3.6	R	310	86	3 (76)	5.2 (132)	0.25 (6.35)	84.3%
3.6	R	400	111	3.5 (89)	6.4 (163)	0.25 (6.35)	71.5%
3.6	R	405	112.5	2.25 (57)	6.1 (155)	0.25 (6.35)	26.6%
3.6	R	485	135	2.5 (63.5)	5.3 (134)	0.25 (6.35)	55.3%
Stevens (1996)							
3.3	R	2500	757	2.5 (63.5)	3.5 (89)	0.19 (4.8)	
7.3	R	1000	137	3.5 (89)	8 (203)	0.25 (6.35)	
7.3	R	500	68	8 (203)	10 (254)	0.5 (12.7)	
7.3	R	250	34	10 (254)	14 (355)	0.5 (12.7)	
7.3	R	125	17	14 (355)	16 (406)	0.75 (19)	
Bushman (1996)							
3.6	R	822**	228	2.5 (63.5)	4.9 (124)	0.25 (6.35)	33.5%
1.42	C	358**	252	2.5 (63.5)	4.9 (124)	0.25 (6.35)	36.6%
3.6	R	580	161	2.4 (61)	3 (76)	0.25 (6.35)	93%
3.6	R	508	141	5.6 (142)	6 (152)	0.5 (12.7)	98%
Harder and Summerfelt (1996)							
1.24	C	440	354	2.5 (63.5)	5 (127)	0.25 (6.35)	6.5%
1.24	C	1012	816	2.5 (63.5)	5 (127)	0.25 (6.35)	6.5%
1.24	C	4448	3619	1.9 (48)	***	0.25 (6.35)	22.8%
1.24	C	530	427		6 (152)	0.25 (6.35)	

\* R- Rectangular, C-Circular

\*\* Hybrid walleye

\*\*\* Divided into two cages represented by the following line.

reach marketable size. Therefore, in planning a cage culture operation it may be necessary to account for two year-classes in the pond at the same time. A single cage with a small mesh size would not be suitable for raising walleye from a small fingerling to a food-size fish. As the fish grow, they should be graded, divided, and transferred to cages with larger mesh to allow better water circulation. Stevens (1996) used cages of four different mesh sizes over a span of three years to produce food-size walleye. By splitting the fish biomass into smaller cages they can be placed at several sites around the pond, thus reducing the possibility that

water quality will become degraded around one large cage.

Walleye have been raised in both rectangular and circular cages. At this time, there is no evidence to suggest that one shape is more suitable. Some species that tend to swim actively much of the time may benefit from a circular cage since the fish are not constantly running into corners which can cause abrasions. Designs for construction of circular and rectangular cages are readily available (Masser 1988b; McKee et al. 1989; Swan 1990; Bushman 1996) and will not be

discussed. Other designs that could potentially be used include floating vertical raceways (Martin and Heard 1987) and floating horizontal raceways (Figure 1).

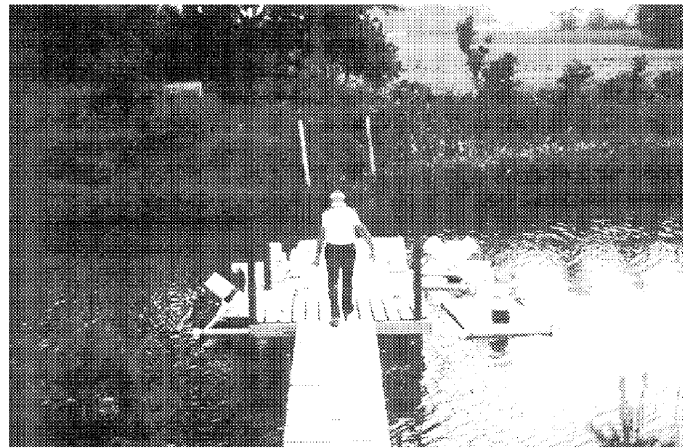
A small mesh will become blocked by biofouling organisms and debris more quickly than a large mesh. The mesh size chosen for a particular cage should be the largest mesh size that will still retain the smallest fish in the cage. Kindschi and Barrows (1991) reported an optimal mesh size to retain walleye fry of no more than 710  $\mu\text{m}$  between threads and no more than 53% open area. A mesh of this size in a pond environment would restrict water exchange and become fouled very quickly. No detailed work has been reported on the optimal mesh size to retain walleye fingerlings of various sizes. The best guide at this point is the criteria used by Stevens (1996): 0.19-in (4.8-mm) mesh for 2.5-in (63.5-mm) fish, and gradually increases **up** to 0.75-in (19-mm) mesh for 14-in (355-mm) fish (Table 1). The 0.19-in (4.8-mm) mesh may be smaller than necessary for 2.5 in fish, Harder and Summerfelt (1996) successfully used 0.25-in (6.35-mm) mesh for 1.9-in (48-mm) fish.

Most aquaculture cages are constructed with black plastic mesh designed specifically for aquaculture. Plastic mesh is easy to cut and it is very durable. If the cages are located in a water body with a large population of gnawing mammals, such as muskrats, there is a possibility that the muskrats will chew through the plastic mesh, and the fish will escape. Welded wire and hardware cloth have been used for cages, but these materials tend to rust. Vinyl-coated hardware cloth is somewhat more expensive than plastic, but has good durability and will resist the chewing efforts of muskrats.

Flotation used for cages includes Styrofoam blocks, net floats, sealed plastic jugs, and sealed PVC pipe. Any of these may work depending on the particular application. It is important, however, to allow ample freeboard, that is the distance between the top of the cage and the water, to avoid possible submergence of the cage. The cage should have excess flotation sufficient to resist submergence. Ducks and other animals may find the cage a convenient place to rest, and add their weight to the flotation requirements of the cage (Harder and Summerfelt 1996). Plastic jugs may deteriorate and leak, which requires sufficient flotation so that the cage

will remain afloat until a water filled jug float can be replaced.

It may be desirable to attach the cage to a floating dock or a pier. A dock provides a stable anchorage, and a stable work platform for servicing the cage (Figure 1). Care must be taken however, to not cluster too many cages around a small dock in shallow water, because water exchange may be reduced and there may be insufficient depth between the bottom of the cage and the pond bottom. Cages not attached to a dock can be serviced by boat, but at times this can become awkward.



**Figure 1. A dock provides easy access and a stable work platform for servicing cages. However too many cages around a small dock in shallow water may lead to water quality problems.**

### Source of walleye

The source of fingerlings is one of the most important considerations in planning a walleye cage culture operation. At this time, there are few commercial sources for feed-trained fingerlings. Habituating pond-reared fingerlings can be done in cages (Harder and Summerfelt 1991), but mortality will be an added expense. Also, transporting fish from the producer to the grow-out site and stocking them into a cage in good condition is another problem. Walleye are easily stressed by handling, and are highly susceptible to columnaris when stressed. Significant mortalities can and often do occur in the first 2 weeks after stocking (Harder and Summerfelt 1991; Harder 1992; Harder and Summerfelt 1996). It is vital to acquire the highest quality fish available and to handle them as little as possible when transporting them to the cage. Unfortu-

nately, walleye growers often have limited choices as to where they acquire their fish. The choice of suppliers of trained fingerlings is likely to increase as the walleye culture industry expands. Factors such as initial condition of fish, distance to be transported, and temperature change are all important considerations when selecting a source of fish.

In northern Illinois, walleye raised in ponds will generally reach about 2 in (50.8 mm) by early-to mid-June. If these fish are transferred to tanks and trained to accept artificial feed for 2-3 weeks, they should be ready for cage stocking in early July. Unfortunately, water temperatures in July can be warm enough to cause stress when the fish are stocked. Timing the cage stocking with cool water temperatures may help reduce stocking mortality.

Significant advances are being made raising fish from the fry to fingerling stage entirely on artificial diets (Moore et al. 1994a, 1994b). If this technology is adopted by commercial producers, then the possibility of acquiring feed-trained walleye fingerlings in June, when water temperatures are relatively cool, may increase survival of fingerlings stocked in cages.

### Training and feeding

walleye have been successfully trained in cages (Stevens 1996; Harder and Summerfelt 1996). Fingerlings to be trained in cages must be in good condition when stocked. They should be stocked at fairly high density and fed often. Stevens (1996) successfully trained walleye at a density of 21/ft<sup>3</sup> (757/m<sup>3</sup>). A commercial vibrating feeder was used to feed the fingerlings once every 5 minutes 24 h/day. He started his fingerlings on Kyowa C-2000 (Biokyowa Inc., Chesterfield, MO) at 10% of their body weight per day, and then converted them to 4 granules of the W-16 diet (Westers and Stickney 1993). Once the fish were feed-trained they were fed W-16 diet at 3-4% of their body weight per day. This ration was divided between two feeding periods. The fish were fed every 30 min for a 3 h period just before daylight, and again for a 3 h period beginning just after dusk.

Harder and Summerfelt (1996) achieved their best results (22.8% survival to 6 in [152 mm]) when fingerlings were stocked at high density during training

(103/ft<sup>3</sup> [3,619/m<sup>3</sup>]) and then thinned for grow-out. They fed their fish once every 15 min for 17 h/day throughout the entire culture period. Their best results were achieved using Biotrainer and Biodry diets (Bioproducts, Warrenton, OR).

Bushman (1996) started with feed-trained walleye fingerlings. He fed his fish every 15 min 24 h/day on various combinations of Walleye Grower (Murray Elevators, Murray, Utah) and Biokyowa, then switched the fish to Silver Cup Salmon feed (Murray Elevators, Murray Utah) for grow-out. As water temperatures cooled in the fall the feedings were reduced to the periods around dawn and dusk. Survival ranged from 93-98% though the mortality associated with training was not a factor.

Blazek (1996) started with fish that were already trained to the W-16 diet. He set his timers to feed 48 times per day, and achieved survival as high as 84%, though training mortalities were not included.

