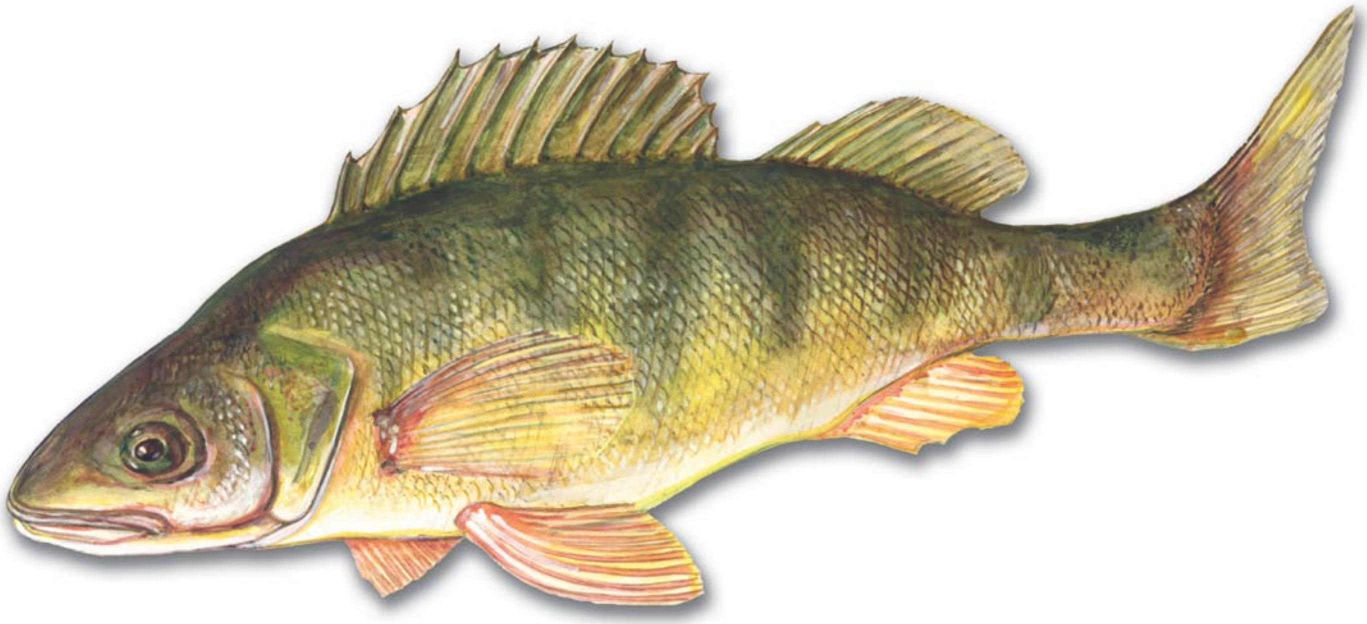
North Central Regional Aquaculture Center



Yellow Perch
(*Perca flavescens*)
Culture Guide

Steven D. Hart, Donald L. Garling, and Jeffrey A. Malison, Editors

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Yellow Perch *(Perca flavescens)* Culture Guide

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Preface

This manual is a summary of information gleaned from scientific and extension publications, NCRAC reports, and unpublished information provided by the contributors and editors. It is not intended as a step-by-step cookbook for production of yellow perch because yellow perch production in the United States is still in its infancy. The industry is best characterized by small-scale producers who use many types of production technologies. Currently, there are no commonly accepted standards for the production of yellow perch. This guide provides a general synopsis of research findings and farming methods currently used. Direct citations are noted in the text when actual information is referred to; other forms of information are noted in general references.

At the NCRAC 2005 planning meeting, Jeff Malison reported on the status of commercial yellow perch culture. He estimated that there are currently about 30 fingerling producers in Nebraska, the Dakotas, Wisconsin, Ohio, Michigan, the Northeast, and the Carolinas, producing between 6,000,000 and 12,000,000 fingerlings per year. Much of the current grow-out production occurs in ponds in Michigan, Nebraska, Ohio, Wisconsin, and the Northeast, totaling less than 226,000 kg/year (500,000 lb/year).

The status of yellow perch aquaculture is constantly changing. As an example, in 1998 there were 33 licensed aquaculturists of all species in Ohio. In 2002 there were 55 licensed yellow perch producers. By 2004 the number of licensed yellow perch producers increased to 68. Consequently, it is anticipated that production will increase if current constraints can be overcome. Jeff Malison's report on yellow perch culture at the NCRAC 2005 planning meeting also summarized the results of the most recent NCRAC Yellow Perch Project. The summary provided key production and economic information on pond, net pen, recirculating aquaculture systems, and flow-through tank grow-out systems (see Chapter 7).

The editors encourage readers of this manual to pay particularly close attention to Chapter 13.

<u>Disclaimer</u>

Chapter 1

Introduction

The yellow perch *(Perca flavescens)* has long been a favorite sport fish in northern states, especially around the Great Lakes. This fish is a highly valued food fish because it has white, flaky flesh that is popular with consumers; the yellow perch is a common fish used for the traditional "Friday-Night Fish Fry". Because yellow perch flesh has a low fat and phospholipid content, it has a long shelf life and is resistant to freezer damage. Hinshaw (2006) noted that yellow perch flesh has less fat (<1%) than other cultured food fish. It also has fewer calories per 100-g serving (91). In addition, this fish is high in protein and contains a modest level of omega-3 fatty acids (0.3%). Low fat and phospholipid content give the fillet a delicate flavor and reduces odor during cooking.

The traditional supply of yellow perch has been through commercial harvests from the Great Lakes. In the upper Midwest, the demand for yellow perch has been increasing rapidly, but the supply from natural sources has been declining; there is no indication that natural supply will meet the increasing demand.

Because of low supplies and high demand, yellow perch has gained interest as an aquaculture species. This interest has been particularly strong in the North Central Region (NCR) of the United States because of the popularity of the fish in the region. Concentrated efforts in yellow perch culture research and extension began at the University of Wisconsin–Madison (UW–Madison) in the early to mid-1970s. These early efforts resulted in the publication of three reports which demonstrate the feasibility of methods for raising yellow perch from egg stage to market size; fingerling production in ponds, and grow out done in a recycle aquaculture system (RAS). Since the inception of NCRAC in 1988, yellow perch has been a high-priority species for production-oriented research. The yellow perch is a candidate for intensive commercial aquaculture because of its marketing and biological characteristics. Positive attributes noted by yellow perch culturists have included their ready acceptance of commercial diets and relative tolerance for intensive culture conditions, e.g., crowding, handling, and marginal water quality. Additionally, through most of its life cycle, yellow perch show very little aggressive or cannibalistic behavior.

Sometimes, farm-raised fish can take on different, undesirable flavors caused by crowding and eutrophication (high nutrient loading) of the water or from the feeds used to culture the fish. Studies have indicated organoleptic differences (flesh texture, taste, and smell) in tank-cultured versus wild-caught yellow perch exist; however, the differences do not affect the perceived overall quality of the product. The tank-cultured yellow perch in-the-round tended to be a bluish green compared with the typical yellow-green of wild-caught perch. Also, the cooked fillets of the tank-cultured yellow perch were whiter than those of wild-caught perch. However, both tank-cultured and wild-caught yellow perch fillets were equal in firmness and overall preference. Additionally, Purdue University researchers conducted a series of organoleptic evaluations and found that yellow perch, both wild-caught and cultured, were significantly preferred over catfish, walleye, and trout in Illinois, Indiana, Kentucky, and Wisconsin.

In spite of its high demand and consumer preference along with its biological characteristics, there are still limitations to yellow perch culture in the NCR.

- First, because yellow perch reach sexual maturity before they reach market size, energy is channeled to sexual maturation instead of flesh production,

- Second, there is a large difference in growth rate between male and female yellow perch; female yellow perch grow significantly faster and larger than males,

- Third, as with many potential aquaculture species, there is limited knowledge of the nutritional requirements of yellow perch to create a complete formulated diet, and

- Fourth, fingerling supplies do not meet current demand for suitable-sized fish for stocking into grow-out facilities.

Finally, as of 2003, other products, such as young European perch or zander (*Sander lucioperca*), walleye (*Sander vitreum*), and sauger (*S. canadense*), have been illegally marketed as yellow perch. At one point this was so widespread that the market price for yellow perch in-the-round (whole, ungutted, scale-on fish) dropped by approximately 50%. As of Autumn 2005, the price had rebounded substantially.