High mortality can occur when cage-training walleye to formulated feed. Mortality is related to handling stress, disease, starvation, and cannibalism. Harder and Summerfelt (1996) achieved 54% survival when walleye were tank-trained to feed and then transferred to cages, but only 22.8% when they were cage-trained to feed. At present, tank-training walleye appears to be more effective than cage-training. However, they did demonstrate that walleye can be trained in cages. As more experience is gained and techniques improve, training walleye in cages may become more effective. For walleye cage culture to develop, a source of high quality walleye diets must be available in the midwest so that feed can be purchased and shipped economically. In 1995, the 9206 Walleye Grower diet developed by F.T. Barrows (National Biological Service, Bozeman, Montana) could be obtained from Nelson and Sons, Inc., Murray, Utah for about \$0.40/lb (\$0.88/kg) including the cost for shipping (A. Moore, Iowa Department of Natural Resources, personal communication).

Plans for building inexpensive feeders suitable for cages are available (Mortensen 1987; Bushman 1996), however, some researchers who have used these feeders to feed walleye in cages have had difficulty achieving uniform and consistent feeding rates (Blazek 1996; Harder and Summerfelt 1996). These homemade

feeders may be suitable for feed-trained walleye but are not accurate or dependable enough to use when training walleye to accept artificial feed. A commercial vibrating feeder and timing system is considerably more expensive than the homemade feeder, but the cost may be justifiable, at least through the training period.

### The cage environment

Environmental conditions must be maintained within a cage for walleye to obtain satisfactory growth and survival. The preferred temperature range for walleye growth is 68-77°F (20-25°C); the ideal temperature is 73°F (23°C) (R.C. Summerfelt, Iowa State University, personal communication). However, the cage culturist has no control over water temperature, and high water temperatures, >80°F (>27°C) can lead to stress and subsequent mortality (Blazek 1996). Walleye will actively seek pellets at temperatures as low as 40°F (4.44°C) (Stevens 1988).

Dissolved oxygen is a critical parameter in **all** fish culture operations. The dissolved oxygen concentration should be measured in the cages on a regular basis. Generally, oxygen concentrations of >6 mg/l are best for walleye growth. If the oxygen level falls below 3 mg/l, the fish may become stressed or die. Most oxygen in a pond is the result of photosynthesis by aquatic plants or phytoplankton. Excess feed or fish waste in the pond will act as fertilizer for these plants and can cause a rich phytoplankton bloom. The same biomass that produced a great deal of oxygen during the day can rapidly deplete that oxygen at night when the plants become net consumers of oxygen for respiration. The lowest oxygen concentration in the daily cycle will usually occur just before dawn. Because it is this lowest oxygen concentration that will stress or kill fish, it is best to measure oxygen just before sunrise. A downward trend in day-to-day observations of pre-sunrise oxygen requires action to prevent a fish kill. Feeding should be stopped, or the cage moved to a location with higher oxygen concentrations, or aerators should be turned on. If a pond has had a rich green color but starts to turn brown, the phytoplankton population may be dying off. When this occurs, the decomposition of the phytoplankton cells coupled with a reduction in oxygen production can cause reduced oxygen levels. Feeding should be halted during this time and aerators should be started.

Photosynthesis in a fertile pond affects pH because the plant cells take up carbon dioxide as a carbon source, and release oxygen. High pH can stress fish, and in some cases can cause mortality (Bergerhouse 1992). Treatment of the pond with herbicides can lower the pH by limiting photosynthesis, but it may also cause an oxygen decline due to decomposing vegetation. The best way to control pH is to limit nutrient input and control vegetation and plankton levels before they reach problematic levels. In general, the pH in culture ponds should be maintained between 6.5-9.

Ammonia is the major nitrogenous waste product excreted by fish. Ammonia occurs in two forms in aqueous solution; the ionized form (NH<sub>4</sub><sup>+</sup>), which is essentially non-toxic, and the un-ionized form (NH<sub>3</sub>) which is highly toxic. As pH and temperature increase, the proportion of ammonia in the toxic un-ionized form increases. In normal cage culture operations where the capacity of the pond to metabolize fish waste is not overloaded, ammonia should not be a problem. However, if the pond is overstocked or is subject to runoff of livestock waste or agricultural runoff, high ammonia concentrations can occur causing gill damage, reduced growth, or mortality. Un-ionized ammonia concentrations of 0.06 to 0.1 mg/l can stress fish.

Most cages used for fish culture should have a cover to keep predators out of the cage. A solid cage cover is preferable to a mesh covering due to the added benefit of providing shade for the fish. Walleye appear to prefer shaded or low light environments.

Aeration in or around a cage can help maintain adequate oxygen concentrations, dissipate supersaturated gases, and flush waste from the cage. Providing aeration with a blower and airstones may be the best way to provide aeration to a large number of cages. In addition, this sort of aeration can be used to circulate water during the winter, bringing warm water up to the surface and preventing the cages from freezing over. Ponds will develop thermal stratification both summer and winter. Stratified ponds have a warm upper layer, a middle zone of rapid temperature change (thermocline), and a lower stagnated zone. Water below the thermocline may have very low oxygen and high ammonia, hydrogen sulfide, and carbon dioxide. Care must be taken that the aerator does not circulate this water from the pond bottom as that water may have a large oxygen demand.

### Cleaning and maintenance

Biofouling by algae or bryozoans on the mesh of the cage will restrict the movement of water through the cage. If the cages are not cleaned regularly the water quality within the cage can deteriorate rapidly, and the fish can become stressed. Harder and Summerfelt (1996) found it necessary to clean cages 1-2 times per week. They used a long handled brush on the inside of the cage, and used a snorkel and a hand brush to clean the outside of the cage. Stevens (1996) recommended cleaning once per month. He also used brushes and snorkel equipment, but in addition he would use a water jet to blast the cages clean. Bushman (1996) noted that circular cages were more difficult to clean with a brush since the sides of the cage were not as well supported. Two advantages to grading fish and transferring them to cages of larger mesh size as they grow are that the larger mesh size will be less likely to become blocked, and it will take longer for filamentous algae to become established on the new cage.

### Disease control and treatment

The best method of disease control is prevention. Disease prevention consists of acquiring fish in good condition and minimizing stress and handling. Activity around a cage should be minimized to avoid stressing the fish. High water quality must be maintained. When fish are handled or hauled, they should be hauled in a 0.5%-1% salt solution to minimize osmotic stress. Even with the best efforts there is the possibility that a disease outbreak will occur. Walleye in cages are difficult to treat effectively. Harder and Summerfelt (1996) found that medicated feed (oxytetracycline) given as a prophylactic treatment was not effective. They resorted to netting the fish out of the cage and giving them a dip treatment of a chemotherapeutant. Currently, however, no drug, chemical, or pesticide is approved by the **FDA** for use in walleye culture. When fish are stressed they often stop feeding, making medicated feed ineffective. Other species have been treated by surrounding the cage with a plastic enclosure to isolate it from the rest of the pond (Kleinholz and Luker 1994). However, it is important to remember that the plastic isolates the cage from its source of oxygen, and supplemental oxygen may be needed during the treatment.

### Survival, growth and feed conversion

Walleye survival in cages has varied from 6.5% (Harder and Summerfelt 1996) to 93% (Bushman 1996). However, the case studies in this volume demonstrate that good survival can be achieved in cages under the right circumstances. Walleye in cages at four sites in Minnesota had survival rates ranging from 0–61.2% after two growing seasons (Mittelmark and Kapuscinski 1993).

Walleye have also demonstrated reasonable growth in cages. Stevens (1996) reported that walleye reached approximately 8 in (203 mm) by the end of the first growing season, 12-14 in (305-356 mm) by the end of the second growing season, and a market size of 1.5-2 lb (681-908 g) by the middle of the third growing season. Mittelmark and Kapuscinski (1993) were able to get only a portion of their walleye to marketable size in three growing seasons (two seasons in the cages). As feed quality improves, it is possible that this market size could be achieved in the second season. Bushman (1996) reported feed conversions of 8.0 for 2.4-in (61-mm) walleye, and 4.4 for 5.6-in (142-mm) walleye. However, the fish may have been overfed.

### Over-wintering

An important consideration in the development of a commercial walleye cage culture enterprise for production of food-size fish is the need to over-winter walleye in cages. When walleye are over-wintered in cages, it is necessary to keep the area of the pond around the cages free of ice. This is necessary to allow winter feeding, allow water circulation through the cage, and to prevent damage to the cage from ice scouring. There are a number of aeration devices available designed to keep ponds from freezing over during the winter. They all operate on the same basic principle, which is to bring warmer water from the bottom of the pond to the surface. Airstones and a blower do an adequate job of circulating the water to the surface (Bushman 1996; Stevens 1996).

Winter feeding is important to increase survival and to avoid cannibalism. Stevens (1996) recommended feeding walleye over-winter at a rate of 0.5% of their body weight per day. Bushman (1996) fed walleye over winter at 1% of their body weight per day. He reported up to 98.5% survival of 6-in (152-mm) fish from November to April. He also reported a slight weight



loss in 6-in (152-mm) walleye over the winter, but a slight weight gain in 3-in (76-mm) walleye over the same time period.