Currently, NCRAC and other institutions are conducting research to address some of the problems in yellow perch culture. Research topics include: production of polyploidy (more than two sets of chromosomes), use of hormones to control the growth of yellow perch at the onset of sexual maturation, out-of-season spawning techniques to enhance the supply of fingerlings, food habituation studies, nutrition, and break-even analysis of various production techniques. As with any aquaculture venture, yellow perch aquaculture must be approached cautiously and with considerable planning.

Chapter 2

Basic Biology and Life History

Family

Yellow perch belong to one of the largest families of North American freshwater fish, the Percidae. This family includes such popular game fish as the walleye and the sauger. The large number of darters are included in this family. There are more than 150 species of percids.

Characteristics

Two separate dorsal (top) fins characterize percids. Yellow perch anterior (front) dorsal fins have 13 to 15 sharp spines; the posterior (back) dorsal fin has one or two spines, but it is mostly made up of soft rays. The anal fin has two spines and six to eight soft rays. The back of the yellow perch is an olive green that blends to a golden yellow on the sides; the belly is white. Yellow perch are characterized by having six to eight regularly spaced bars that extend onto its sides (Figure 2.1). The Latin name for perch, (*Perca flavescens*) describes the fish: *Perca* = perch, *flavescens* = yellowish. These fish are typically no longer than 15–30 cm (6–12 in) and weigh 113–454 g (4–16 oz); however, yellow perch >51 cm (20 in) and >1,360g (3 lb) have been caught.

Figure 2.1. Yellow perch have characteristic dark bars that extend onto their sides (photo by LaDon Swann.)

Range

Yellow perch typically inhabit lakes and large rivers where they live in large schools. Their natural range extends from Nova Scotia southward along the Atlantic coast to northern South Carolina west through Alabama to Kansas, Missouri, and Iowa to the Dakotas and eastern Montana, extending northward to include most of Canada. There have been reports of successful introductions of yellow perch in most states outside this range, including Alaska, Arizona, California, Nevada, New Mexico, Oregon, and Washington.

Temperature and Water Quality Requirements

Yellow perch are deemed a cool water fish and show a preference for water temperatures between 21–24°C (70–75°F); they have a physiological optimum temperature of 22–24°C (72–75°F). Upper lethal temperatures for yellow perch have been reported as 26–30°C (79–86°F). Yellow perch are more tolerant to low dissolved oxygen levels than sunfish. Reports have indicated dissolved oxygen levels as low as 3.5 mg/L (ppm) for 67 d will not be detrimental to yellow perch growth.

Juvenile yellow perch growth has been evaluated for 14 weeks at 16 and 22°C (61 and 72°F) and 8 or 16 hour of light/d. The best growth occurred at 22°C (72°F) and 16 hr of light. Growth of the yellow perch was more dependent on photoperiod (ratio of hours of light to hours of dark) than on temperature at temperatures that support active growth. This finding has been confirmed by additional laboratory experiments and under commercial tank culture system conditions.

Sexual Maturation and Spawning

Yellow perch males mature at year 1 or 2 at 68–168 mm (2.7–6.6 in) total length (TL) and as small as 14 g (0.5 oz). Females usually mature at year 2 or 3 at 94–173 mm (3.7–6.8 in) TL and weigh >57 g (2.0 oz).

Spawning begins in the spring when temperatures are approximately 6–12°C (43–54°F), which may be as early as January in North Carolina and as late as June in Canada. Spawning usually occurs over a two- or three-week period.

Females have fused, paired ovaries with no oviduct or connection to the vent. Papillae form on the ventral midline between the anus and the urinary pore in the vent, which swell and then rupture to release the eggs. Females deposit eggs over vegetation, sand, or gravel. When spawning, groups of males pursue one large female. The eggs of yellow perch are released in a long gelatinous matrix in accordian-pleasted tubes (ribbons) (Figure 2.2) that remain attached to structures in the water after they are expelled from the female (Carlander 1997:125-179). Depending on the temperature, it may take from several minutes to several days for the female to entirely extrude the egg mass. Yellow perch females produce from 79–233 eggs/g (2,238–6,600 eggs/oz) of female body weight. After the eggs are fertilized, they are left to develop on their own. As with many fishes, parental care is not given by either gender of yellow perch.