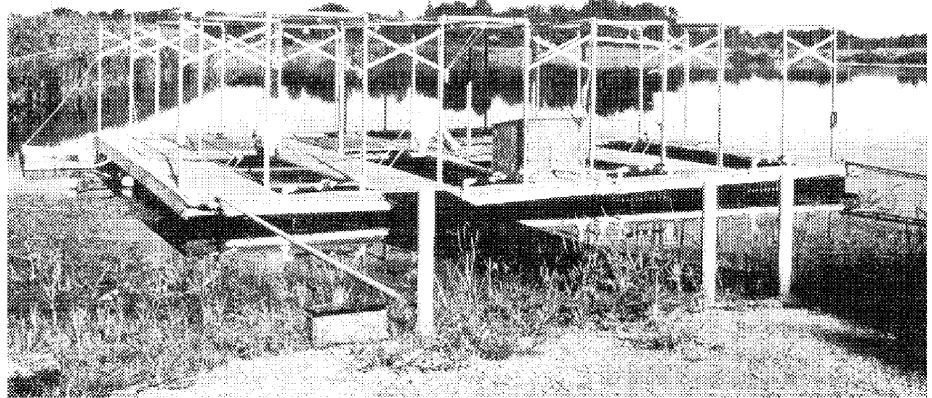
### Environmental concerns

Cage culture may have environment impacts. Wastes from cage culture are normally released directly into the environment without any kind of treatment. Overloading a water body's capacity to deal with fish waste will have negative effects on both the caged fish, the native biota, and other uses. If cage culture is undertaken in public waters, the excess nutrients could degrade water quality of that lake or stream. Nutrient rich water discharged from a constructed pond or lake may alter the nature of a receiving stream.

Some work has been done to reduce the waste released from cage culture (Lewis and Wehr 1976), but these techniques are not in general use. A floating raceway system (Figure 2) has a collection box for solid waste, but dissolved solids (inorganic phosphorus) are released into the pond. The best way to avoid environmental degradation is careful site selection and to size the operation well within the regeneration capacity of the water body.

### Summary

Cage culture has the potential to contribute to the development of walleye as a commercial species. The low initial cost of cage construction and use of existing water bodies are attractive to walleye culture. Walleye can be successfully trained, fed, over-wintered, and grown to food size in cages. Procurement of trained fish early in the first season, stress and disease control, and high quality but practical feed formulations are all important factors in the development of a successful and economically viable walleye cage culture enterprise.



**Figure 2. Caillouet floating raceway system, Mid-Central Fisheries, Marion, IL. Airlift pumps are used to circulate water through each raceway.**

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# Cage Culture of Walleye and Walleye x Sauger Hybrids

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## Introduction

Resource Conservation and Development for Northeast Iowa, Inc. (RC&D) initiated a project in the fall of 1992 to evaluate the potential for coolwater food fish production in northeast IA farm ponds to provide supplemental income to pond owners. Because most farm ponds are not seizable or drainable, cage culture was selected as the culture method. Walleye and hybrid walleye (walleye x sauger) were chosen because of their reputation as a high quality food fish and compatibility of these fish species for the climate in northeast IA. The objectives of this project were to develop recommendations for the utilization of northeast Iowa farm ponds for culturing food fish species for sale as food fish and to educate pond owners of the benefits of aquaculture as an additional form of agriculture.

long; 10 pieces, 43.7 in (111.1 cm) long; 8 pieces, 44.7 in (113.7 cm) long; 8, 3 way elbows; 4, 4 way elbows; 4, tees.

High density polyethylene netting was used for the bottom and the sides of the cages. The netting was secured to the PVC pipe with 8 in (20.3 cm) UV resistant cable ties. The mesh size used on the cages was determined by the size of the fish at stocking: 0.25 in (0.6 cm) mesh was used for 2.0–3.0 in (50.8–76.2 mm) fish and 0.5 in (12.7 mm) mesh was used for 4.0–5.0 in (101.6–127.0 mm) fish. One 4.5 ft (1.3 m) long 6.0 in (15.2 cm) PVC pipe was capped at each end and was secured to each end of the rectangular cages with 1.5 in (3.8 cm) U-bolts and 28.3 in (71.8 cm) long UV resistant cable ties. These were used as floats to keep

## Methods

Two ponds in Allamakee County, IA were used for this project. Walleye were raised in cages in a 1.2 acre (0.5 ha) pond, with a mean depth of 7 ft (2.1 m) and hybrid walleye were raised in a cage in a 4.0 acre (1.6 ha) pond, with a mean depth of 10 ft (3.1 m).

## Cage construction

Two rectangular cages (length x width x height) 8.0 x 4.0 x 4.0 ft (2.4 x 1.2 x 1.2 m) (Figure 1), were placed in each pond. The frames were constructed of 1.5 in (3.8 cm) PVC pipe: 8 pieces, 20.8 in (53.0 cm)

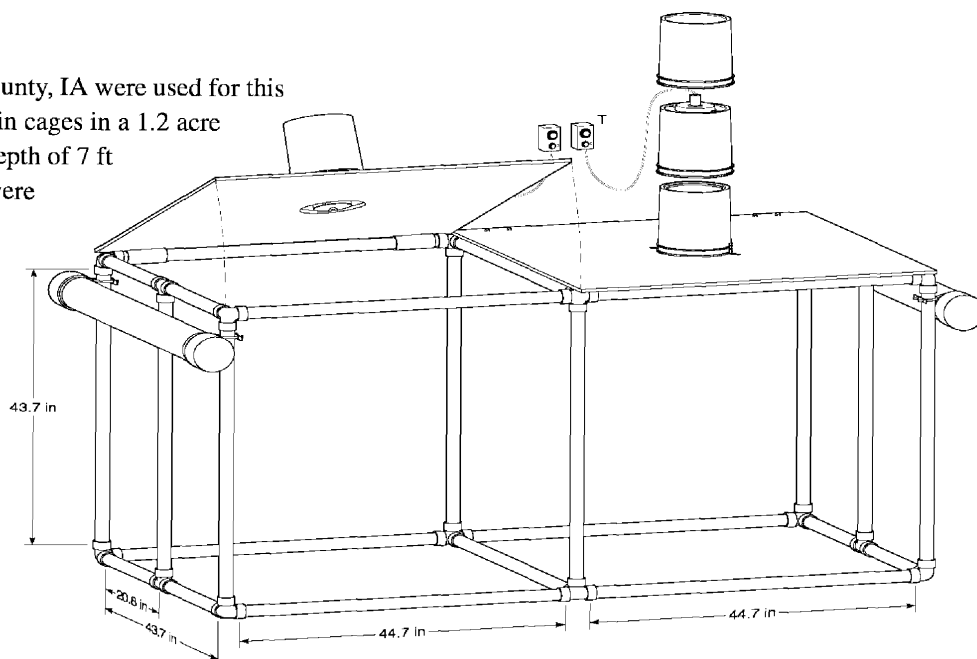


Figure 1. Rectangular cage diagram; timers (T) were placed on dock (not shown).

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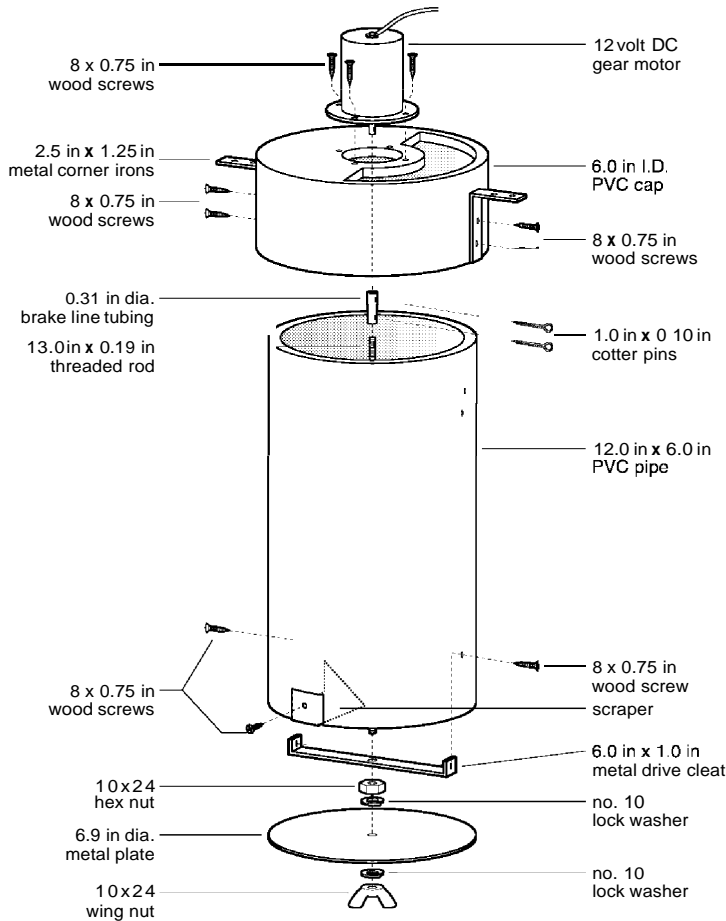


Figure 2. Rotating disk feeder.

the top of the cage about 4 in (10.1 cm) above the water surface. At the waterline, the capacity of the cages was 117.4 ft<sup>3</sup> (3.3 m<sup>3</sup>).

To evaluate different cage designs, an additional cylindrical cage (4.0 x 4.0 ft, 1.2 x 1.2 m) was placed in the pond. The frame for the cylindrical cage was constructed of 0.75 in (1.9 cm) black plastic tubing and four pieces of 4.0 ft (1.2 m) long, 2.0 x 2.0 in (5.1 x 5.1 cm) lumber for vertical supports. A square collar constructed of 2.0 in (5.1 cm) PVC pipe was used to keep the top of the cylindrical cage about 4.0 in (10.1 cm)

above the water surface. There was 46.0 ft<sup>3</sup> (1.3 m<sup>3</sup>) of water in this cage.

Cage lids were constructed of 0.5 in (1.2 cm) plywood. The rectangular cage lids were hinged using two 6.0 in (15.2 cm) long x 2.0 in PVC pipe and four 1.5 in (3.8 cm) long x 0.5 in (1.3 cm) carriage bolts. Two 2.0 in (5.1 cm) flat hinges were used on the cylindrical cage lids, which allowed one-half of the lid to be opened. The cages were secured with nylon rope to floating docks constructed from used oak pallets (40.0 x 48.0 in, 101.6 x 121.9 cm) and 55.0 gal (208 L) plastic barrels.