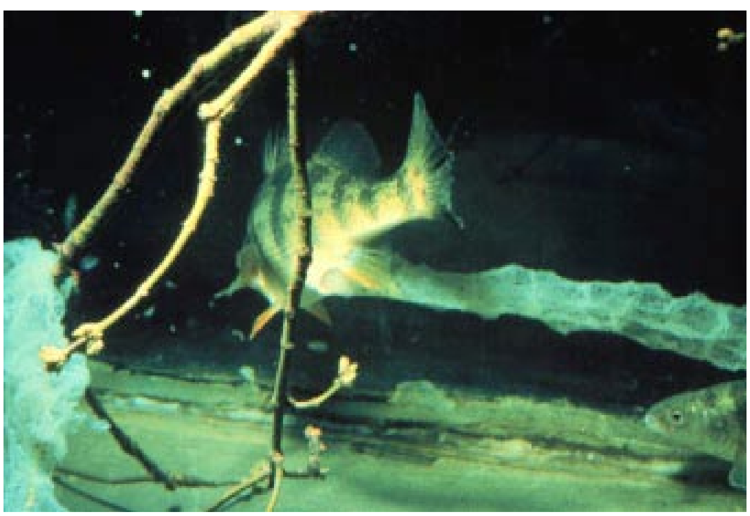

Figure 2.2. Yellow perch eggs are released in long gelatinous ribbons and attach to structures in the water (photo by Bill Manci).

Hatching

Before water hardening (water absorbed by fertilized eggs) the fertilized yellow perch eggs range from 1.6–2.1 mm (0.06–0.08 in) and increase in diameter 1.7–4.5 mm (0.07–0.18 in). After eggs are fertilized, they take from 6 to 51 d to hatch, depending on water temperatures. Optimum yields have been reported to occur when initial temperatures were 5–10°C (41–50°F) combined with daily increases in water temperature of 0.5–1.0°C (1.0–2.0°F).

Feeding Habits

When yellow perch fry hatch, they are 4.5–7.0 mm (0.18–0.28 in) TL and are photopositive (attracted to light) and pelagic (found in open water). Within a few days, depending on the temperature, they begin feeding on algae, protozoans, ostracods, and early life stages of larger zooplankton, rotifers, small copepods or early life stages of larger cladocerans, e.g., *Daphnia*, *Alona*, and *Bosmina*. As the fry grow, they gradually begin to eat insects or other small invertebrates. Zooplankton remain a part of the yellow perch diet throughout their life, but adult yellow perch mainly eat larger insects and other fishes.

Table 2.1. Mean calculated lengths (mm/in) of yellow perch from the Great Lakes region. Source: Carlander (1997:125-179).

	Age (Years)						
	1	2	3	4	5	6	7
Males	77/3.03	134/ 5.28	173/6.81	199/7.83	222/8.74	238/9.37	263/10.35
Females	137/5.39	183/7.20	215/8.46	242/9.53	268/10.55	294/11.57	354/13.94
Average	78/3.07	140/5.51	184/7.24	217/8.54	242/9.53	266/10.47	291/11.46

Growth

Although it was previously noted that females generally grow faster than males under natural conditions, no differences were observed between the growth of females and males from one reservoir in South Carolina. Under natural conditions, average yellow perch growth is generally greater in the Great Lakes region than other parts of its range. Mean calculated lengths of yellow perch males, females, and the non gender-based average by ages in the Great Lakes region were summarized by Carlander (1997:125–179) and are provided in Table 2.1. Historically, minimum legal harvest size has been 190 mm (7.5 in), meaning fish were three to four years old. Growth under natural conditions can be affected by many factors, including temperature, food availability, and population density.

Summary

- Yellow perch belong to the Percidae family and have characteristic dark bars that extend onto their sides.
- Yellow perch are a cool water fish that show optimum growth at 22–24°C (72–75°F) and are relatively tolerant of poor environmental conditions.
- Male yellow perch mature at year 1 or 2 and females at year 2 or 3.
- Spawning occurs in the spring when temperatures are 6–12°C (43–54°F).
- After spawning, eggs hatch anywhere from 6 to 51 d, depending on temperature, and produce fry 4.5–7.0 mm (0.2–0.3 in) TL.
- The first food organisms of yellow perch are algae, potozoans, ostracods, and small zooplankton; as the fish grow, they begin to consume larger invertebrates, and eventually eat other fish along with macroinvertebrates, e.g., insects.
- Yellow perch tend to grow fastest in the Great Lakes region.
- Females usually grow faster than males.
- Fish generally reach a harvest size of 190 mm (7.5 in) in 3–4 years.