### Feeders

Two rotating disk style feeders (Figure 2) were fastened to the rectangular cage lids, and one feeder was fastened to the cylindrical cage lid using 2.0 in (5.1 cm) corner irons. The feeders we used were originally described by Steve Mortensen (1987 Coolwater Fish Culture Workshop). The feeder motor was a 12V DC, 40 rpm, reversible gear motor (Barber Colman, Rockford, IL). Each feeder was fastened to and covered with a 5.0 gal (18.9 L) plastic bucket. The feeding regimen was controlled at the ponds using 12V



Figure 3. Cage culture setup on pond in northeast Iowa showing cages tethered to T-shaped floating dock. White buckets provide protection for feeders on cages.

timers (DFT1-Q, Sweeney Enterprises, Boerne, TX). The power supply was a 12 V garden tractor battery, and the feeders were connected to the timers using 12 gauge two-stranded wire. The timers and battery were placed on the dock, underneath a 5 gal (18.9 L) bucket for protection from rain (Figure 3).

**Fish stocking**

On July 19, 1993, fingerling hybrids were obtained from the University of Wisconsin Aquaculture Center, Madison, WI and stocked into cages in the 4.0 acre (1.6 ha) pond (Table 1). On August 5, 1993 and August 30, 1993, fingerling walleye were obtained from Iowa State University, Ames, IA and stocked into cages in the 1.2 acre (0.5 ha) pond. All fingerlings obtained for this project had been trained in tanks to consume formulated feed.

Fingerlings were transported in a 200 gal (757 L) hauling tank supplied with oxygen at a rate of 1–2L/min. Salt was added to provide a 0.5–0.7% concentration, and ice was added to the tank to maintain the water temperature at 68.0–72.0°F (20.0–22.2°C) during the 3–4 h trips.

Upon arrival at the cage site, the fish were tempered with enough water to cause a 2°F (3.6°C) temperature change every 30 min. As the fish were being tempered, a sample of 50–70 fish were measured to the nearest millimeter (TL) and weighed to the nearest gram. The number of fish in one pound was then determined.

Each cage was stocked by weighing groups of fingerlings in a 5 gal (18.9 L) bucket suspended from a 20 lb (9.0 kg) hanging scale. The bucket was filled with 10 lb (4.5 kg) of water to zero the scale. The two rectangular cages in the 4.0 acre (1.6 ha) pond were stocked with 882 fish/cage, and the cylindrical cage was stocked with 358 fish

(Table 1). In the 1.2 acre (0.48 ha) pond, one cage was stocked with 580 fish and the other cage was stocked with 508 fish.

A sample of 20–25 fish was sampled from each cage at 2 week intervals during the growing season. The fish were measured to the nearest millimeter and weighed to the nearest gram. Condition factor (K) was also calculated,  $K = (\text{weight}/\text{TL}^3) \times 10^5$ , where weight in g, and TL in mm.

**Feeding**

Feeding began on the day after the fish were stocked. The feeding rate for each cage was calculated using the following formula: daily ration = (initial number of fish - cumulative mortalities) × mean weight × percentage of body weight to feed. In July and August, the feeding rate was 7.0%, in September, the feeding rate was 4.0–5.0%, and in October, the feeding rate was 2.0–3.0%. The feeding rate from November through April was 1.0% body weight/d.

The timers were set to feed every 15 min during the growing season. This feeding regimen was maintained until water temperatures decreased to 60° F (15.6° C). At that point, the timers were set to feed once every 15 min from 0600–0830 and from 1700–1930 during September and October. Over the winter, timers were set to feed three times/d: at 0800, 1200, and 1700.

Fingerling hybrids were initially fed number 3 crumble Walleye Grower 9015 (Murray Elevators, Murray, UT). Feed size was gradually increased to a 3/32 pellet (Silver Cup Salmon, Murray Elevators, Murray, UT) by November. The fingerling walleye

stocked on August 5, were initially fed a mixture of 25% FFKC formula (Kyowa Hakko Kogyo Co., Ltd, Tokyo, Japan) and 75% Walleye Grower, and were gradually switched to 100% number 4 crumble Silver

**Table 1. Fingerling stocking by cage for hybrid walleye and walleye.**

Stocking date	Fish	Cage shape <sup>1</sup> (in)	Mean length (no/lb)	Mean weight	Number per cage	Stocking density (no/ft <sup>3</sup> )
7/19/93	Hybrid	R	2.5	215.9	822	7.0
7/19/93	Hybrid	C	2.5	215.9	358	7.8
8/5/93	Walleye	R	2.4	197.5	580	4.9
8/30/93	Walleye	R	5.6	22.3	508	4.3

<sup>1</sup> R = rectangular cage, C = cylindrical cage.

Cup Salmon by November. The fingerling walleye stocked on August 30, were initially fed  $\frac{3}{32}$  Silver Cup Salmon pellets and were gradually switched to  $\frac{1}{8}$  Silver Cup Salmon pellets by November.

### Cage cleaning

Each cage was cleaned 3 times/week using a floor broom. This prevented algae and fouling from accumulating on the mesh, which decreases water exchange between the cage and the pond.

### Water quality

Water temperature and dissolved oxygen profiles were taken at least 3 times/week using a YSI DO meter (model 51B, YSI Inc., Yellow Springs, OH). Vertical profiles of DO in the pond were taken between 0500 h and 0700 h, at the water surface, at 4.0 ft (1.2 m), and at 12.0 ft (3.6 m). Weekly water samples were also collected using a Kemmerer bottle lowered 3.0 ft (0.9 m) inside a different cage each week. These samples were analyzed (HACH Kit, FF-2, HACH CO, Loveland, CO) for the following parameters: pH, total alkalinity, total ammonia nitrogen (TAN), un-ionized ammonia (UIA), nitrite-nitrogen, and chloride. Nitrate-nitrogen and nitrate concentrations were measured using a HACH kit (NI-14). During July and August, a dissolved gas meter was used to measure dissolved gas pressures (percent saturation).

A 0.5 hp air blower was installed at each pond. Air was delivered through 0.5 in (12.7 mm) black plastic tubing to four, 6.0 in (15.2 cm) air stones. The air stones were connected together on a grid constructed from 0.75 in (1.9 cm) PVC pipe which was placed about 18.0 in (45.7 cm) off the pond bottom. The air stone grid was positioned 20.0–30.0 ft (6.0–9.0 m) from the cages. A 115 volt, 24 h timer was used to start the blower.

During the summer, the aerators were used to maintain dissolved oxygen levels at night and to keep

water circulating through the cages on calm days.

Throughout the winter, the aerators were used to keep the area around the cages ice-free. During periods of sub-zero weather, the aerators operated at least 18 h/d to maintain a 10–30 ft (3.0–9.0 m) diameter ice-free area (Figure 4). During less severe weather, the aerator could be operated 12 h/d, which would maintain a 25–50 ft (7.5–15.0 m) diameter ice-free area.

The fish were not completely harvested in any cage, as this is an ongoing project. On September 29, 1993, the cages with hybrids were raised from the water, the fish weighed, measured and restocked (240 fish/cage) into cages with 0.5 in (12.7 mm) mesh. The cylindrical cage was removed and an additional rectangular cage was placed in the pond. On November 8, a sample of 50 walleye/cage were weighed and measured, survival was estimated from the number of cumulative mortalities to date.

### Results

Survival of the fingerling hybrids raised in the rectangular cages was 33.5%. These fish grew to a mean length of 4.9 in (12.4 cm) and averaged 31.8 fish/lb (14.2 g). Survival of the hybrids stocked in the cylindrical cage was 36.6%. The fish raised in the cylindrical cage grew to a mean length of 4.9 in and averaged 36.9 fish/lb (12.3 g). Survival during the overwinter period



Figure 4. Winter scene of cage culture in northeast Iowa showing ice-clearing effect of aeration apparatus.

was 98.0%, however the fish lost weight (Table 2).

Survival of the 2.4 in (6.0 cm) walleye stocked on August 8, was 93.0%. The fish grew to a mean length of 3.0 in (7.6 cm) and averaged 132.0 fish/lb (3.4 g) on November 8. Survival of the 5.6 in (14.2 cm) walleye stocked on August 30 was 98.0%. These fish grew to a mean length of 6.0 in (15.2 cm) and averaged 16.0 fish/lb (28.3 g) on November 8.

In November, 250 of the 6.0 in (15.2 cm) walleye were stocked into a private lake, which reduced the density in this cage to 0.13 lb/ft<sup>3</sup> (2.1 kg/m<sup>3</sup>).

Survival over the winter was 96.7% for the 3.0 in (7.6 cm) walleye, and 98.5% for the 6.0 in (15.2 cm) walleye. The 6 in (15.2 cm) fish lost weight, while the 3.0 in (7.6 cm) fish gained weight over the winter (Table 2).

Feed conversion was calculated from the time the fish were stocked through the fall sample date. For the hybrids reared in the rectangular cages, feed conversion was 3.6, and 5.0 for those raised in the cylindrical cages. The feed conversion was 8.0 for the 2.4 in (3.5 cm) walleye and 4.4 for the 5.6 in (14.2 cm) walleye.

Average water temperature at a depth of 4 ft (1.2 m) in the hybrid pond averaged 65.8°F (18.8°C) during July, 70.3°F (21.0°C) in August, and 53.5 °F (12.0°C) in October. Dissolved oxygen at the 4 ft (1.2 m) level averaged 13.3 mg/L in July and 14.9 mg/L in October. The means for pH, total alkalinity, TAN, UIA, nitrite-nitrogen, chloride, nitrate-nitrogen, and nitrate were: 7.9, 205.8 mg/L, 0.32 mg/L, 0.012 mg/L, 0.01 mg/L, 4.9 mg/L, 5.3 mg/L, and 23.3 mg/L, respectively (Table 3).