Chapter 3

Brood Fish Management and Methods of Spawning

Brood Fish Acquisition

Acquiring brood fish yellow perch can be problematic. Commercial producers have two main choices for obtaining brood fish—either capture brood fish from the wild just before spawning or raise their own fish to reproductive maturity. It may be illegal to collect yellow perch from public waters to use as brood fish in some states. There are currently no commercial suppliers specializing in genetic selection, production, and sale of yellow perch brood fish. However, adult fish purchased from grow-out producers could be used as brood fish.

Catching wild fish, where legal, is the most common method used to obtain brood fish for yellow perch producers. Yellow perch are captured from the wild just before or during the spawning season. Captured fish are either spawned at the harvest site and the fertilized eggs are taken to the hatchery, or the captured brood fish are taken to the hatchery for spawning at a later time when the fish are ripe. In contrast to other fish species, yellow perch eggs are spawned in a continuous long ribbon. Some producers harvest fertilized egg ribbons from the wild; however, egg ribbons collected in this manner may not be fully fertilized or may be at a stage in development that might be sensitive to handling. However, capital costs are reduced by using these methods because specialized facilities are not required.

Problems exist when relying on wild stocks for brood fish. Most states in the Great Lakes region no longer allow commercial harvest of yellow perch; thus, wild yellow perch can only be obtained from private sources or under sport fishing guidelines. These methods are not a reliable way of obtaining fish that will provide the number and quality of eggs needed for commercial production.

Another problem associated with using wild yellow perch for brood fish is the lack of known genetic history of those fish. Wild yellow perch may have a genetic predisposition for slow growth, even under the ideal culture conditions associated with aquaculture operations. The continued use of wild brood fish will not allow a producer to make genetic improvements through selection of desirable traits.

The ideal brood fish for commercial producers are yellow perch that have been selected for good performance, e.g., growth, food conversion, health, and dress-out percentage. Although wild brood fish are often initially used, the subsequent generation of brood fish can be selected from those offspring that exhibited desired culture characteristics. Subsequent generations of offspring should continually be selected for desired traits in commercial systems. By continuing this process, producers can develop a brood fish that produces the best possible fish for their production system.

Raising captive brood fish can eliminate some of the problems associated with using wild fish. Culturists using their own brood fish are not limited by state regulations restricting the harvest of wild fish. Also, by having in-house brood fish the producer has greater control of fish production. Previously mentioned genetic selection and improvements of brood fish can only be possible if a producer takes the time to enhance brood fish selection.

Brood Fish Management

When raised under ambient temperatures, yellow perch females can reach sexual maturity by year 2 at a size of >57.0 g (2.0 oz). Males can reach sexual maturity by year 1 at a size as small as 14.0 g (0.5 oz). Commercial feeds formulated specifically for yellow perch brood fish are not currently available, so producers must use conventional grower diets, e.g., trout feeds.

Yellow perch producers maintaining brood fish must have specific facilities to hold them. Ambient conditions in outdoor ponds, or indoor tanks and environmental controls designed to mimic normal seasonal changes in temperature and day length, are necessary to induce normal sexual maturation. Normal winter conditions, or a "chill period", are required for female yellow perch to experience normal yolk deposition and to undergo final sexual maturation. The optimum chill period for yellow perch varies from their northern to southern natural range. Yellow perch from Minnesota were determined to need 185 d at temperatures of 6°C (43°F) or lower. However, yellow perch from more southern latitudes may not need as long or as cold a chill period to complete maturation.

Upon completion of the chill period, sexually-mature yellow perch spawn once per year in the spring concurrent with increasing photoperiod and water temperature. Yellow perch in any given lake or region normally spawn over a 2- to 3-week period. Spawning season begins as early as January in North Carolina and as late as June in Canada. In general, yellow perch spawn from late March through May in the NCR.

Each female produces one egg ribbon per year. The number and size of eggs in a ribbon are affected by several factors, including, but not limited to, fish size, age, and nutrition. Ribbons collected from females 18–25 cm (7–10 in) in length normally contain 7,000–45,000 eggs that range in size from 106–211 eggs/mL (100,000–200,000 eggs/qt). Ribbons from 2- to 3-year-old (100–125 g; 3–4 oz) pond-raised perch average 15,000 eggs.

Both male and female yellow perch have high fecundity rates (production of sperm and eggs); thus, relatively few spawners are needed to collect and fertilize a large number of eggs. However, larger numbers of brood fish (50–100 breeding pairs) should be spawned to promote genetic diversity.

Spawning Methods

Several methods can be used to produce yellow perch fry with varying degrees of success. The simplest approach is to stock several brood fish of each sex in a pond containing suitable substrate, such as brush piles, and to allow the fish to spawn over the vegetation. The eggs are left to hatch naturally. Although simple, this method provides little control over when the fish spawn or the number of fry released into the pond. Fry that do hatch may vary in age by 2 to 3 weeks, leading to large variations in size and high levels of cannibalism. Brood fish should be removed from the ponds, or they will eventually eat their offspring, reducing the number of fingerlings for harvest. This method of spawning is the most simplistic; however, it will most likely exhibit the most variation in fry production and should be considered the least desirable.

Fertilized egg ribbons can also be collected from a pond after spawning by removing them from the supplied spawning vegetation. However, harvesting intact perch egg ribbons is difficult, and it is even more difficult to incubate small, broken pieces of ribbons. Complete fertilization of ribbons cannot be guaranteed when using the pond spawning technique; thus, removing fertilized egg ribbons from the pond may result in variable numbers of fry produced from year to year.

Yellow perch will also spawn in tanks or net pens if males and females are stocked together at low densities (for example, six males and six females in a 1,892-L [500-gal] tank). As with collecting ribbons from the wild, it can be difficult to harvest and subsequently incubate intact yellow perch ribbons from tanks, and there is no guarantee that the ribbons will be completely fertilized.

Perhaps the most desirable method of fry production is to hold brood fish in tanks during the spawning season, manually strip the eggs from ripe females into a bowl, fertilize them, and incubate the eggs in tanks until they hatch. This method allows for the greatest percentage of fertilization and should have the least amount of variability. Manual spawning is more labor-intensive than previously mentioned spawning techniques, but it allows for producer control throughout the process. Learning the process of obtaining milt (semen) from males is relatively easy. Semen extenders (dilution method to fertilize more eggs) can be used to dilute milt and allow it to be stored for 5–10 d after collection. In contrast, stripping intact, ripe egg ribbons from females is a skill that requires time and practice to learn. One of the most difficult steps in artificial propagation is to identify newly ovulated “ripe” females that are ready to be stripped.

There are several problems associated with improperly checking female yellow perch for ripeness. Excessive abdominal pressure on a fish whose eggs have not reached optimum ripeness causes the urogenital membrane to rupture and clear ovarian fluid to discharge from the urogenital opening. This pressure may injure the fish and prevent successful ovulation in the following days. Eggs that remain inside the female after the spawning season may prevent normal ribbon development the following year. Eggs that are past optimum ripeness and are stripped are likely to be of poor quality. Applying insufficient abdominal pressure to a female that has ripe eggs will not expel the egg ribbon. These fish release their eggs shortly after being returned to the holding tank, thus wasting the egg ribbon unless retrieved from the tank soon thereafter. Inexperienced perch culturists often lose half or more brood fish ribbons by applying excessive or insufficient abdominal pressure.

To identify ripe females (females just before spawning), begin by removing each fish from the water and examining the abdomen. Ripe females will have abdomens swollen by their egg ribbon. To further identify a ripe female, look at the urogenital pore (the single opening on the bottom of the fish where waste products and reproductive material are both expelled). After ovulation, the urogenital pore of 3- to 4-year-old female yellow perch becomes swollen and slightly reddish (Figure 3.1). However, younger, smaller females may show significantly less swelling and redness.