Average water temperature at a depth of 4 ft (1.2 m) in the walleye pond was 65.0°F (18.3°C) during August, it decreased to 58.0°F (14.4°C) in September, and 50.8°F (10.5°C) in October. Dissolved oxygen at the 4 ft (1.2 m) level averaged 8.9 mg/L in July and 11.4 mg/L in October. The means for pH, total alkalinity, TAN, UIA, nitrite-nitrogen, chloride, nitrate-nitrogen, and nitrate were 7.8, 307.0 mg/L,

**Table 2. Lengths and weights of fish overwintered.**

Fish	Survival (%)	Fall length (in)	Spring length (in)	Fall weight (no/lb)	Spring weight (no/lb)	Fall condition (K)	Spring condition (K)
Hybrid	34.0	4.9	4.8	31.8	40.9	0.74	0.61
Walleye	93.0	3.0	3.1	133.5	116.4	0.77	0.82
Walleye	98.0	6.0	6.1	16.0	17.1	0.80	0.72

**Table 3. Means (±S.D.) and ranges of water quality parameters measured from July through October 1993.**

Parameter	Ponds used for	
	Hybrid walleye	Walleye
Temperature (°F)	59.2±11.3 (35.6–73.4)	54.9±10.4 (34.7–71.6)
Dissolved Oxygen (mg/L)	14.4±1.4 (9.2–23.5)	11.6±2.4 (7.2–15.0)
pH	7.9A0.1 (7.8–8.0)	7.8±0.1 (7.8–8.0)
Total Alkalinity (mg CaCO <sub>3</sub> /L)	205.8f24.4 (182.0–242.0)	307.0f19.1 (290.0–349.0)
Total Ammonia Nitrogen (mg NH <sub>3</sub> -N/L)	0.32±0.20 (0.00–0.70)	0.36±0.12 (0.20–0.60)
Un-ionized Ammonia (mg NH <sub>3</sub> /L)	0.012f0.011 (0.000–0.034)	0.007A0.004 (0.003–0.011)
Nitrite-Nitrogen (mg/L)	0.01±0.02 (0.00–0.04)	0.39A0.20 (0.00–0.65)
Chloride (mg/L)	4.9f2.8 (1.6–8.3)	9.7±6.7 (4.0–17.5)
Nitrate-Nitrogen (mg/L)	5.3f1.4 (3.4–7.3)	2.5±1.0 (1.0–4.0)
Nitrite (mg/L)	23.3A6.3 (15.0–32.1)	10.9f4.4 (4.4–17.6)

0.33 mg NH<sub>3</sub>-N/L, 0.007 mg NH<sub>3</sub>/L, 0.39 mg/L, 9.7 mg/L, 2.5 mg/L, and 10.9mg/L, respectively (Table 3).

During the summer of 1993, rainfall was above average in northeast Iowa and water quality in the pond with hybrids was affected by runoff. After periods of heavy rain, the pond was frequently observed to be turbid, with visibility less than 6.0 in (15.2 cm). As the ponds cleared, algae blooms would occur as nutrients were released from the runoff water.

During algae blooms, dissolved oxygen readings were frequently greater than 15.0 mg/L, even in the early morning. Dissolved gas pressures were monitored when D.O. readings exceeded 15.0 mg/L, and the percent saturation was nearly 170%. Algicides (copper sulfate and Cutrine-plus) were used at 2.0–4.0 ppm in an attempt to control the planktonic algae blooms. Continuous aeration was also found to bring the dissolved oxygen level in the pond to saturation.

The high levels of dissolved gases in the pond had a negative effect on fish health, causing mortality during a 6 d period (August 24–30). A sample of hybrid walleye taken to the Fish Disease Control Center (U.S. Fish and Wildlife Service, Lacrosse, WI) were diagnosed as having gas bubble disease. Gas bubbles were found lodged between the fin rays and on the roof of the fishes mouth. Also, microscopic examination revealed small embolisms on the distal ends of the gill filaments. No signs of bacterial infection were found. The dissolved gas levels eventually decreased in the ponds, and mortalities ceased.

### Discussion

There are many obstacles to overcome before cage culture of a coolwater fish species is successful in northeast Iowa farm ponds. Hybrid walleye had an average growth rate of 0.16 g/d and 0.83 mm/d. Although survival over the winter period was high, some fish lost weight. There was little difference in growth between hybrids raised in the cylindrical and rectangular cages. The only noticeable difference in

performance between the two cage designs was that the cylindrical cage was more difficult to keep clean with a floor broom, as there was not enough support on the side of the cage to keep it rigid during cleaning.

In addition to the high gas pressures experienced in the pond used to rear hybrids, cannibalism may have contributed to low survival of hybrids. When the cages were raised and the fish were counted in the fall, 2–3 fish were found in each cage that were 2.0–3.0 in longer than the average fish in the cage even though cannibals that were seen as the fish were being stocked in July had been removed. However, either some cannibals must have been stocked initially, or some of the trained fingerlings did not accept the diet we were using and reverted back to a fish diet.

Fingerling walleye had growth rates of 0.18–0.22 mm/d and 0.01–0.16 g/d, much slower than hybrid walleye. The slow growth of the fish in the walleye pond was probably due to low water temperatures, which were typically less than 70°F (21.1°C). The relatively high survival rate of these fish was due to good condition of the fish at stocking and a high quality culture environment.

Cage culture allows existing ponds and lakes to be utilized for fish production. Fish can easily be harvested, and sport fishing can be continued in the ponds. However, cages require daily cleaning to remove algae, organic matter, or other attached growth, which may accumulate on the mesh and reduce water exchange. Also, caged fish cannot move to different areas of the pond if water quality deteriorates. When water quality is poor, the resulting stress on the fish may predispose them to disease.

Feed trained fingerlings for this project could not be obtained from commercial sources, so fingerling availability is a major problem for potential growers. Due to the short growing season in northeast IA, it will take at least 2, but probably 3 years to raise a coolwater fish to marketable size. The long time to reach market size will probably make cage culturing of walleye or hybrid walleye to food size unprofitable in pond environments at similar latitudes.



# Training Walleye to Formulated Feed in Cages

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## Introduction

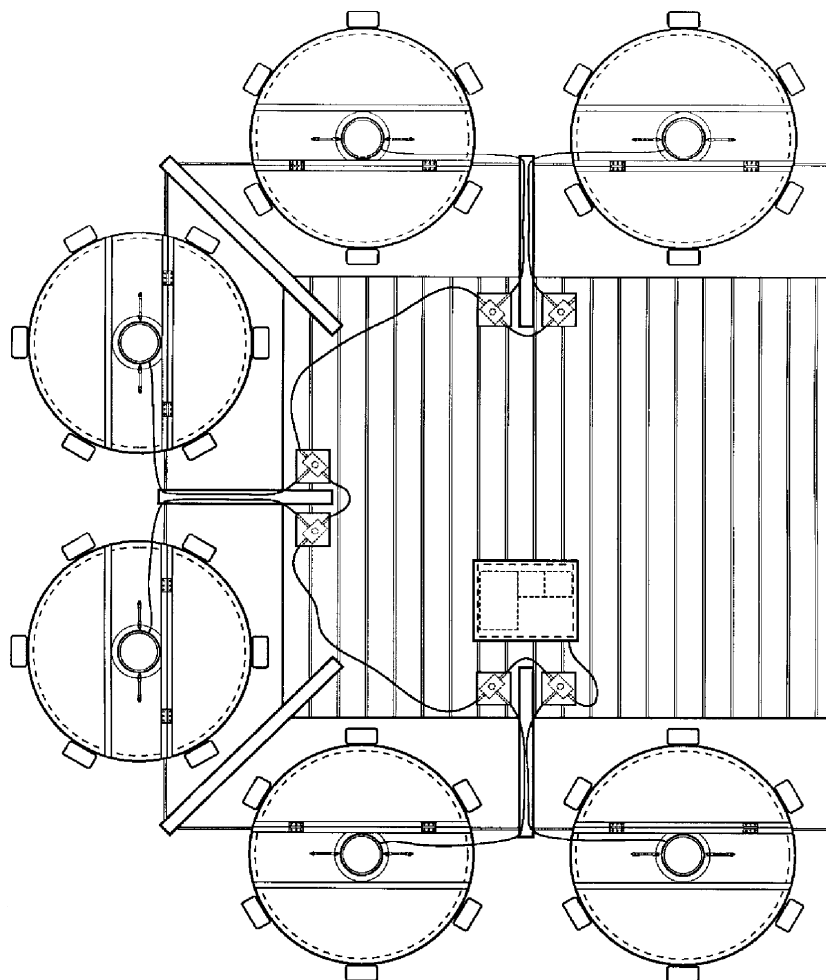
Cage culture is an alternate method for raising fish when ponds or raceways (tanks) are not available. Cage culture may be appropriate for producing 6-in (15 cm) fingerlings for stocking lakes or as a “starter” size for commercial farms which grow walleye to food size. The objective of this project was to develop techniques for training 2-in (5-cm) pond-raised fingerlings to accept commercial feed in cages and to raise feed-trained walleye to a target size of 6 in (15 cm) by the fall of their first summer. Although cage culture has been studied in several other species of fish, in 1989 when this project was initiated, there were no reports dealing with cage culture of walleye.

## Methods

### Cages

Cages were located in a 30-acre (12.1-ha) reclaimed limestone quarry lake in northeastern Illinois on the property of the Max McGraw Wildlife Foundation. The cage site was at the east end of the lake where the cages were partially protected from strong westerly winds by a peninsula, but the location still had exposure to sufficient wave action to furnish a satisfactory water exchange through the cages. Water depth beneath the cages was 22 ft (6.7 m).

Six cages were attached to a floating 8-ft x 8-ft (2.4-m x 2.4-m) raft. The deck of the raft was constructed from treated lumber. The raft had seven 4-ft-long (1.2-m)

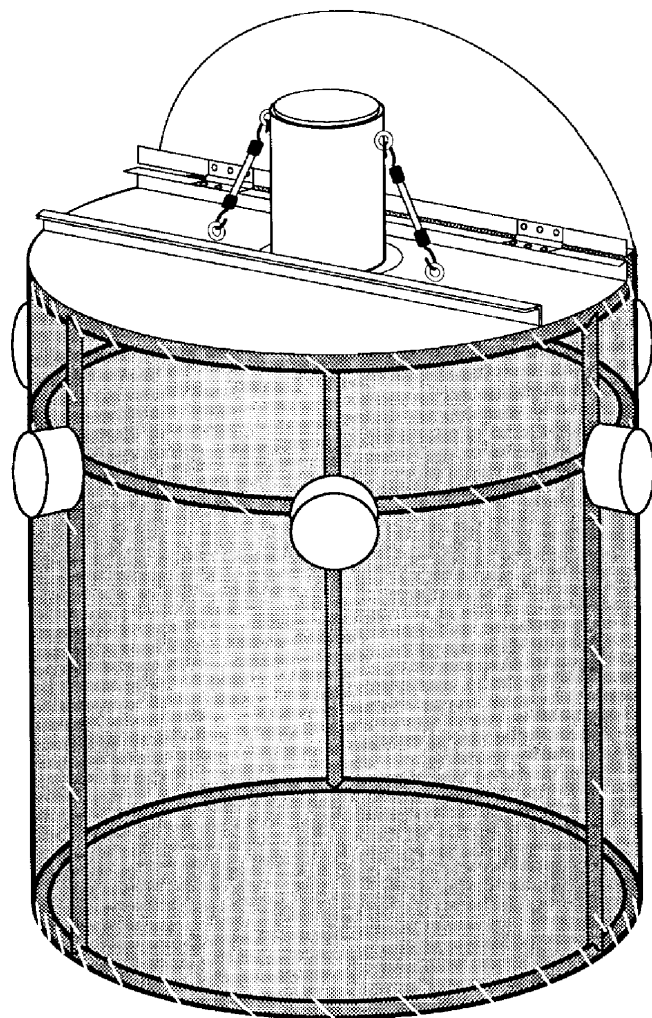


**Figure 1.** The floating 8-ft x 8-ft (2.4-m x 2.4-m) raft to which six cages were tethered. Other components are: 12 volt deep cycle battery; timers; RPM control boxes; hinged sheet-metal lids; and feeders.

extensions radiating outwards, and the cages were attached to these extensions (Figure 1).

Cylindrical 4-ft-diameter x 4-ft deep (1.2 m x 1.2 m) cages were constructed from two 4-ft-diameter (1.2-m) hoops made from 13-ft (3.9-m) pieces of 0.75-in (19-

mm) diameter black plastic tubing (Figure 2). The cage frames were covered with 0.25-in (6-mm) diamond-mesh black plastic. Six 4-ft (1.2-m) pieces of 0.75-in (19-mm) PVC pipe connected the top and bottom hoops to make the cages rigid. The edges of the mesh cylinder were laced to the hoops with bell-wire. Mesh along the cylinder sides was overlapped by about 6 in (150 mm) and double-laced. To keep feed from falling through the bottom of the cage and to allow visual assessment of feed accumulation, plastic garbage can lids were fastened to the inside bottom of each cage. The cage lid was light-weight galvanized sheet metal. Holes were cut in the lid to accommodate feeders, and half the lid was hinged to provide for cage access. The lid was



**Figure 2.** A 44-ft<sup>3</sup> (1.24-m<sup>3</sup>) plastic mesh cage with 6-in (150 mm) seine floats (replaced by a foam ring) for flotation; sheet-metal lid; PVC cover for feeder (used the first year only); top and bottom support rings; PVC upright supports.

attached to the cage using plastic cable ties. In 1989, materials used to build the cages cost \$85 per cage.

Cages were made buoyant by attaching 1.5-in (38-mm) slotted foam pipe insulation around the cage 12 in (30.5 cm) below the lid. Water volume in each cage was 44 ft<sup>3</sup> (1.24 m<sup>3</sup>). The foam insulation was not sufficiently buoyant to support the cages when wild ducks used the cage lid as a resting site. To keep ducks off the cages, 3-in (7.6 cm) mesh bird netting was draped across the cages and over their sides to water level.

Cages were cleaned once or twice a week to remove filamentous algae. Cages were cleaned on the inside by using a long-handled brush and on the outside by hand-brushing while swimming around the cage.

### Feeders

In the first year (1989), we made the feeders from a design by Steve Mortensen (see illustration in case study by Bushman [1996]). Mortensen's (1987) design used a rotating disc mounted under a piece of PVC pipe. A small DC motor rotated the disk. Feed was dispensed in a uniform pattern out from the center of the cage; however, these feeders were difficult to calibrate, they jammed when the feed got wet, and sometimes the electrical connections between feeders and control boxes shorted out. Because of these problems, in 1990 and 1991, commercial vibrator feeders were used (model AF7, Sweeney Enterprises, Boerne, TX).

The power system for the feeders was a single 12-v deep-cycle battery. This was wired to two electrical timers (Sweeney model DFTIQ). Each timer was able to turn on the feeders twice per hour. To obtain four feedings per hour, the two timers were wired in series and their trip levers set so that the feeders would go off four times each hour, 17 h/d. Each feeder was controlled by an electrical power source (Sweeney SE-70D RPM) that regulated the intensity of vibration of the feeder. The amount of feed dispensed each day was regulated by feeding frequency, by adjusting the gap above the feeder plate, and by adjusting the intensity of vibration.

In 1989, one feeder was located on the center of each cage. However, we found that walleye spent most of their time cruising the cage perimeter where they would be less likely to see the sinking feed. Therefore, in 1990

and 1991, two or three feeders were used for each cage to ensure that the fingerlings encountered the falling feed.

### **Feed and Feeding**

In 1989, as a prophylactic measure, a medicated (oxytetracycline) feed formulation of the W-16 diet (Balshi, Inc., Catawissa, PA) was used to cage-train walleye in groups 1 and 2. This feed was hard, it had sharp edges, and sank quickly. Feed size was initially number 3 granules; but as the fish grew, the feed size was increased to granule number 4, and then to  $\frac{3}{32}$ -in (2.3-mm). In 1989, cost of the W-16 diet was about \$0.45/lb (\$0.99/kg) delivered. In 1990, fish were started on a medicated 4 Biotrainer feed (Bioproducts, Warrenton, OR), followed by number 5 Biotrainer, then 1.5-mm Biodry 4000. The Biotrainer formulations were semi-moist crumbles, and they were slower sinking than the W-16 feed. The delivered cost of Biotrainer was \$5.94/lb (\$13.06/kg) and of Biodry 4000 was \$1.00/lb (\$2.21/kg). The feed was expensive because small quantities were ordered and it was shipped by parcel delivery service rather than common freight. In 1992, group 4 was also fed Bioproduct feed up to 1.5-mm pellet size, but they were finished on locally available trout feed (Purina 5104 crumble; Purina, St. Louis, MO) which cost \$0.44/lb (\$0.97/kg).

During cage training, feeding rates were initially 18–20% of total body weight/day. This was well above the 6–8% feeding rates used to train walleye in tanks (Kuipers and Summerfelt 1994); however, the higher rate was used to compensate for feed loss through the cage. The high initial feeding rate was reduced to 6–10% as the fish were habituated to the feed and as they grew. Periodic length and weight measurements were taken and daily mortalities monitored to maintain an inventory, which was needed to determine the amount of feed to add.

### **Water quality**

During the three growing seasons, water temperatures ranged from 68 to 79°F (20 to 26°C). Dissolved oxygen ranged from 7 to 10 ppm. Secchi disc visibility was 14 to 20 ft (4.3 to 6.1 m). Alkalinity ranged 300 to 400 ppm as CaCO<sub>3</sub>, which is high but typical of limestone quarry lakes.

### **Fish**

Four groups of walleye were cultured in cages between 1989 and 1991: groups 1 and 2 in 1989, group 3 in 1990, and group 4 in 1991. Fingerlings were purchased from sources in Wisconsin and Iowa. Fish were transported in 0.5% salt solution. At the lake, fish were tempered by pumping lake water into the hauling tank. Only group 4 was feed-trained prior to stocking. At stocking, fingerlings ranged from 1.8 to 2.7 in (46 to 70 mm). Initial stocking densities for group 1 were 10 and 20 fish/ft<sup>3</sup> (350 or 700/m<sup>3</sup>) (440 and 880 fish per cage) (Table 1). Fish in group 2 were stocked into two cages on August 24 at a density of 23 fish/ft<sup>3</sup> (805/m<sup>3</sup>). To avoid the high mortality experienced with group 1, handling was kept to a minimum. Water temperature at stocking was 75°F (24°C). Group 3 walleye were stocked into two cages on July 29. Handling was kept to a minimum. Each cage was provided with three feeders. Stocking density was 51 fish/ft<sup>3</sup> (1,250/m<sup>3</sup>). Water temperature was 72°F (22°C). In 1991, group 4 walleye were tank-trained to formulated feed prior to stocking. These walleye were stocked into three cages on July 25 when water temperature was 77°F (25°C) which was at least 2°F warmer than these temperatures at the time of stocking of the previous groups in 1989 and 1990. Fish were stocked at 11 fish/ft<sup>3</sup> (385/m<sup>3</sup>) or 484/ cage.

### **Results**

In 1989, about 76% of the first group of fish died within 6 days of stocking. Handling fingerlings to obtain lengths and weights contributed to this problem, but it seemed that the major factor was the fact that the producer had held the fish in tanks without feeding for several days prior to transport. On arrival, the fish were emaciated and showed clinical signs of columnaris. Water temperature was 73°F (23°C) when they were stocked on July 24. After the sixth day, the 960 survivors were consolidated into three cages. Survival of these fish to 105 days was 27% (Table 1).

Group 1 grew from an average stocking weight of 1.7 g (267 fish/lb; 587/kg) to 14.2 g (32 fish/lb; 70 fish/kg) over 105 d. Their specific growth rate (percentage of body weight gain per day) was 2.02%. They averaged 5.1 in (131 mm) at harvest (Table 1). Density at harvest was 6 fish/ft<sup>3</sup> (210/m<sup>3</sup>) or 260 fish per cage.