In the hatchery, an entire tank of females is normally sorted, and all ripe fish are placed in a separate tank before stripping eggs. Because of their small size, yellow perch can be handled without using anesthetics; however, an anesthetic can be

Figure 3.1. Ripe female yellow perch can be identified by examining the urogenital pore, which becomes markedly swollen and slightly reddish. Fish A is under ripe; fish B is ripe (photo by Jeff Malison).

used to reduce stress on brood fish. Finquel® (tricaine methanesulfonate) and carbon dioxide are common anesthetics used for fish. In the United States, applications of 80 ppm Finquel® (Argent Chemical Laboratories, Redmond, Washington), have proven to be useful for brood fish. Because there is a 21-d withdrawal time for fish anesthetized with Finquel® before they can be consumed, they need to be held for that time period before being released into a fishery. Peake (1998) found that applications of 2.66 g of sodium bicarbonate/L can be an effective anesthetic; sodium bicarbonate releases CO_2 ,which is the actual anesthetic agent.

Yellow perch need to be frequently visually inspected during the spawning season to successfully strip a high percentage of egg ribbons from captive female brood fish. Once ovulation has occurred, a female expels the egg ribbon within several hours if it is not manually stripped. Generally, 50% of available females are successfully stripped if evaluated once per day. If the fish are checked twice daily, success rates increase to about 80%. Most of the remaining females release eggs in the tank, and a few simply do not spawn; perhaps because of the repeated stress of handling or premature rupture of the urogenital membrane.

The repetitive handling of individual female brood fish over the course of a 3-week spawning season is extremely stressful to the fish, and severe bacterial infections and significant mortality can occur. Human chorionic gonadotropin (HCG) can synchronize the spawning of a group of female brood fish and shorten the spawning season from three weeks to 3–4 d. In a group of female perch, more than 75% spawn 4–7 d after an intraperitoneal injection (injection into the body cavity) of 150–300 international units (IU) HCG/kg body weight (68–136 IU/lb). By using this strategy, the fish are handled less frequently, and a large number of fry of uniform age can be produced.

The United States Food and Drug Administration (FDA) regulates the use of chemicals and drugs for fish. In 1999, the FDA approved the use of Chorulon® (HCG) for all finfish brood fish. There are some stipulations to its use and federal (United States) law restricts this drug to use by or on the order of a licensed veterinarian.

Summary

- Brood fish spawn once each year in the spring and require a “chill” period for normal development of gametes.
- It is recommended that captive yellow perch brood fish be used rather than depending on wild brood fish.
- “Domesticated” brood fish give the producer much more control over spawning.
- Various methods can be used to acquire fry.
  - Stocking adult fish in ponds or tanks and allowing them to spawn naturally.
  - Collecting egg ribbons from the pond.
  - Holding brood fish in tanks and manually stripping the eggs.
  - Use of hormone injections to help synchronize spawning.

Constraints

- Stripping the eggs requires expertise to:
  - Detect when females are “ripe” and ready to be stripped.
  - Reduce the impact of repetitive handling of the brood fish.

Chapter 4

Egg Fertilization, Incubation, and Hatching

As discussed in Chapter 3, there are several methods available to culturists to obtain eggs from adult yellow perch. Brood fish can either be allowed to spawn naturally in ponds, tanks, or net pens or producers can strip eggs and milt from adults and manually fertilize the eggs. Because of the variability in success of natural spawning techniques, manual spawning is the recommended method of obtaining fertilized eggs for larger-scale production.

Semen and Egg Collection

Applying gentle pressure to the abdominal area of the male will cause the semen to excrete from the urogenital opening. Early in the spawning season male yellow perch produce copious amounts of highly concentrated semen (10–40 billion sperm cells/mL; 296–1,183 billion/oz). As the season progresses, semen volumes decrease and the milt becomes less viscous and somewhat watery. A solution of 0.7% NaCl or a semen extender developed for use in walleye (Moore 1987) can be used to dilute yellow perch semen for storage in the refrigerator. When semen is stored for future use, the extender provides nutrients and prevents bacterial growth and pH changes. Extended semen can be stored for 2–3 weeks if kept under refrigeration at 3–5°C (37–41°F) and oxygenated daily. For best results, milt should be collected into chilled glass containers over ice and chilled extender should be slowly added and gently incorporated to a final dilution of 2–9:1 (extender to semen by volume). The extended semen should be stored as a thin layer <3-mm (0.1-in) thick in airtight plastic containers and oxygen or air should be exchanged 1× or 2× daily. Rapid warming, pH changes, and agitation can prematurely activate the sperm cells resulting in poor fertility rates. Contaminants, e.g., feces and urine, should be carefully excluded during milt collection because they can significantly shorten shelf life.