There were no mortalities in group 2 fish until the fifth day after stocking. They grew from 2.1 in (53.3 mm) to

## Chapter 10 — Cage Culture of Walleye

3.9 in (99.1 mm) in 76 d in cage culture (0.6 mm/d). Weight gain was 2.1 g (216 fish/lb; 476/kg) to 8.7 g (52 fish/lb; 114/kg). Their specific growth rate was 1.87%, the lowest of all four groups. Finished density was 6 fish/ft<sup>3</sup> (210/m<sup>3</sup>), the same as that of group 1. Survival was 13.5%.

In 1990 (group 3) mortalities were low until day 9. Fish in group 3 grew from 0.8 g (568 fish/lb; 1250/kg) to

30.3 g (15 fish/lb; 33/kg) in 105 d and averaged 6.2 to 6.3 in (157 to 159 mm) at harvest. Survival was 22 to 23%. At harvesting, density averaged 11 and 12 fish/ft<sup>3</sup> (385-420/m<sup>3</sup>) (Table 1). Although stocking density for group 3 was 2.2 times greater than for group 2 (1990), survival doubled.

In 1991, the average survival to 79 d was 85.6% (Table 1). Fish grew from 168 fish/lb (370/kg) to 19 fish/lb

**Table 1. Summary of stocking and harvest data for walleye cage (44 ft<sup>3</sup>; 1.25 m<sup>3</sup>) culture field trials at the Max McGraw Wildlife Foundation, 1989–1991.**

Year (group)	Cage (stocking date)	Initial				Final <sup>1</sup>				
		Fish/ Cage	Fish/ft <sup>3</sup> (fish/ m <sup>3</sup> )	Fish/lb (fish/ kg)	Mean weight (g)	Survival (%)	Fish/ft <sup>3</sup> (fish/m <sup>3</sup> )	Fish/lb (fish/ kg)	Mean weight (g)	Mean length (mm)
1989										
(1)	1,2,3 (7/24)	440	10 (350)	267 (587)	1.7	260 (6.5)	6 (210)	32 (70)	14.2 (0.12) <sup>4</sup>	5.1 (131)
	4,5,6 (7/24)	880	20 (700)	267 (587)	1.7					
(2)	1 (8/24)	1,012	23 (805)	216 (476)	2.1	258 (13.5)	6 (210)	52 (114)	8.7 (0.09) <sup>4</sup>	3.9 (99)
	2	1,012	23 (805)	216 (476)	2.1					
1990										
(3)	1	2,250	51 (1,785)	568 (1,250)	0.8	506 (22.5)	11 (385)	15 (33)	30.3 (0.28) <sup>4</sup>	6.3 <sup>2</sup> (159)
	2	2,250	51 (1,785)	568 (1,250)	0.8	519 (23.1)	12 (420)	16 (34)	28.4 (0.34) <sup>4</sup>	6.2 (157)
1991										
(4)	1	510	12 (420)	168 (370)	2.7	425 (83.3)	10 (350)	19 (42)	23.9 (0.27) <sup>4</sup>	5.8 (148)
	2	510	12 (420)	168 (370)	2.7	494 (96.9)	11 (385)	21 (46)	21.7 (0.24) <sup>4</sup>	5.8 (148)
	3	510	12 (420)	168 (370)	2.7	390 (76.5)	9 (318)	17 (37)	26.7 (0.30) <sup>4</sup>	6.0 <sup>3</sup> (153)

<sup>1</sup> The length of the cage culture interval was 105 days (consolidated cages) for group 1; 76 days (consolidated cages) for group 2; 105 days for group 3; and 79 days for group 4.

<sup>2</sup> Percent of fish of target size was 72 and 78%.

<sup>3</sup> One cage had 70% of fish of target size.

<sup>4</sup> Growth rate (g/d) for the culture interval.

(42/kg). They averaged 5.9-in (150 mm) at harvest. Final density was 9–11 fish/ft<sup>3</sup> (318–385/m<sup>3</sup>).

## Discussion

The objective of these trials was to convert pond-cultured walleye fingerling in cages and then to raise them to a target size of 6 in (150 mm). Four groups were evaluated in three years, groups 1, 2, and 3 were taken straight from ponds, but group 4 was trained to accept formulated feed before it was stocked. Survival of groups 1, 2 and 3 ranged from 6.5–23.1, while that of group 4 was 85.6%. Although a simultaneous comparison of feed-trained fish (group 4) with fish taken directly from ponds (groups 1, 2 and 3) was not done, the findings are a strong basis for recommending stocking cages with feed-trained fish.

If the field trials were evaluated on the basis of the percentage of fish that reached the 6-in (150-mm) target size, the 1990 field trial was the most successful because 72 and 78% of the surviving fish in the two cages reached the target size. In 1991 (group 4), 70% of the fish in one of three cages reached the target size; however, fish in group 4 were raised for only 79 d while group 3 fish were raised for 105 d.

Using all groups as a database, the correlation between stocking density and survival was low ( $-0.41, P > 0.05$ ), as was the correlation between density and growth rate ( $-0.54, P > 0.05$ ), but these correlations suggest that density has a negative effect on both survival and growth. The correlation between growth rate and survival (**0.68,  $P < 0.05$** ) was significant, which suggests that growth rate is affected by fish health.

Two commercial vibrator feeders per cage worked best for training purposes; however, after fish were trained, a single feeder was adequate. Medicated feed seemed to help reduce disease, but stocking healthy fish in good condition is more important. There are no approved chemotherapeutics for treating bacterial diseases of walleye; because this was an experimental project, several treatments were evaluated. We tried treating fish that had columnaris with one-minute dip treatments in copper sulfate or Diquat; however, netting fish from the cages was labor intensive and further stressed weak fish. Direct application of copper sulfate or Diquat to the cages was ineffective because the chemicals were quickly diluted. Surrounding cages with clear plastic and giving standing bath treatments with Diquat was also ineffective. Generally, mortalities seemed to subside as an epizootic ran its course, rather than from any treatment efforts. The key to disease control is to stock healthy fish and reduce handling to a minimum.

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# Cage Culture of Walleye and its Hybrids to Food Size

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## Introduction

This paper describes techniques I have used to raise walleye to food size in cages. The cages were located in strip mine lakes in south-central Iowa.

## Methods

The cages I used to habituate pond-reared fingerling walleye to dry diets, measured 3 x 4 x 10 ft (0.91 x 1.22 x 3.05 m) (width x depth x length), with  $\frac{3}{16}$ -in (4.8-mm) mesh openings. The cages were attached to a floating dock where water depth under the cages was 8–10 ft (2.44–3.05 m) deep (2 net pens can be attached to each dock). Two pieces of 0.5-in (12.7-mm) plywood 4 x 4 ft (1.22 x 1.22 m) with a 16-in (0.406-m) hole centered in them are placed over each net pen. The plywood supported the feeders and provided shade for the fingerlings. One 0.25-in (6.35-mm) air line with an airstone, 2 x 2 x 4 in (50.8 x 50.8 x 101.6 mm), was placed in each cage to provide supplemental aeration. Four vibrating feeders (2/cage) with conical extensions and covers were also placed on the cage dock configuration.

Walleye fingerlings were harvested from ponds in southern Iowa during the second and third week of June when the fingerlings were 2–3 in (51–76 mm) in length and 600 fish/lb (1,322/kg). Each cage was stocked with 2,500 fingerlings. The fingerlings were fed every 3–5 min during the initial training period. Fry Feed Kyowa (FFK) C2000 (Biokyowa Inc., Chesterfield, MO) was fed at 10% body weight/d for the first 7 d, at which time they were weaned to the Fish and Wildlife Service W-16 formula, or a commercial salmon starter diet. At this time, the 9206 formula of Richard Barrows, (USFWS, Bozeman, Montana) would be preferred. Each day, the amount of FFK C2000 starter diet was reduced, and by 16 d the surviving fingerlings were ready for 4 granules of W-16. By 26 d, the surviving fingerlings, which now readily accepted formulated feed, were moved to another set of cages.

Feed-trained fingerlings were stocked at 1,000 fish/cage in cages that measured 4 x 8 x 8 ft (1.22 x 2.44 x 2.44 m), with 0.25-in (6.35-mm) mesh. The cages had aluminum tops with a 16-in (0.406-m) hole cut into the center for feeding. Vibrating feeders with conical extensions were used to feed the fish. The fingerlings were fed at 3–4% body weight/d; they were fed every 30 min in two, 3-h feeding intervals; the first began just before daylight, and the second began just before dusk.

At least 10% of the fish were sampled monthly with a dipnet to measure growth. The daily feeding rate was adjusted after sampling to the larger total biomass. Some mortalities usually resulted from handling stress, however, the monthly assessments of growth was necessary to calculate growth rates and to adjust feeding rates.

By fall of the first year, walleye fingerlings reached about 8 in (203 mm), they were graded and the larger fish were moved to cages that had 0.5-in (12.7-mm) mesh openings and measured 4 x 8 x 8 ft (1.22 x 2.44 x 2.44 m). The fish were stocked at 500 fish/cage and fed at 3% of their body weight/d. Aeration with diffused air (air stones) in the cages kept an area around the cages ice-free over winter. (Figure 1).

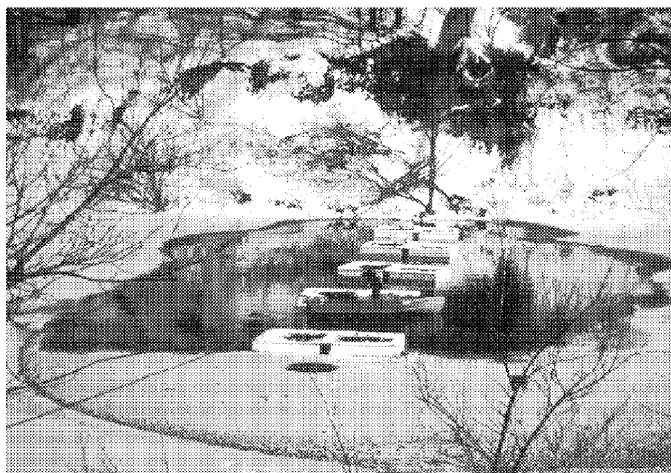


Figure 1. Cages kept ice-free all winter with diffused air.

By the the second spring, some fish reached 10–12 in (254–305 mm); but most were 8–10 in (203–254 mm).

When the fingerlings reached 10–12 in (254–305 mm), they were again graded and divided. Fish were moved to identically sized cages with either 0.5-in (12.7-mm) or 0.75-in (19.0 mm) mesh openings. They were stocked at 225–250 fish/cage. The fish were still fed at 3% of their body weight.

Near the end of the second growing season, most of the fish were in the 12–14 in (30.5–35.5 cm) range. They were again divided and graded. These fish were stocked into cages 4 x 8 x 8 ft (1.22 x 2.44 x 2.44 m), with 0.75-in (19.0 mm) mesh opening. The fish were stocked at 125 fish/cage. Because of the larger size, large quantities of feed are used and any mortalities during this time can be quite costly. Fish did not reach 1.5–2 lb (0.681–0.91 kg) until the middle to latter part of the third year. Slun-on fillet dressout was 45–50%.

### Suggestions

1. Water quality is an important part of a successfully managed cage production system. Variables such as pH, temperature, dissolved oxygen, total ammonia, and alkalinity should be monitored. Water quality should be monitored weekly when growing larger fingerlings. Measurements should be made both inside and outside the cages. It is necessary to aerate the water around the cage to prevent ice formation in and around the cage system and to allow the fish to feed. In the strip-mine lakes where this study was done, maximum depths were around 40 ft (12.2 m), but aeration was maintained with airstones to a depth of 10 ft (3 m).
2. Cages should be cleaned monthly from April through October. Snorkeling or SCUBA equipment expedites the cleaning process. This type of equipment can also be used to visually observe fish in the cages.
3. Walleye will continue to feed down to a water temperature of 40°F (4.4 °C). Winter feeding should be done at 0.5% body weight/d.



# Cage Culture of Walleye at Mormon Trail Lake, Iowa

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## Introduction

The objective of the cage culture project at Mormon Trail Lake, Iowa was to raise walleyes from about 3–3.5 in (76–90 mm) to about 6 in (15.2 cm) for release into the lake, which has an existing population of large-mouth bass. The lake is a 35 acre (14.2 ha) artificial impoundment located in southwest Iowa. Water depth where the cage was located was about 23 ft (7 m). Walleye culture was to be done on a low budget, using cages and feeders previously used for a channel catfish cage culture program, with about 15–30 min of labor/d to feed the fish.

## 1987 Trial

On July 31, 310, 3-in (77-mm) walleye were purchased from a private hatchery and stocked in the cage. The fish had been trained to eat a formulated feed (W-16) for about 4 or 5 weeks prior to delivery. The fish were transported from the hatchery in plastic bags with a small volume of water and a larger volume of pure oxygen. Transportation loss was 3.2%, which was considered low considering the 100°F (37.8°C) air temperature when the fish were transported from the hatchery to the lake.

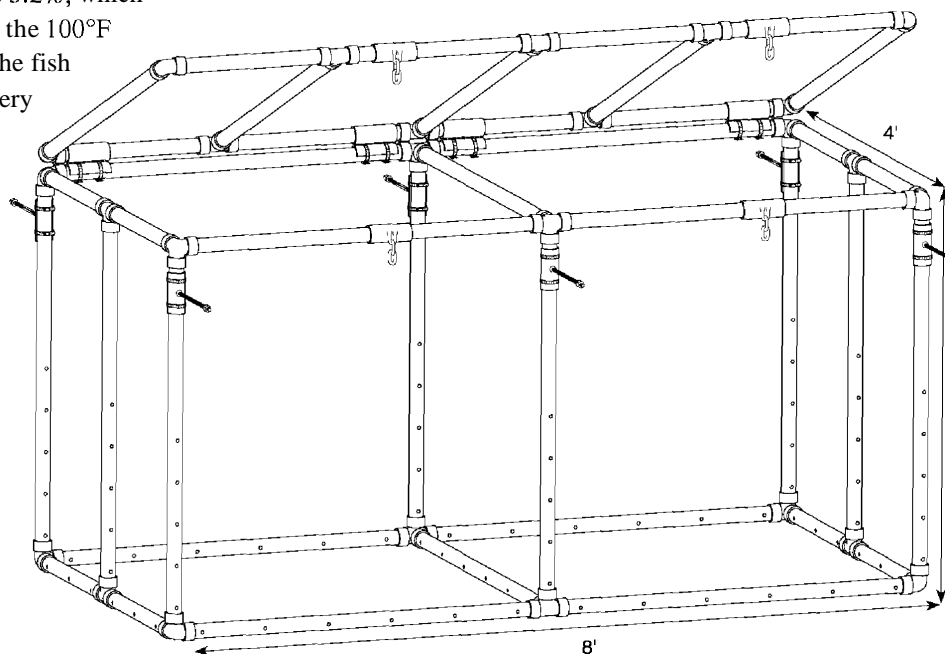
After acclimation to the lake water, fish were stocked immediately into a floating cage with a 1.5-in (38-mm) PVC pipe frame (Figure 1). The frame was covered with 0.5-in (13-mm) plastic mesh but also lined with 0.25-in (6.0-mm) plastic mesh to prevent the 3-in (76-mm) fingerlings from escaping. The feeder was fabricated of PVC pipe from a plan developed by

Mortensen (1987). An illustration and description of that feeder is given by Bushman (1995). Materials to make the feeder cost about \$12. Feeding frequency (48 times/d) was controlled by an electronic timer powered by a 6-V rechargeable gel battery.

In 80 days, walleye were fed a total of 17 lb (7.7 kg) of #4 crumbles, 50 lb (22.7 kg) of 3/16-in (4.8-mm) pellets, and 25 lb (11.4 kg) of 1/8-in (3.2-mm) pellets of the W-16 diet formulation (Glenco Mills, Glenco, MN).

Walleye were harvested 80 d after stocking (October 19). The fish averaged 5.2 in (132 mm), and ranged from 2.9–6.7 in (74–176 mm). Survival was 84.3%. The 253 walleyes that were harvested were stocked in the lake. Major problems encountered in the 1987 trial were difficulty in calibrating the feeder to maintain a

**Figure 1. Cage frame (4 x 4 x 8 ft), (1.2 x 1.2 x 2.4 m) made with 1.5 in (3.8 cm) PVC pipe.**



consistent delivery rate, difficulty monitoring growth and condition of fish without removing them from the cage, and determining if the walleyes were eating.

### 1988 Trial

A new PVC pipe frame cage was fabricated, and covered with 0.25-in (6.35-mm) plastic mesh. The same feeding system was used, but the feeder was modified. A heavier gauge aluminum feed dispensing plate, motor bracket, and lower shaft alignment bracket replaced the 30 gauge aluminum flashing plate and brackets used the previous year. These modifications improved the accuracy of the calibrated feeder rate and dependability.

On July 15, 400, 3.5-in (88.9-mm) feed-trained walleye were stocked. The temperature at stocking was 75°F (24°C) at the surface and 73°F (23°C) at 4 ft (1.2 m). Over the 102-d culture period, we fed 50 lb (22.7 kg) of #4 crumbles, and 85 lb (38.6 kg) of 3/32-in (2.4-mm) pelleted W-16 feed. Fish were fed 48 times/d. On October 25, we harvested 286 walleye (71.5% survival) that averaged 6.4 in (16.3 cm) and ranged from 4.5–7.9 in (11.4–20.1 cm).

The main problem encountered during 1988 was high water temperatures. The August temperature in the top 4 ft (1.2 m) was 84°F (29°C) for 3 weeks. An epizootic of undetermined etiology caused mortality of 3–9 fish/d. The major symptom was a white growth on the tip of the tail and or the base of the dorsal fin. Feeding terramycin treated feed seemed to be beneficial.

### 1989 Trial

In 1989, the private hatchery that provided the trained walleyes in 1987 and 1988 was unable to raise any fish. Consequently, fish were purchased from two other private hatcheries (designated A and B). We purchased 405 2.25-in (57-mm) fingerlings from hatchery A. Transportation losses from hatchery A were 19.9%. The fish appeared to be in poor condition, which, coupled with the 100°F (37.8°C) temperature on the day of transportation, may account for the high transportation losses. Later we found out these fish had been held in a tank in a pickup for 12–15 h prior to delivery. On

October 25, 108 walleye were harvested from cage A. Survival was 26.6%. Average length was 6.1 in (15.5 cm) and ranged from 4–7.9 in (102–201 mm).

On July 28, 485 2.5-in (63.5-mm) feed-trained walleye were acquired from hatchery B; they were stocked in a second cage (cage B). Transportation loss was 3%. On October 25, after 89 days in culture, 268 walleye were harvested (55.3%). Fish from cage B averaged 5.3 in (135 mm) and ranged 4–7.9 in (102–201 mm).

In 1989, we fed a total of 50 lb (22.7 kg) of #4 crumbles and 100 lb (45.4 kg) of 3/32-in (2.4-mm) pellets of W-16 purchased from Sterling H. Nelson & Sons, Inc. Murray, Utah. The fish were fed 48 times/d.

Survival from stocking to harvest in 1989 was much less than that in 1987 and 1988. The fish purchased from hatchery A were delivered in poor condition. The fish purchased from hatchery B seemed to be in good condition, but they had not been sorted by size. We think that the large range in size of fish in cage B resulted in cannibalism.

A major problem encountered in this project was finding a steady affordable source of healthy, feed-trained fish, graded to a uniform size. Perhaps when tank-culture of walleye can be used to produce 3-in (7.6-cm) feed-trained fingerlings, the chances for success of cage culture will be greatly improved, and cage culture could be used to expand production of state hatcheries to meet local needs for small lake management.

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