Generally, fresh milt exhibits good fertilization characteristics. Assessing the viability and motility of extended or stored semen is recommended before use and is easily done by activating a drop of milt with water while observing the sperm under a microscope. Once activated, most to all of the sperm in a sample should react vigorously for 15–30 sec.

The FDA, under its Investigational New Animal Drug (INAD) program, has permitted specific sites to use methyltestosterone (MT) to create masculinized brood fish (genetic female that has ability to produce sperm), which produce all female offspring when crossed with normal females. When using milt from masculinized brood fish, the testis is dissected out of the body cavity, placed in a dry dish over ice, and then finely minced with a scalpel (Chapter 10 covers the creation of masculinized female perch). During the mincing process, chilled extender is slowly added to a final dilution of 4–5:1 (extender to semen by volume). Milt collected from minced testes should be stored only 2–3 d before use; tissue particles and blood contribute to bacterial growth.


Figure 4.1. When stripping eggs from ripe yellow perch, angle the head upward and apply slight pressure to the sides of the abdomen (photo by LaDon Swann).

The egg ribbons of yellow perch are tube shaped and folded like a bellows. They expand to lengths of up to 1.2–2.4 m (4.0–8.0 ft) or more when exposed to water. The number of eggs can be measured volumetrically. Eggs are placed into a graduated cylinder; about 160 to 200 eggs occupy 1 cm^3 which displaces 1 ml of water. Under controlled conditions, i.e., manual spawning, fertility can be >90%. On a commercial scale, overall hatch rates of 70% can be attained using these manual spawning techniques.

Stripping egg ribbons should only be done when the fish has ovulated and is ready (see Chapter 3). Applying pressure to the abdomen of a female causes the egg ribbon to burst through the membrane, separating the eggs from the urogenital opening. The eggs should be stripped into a large container (Figure 4.1).

When stripping eggs from a female, fertilization is enhanced by slightly stretching the ribbon over the bottom of a large container (Figure 4.2). Stripping ribbons into piles can cause areas of infertility, particularly if the ribbons are not fertilized immediately after collection.

Fertilization

Manual fertilization of eggs include either the wet or dry method. The wet method of fertilization involves adding the eggs and milt directly to water and mixing them. This method results in a shorter time in which sperm can fertilize the eggs. The wet method can be used with yellow perch but control over fertility rates can be hard to manage.

When using the preferred dry method, care should be taken to avoid getting water on the milt and eggs before they are ready to be fertilized. Sperm are only mobile for 15–30 sec once they come into contact with water. Eggs can only be fertilized for several minutes after water contact because of hydration and closure of the micropyle (opening in the egg that accepts sperm entry). Fertilization can be managed by drying the underbellies of yellow perch with a soft towel before stripping the gametes. Drops of milt are added to the ribbons, either from storage or directly from several males (Figure 4.2). The milt and eggs are gently mixed using feathers, sticks, and even a finger, and finally water is added.

Once water is added to cover the ribbons, the producer should gently mix the eggs, milt, and water. Fertilization occurs within 30 sec after the addition of water. Before contact with water, the egg strand is slightly sticky and firm in texture.

Figure 4.2. The dry method of fertilizing yellow perch eggs is to strip the fresh milt from the males directly onto the eggs. Ribbons should be stretched out to ensure the highest rate of fertilization (photo by Jeff Malison).

As the ribbons hydrate (take on water), the texture eventually becomes more slippery and less turgid. Strands or portions thereof that remain firm may not have undergone complete ovulation and generally have little or no fertility. Unfertilized eggs soon die and are usually the first sites of fungal infection during the subsequent incubation period. Regardless of the method used, ribbons with excessive areas of clumping or bloody appearance are usually not worth incubating.

Incubation

In the wild, eggs are deposited in sheltered areas and can be found draped over aquatic vegetation; yellow perch do not construct nests or guard their young. The egg strand's form, along with its breakdown during incubation, makes it more challenging to incubate yellow perch eggs compared with other cultured fish. Physical contact with eggs must be minimized during incubation because too much contact leads to egg damage. The strands need a constant, gentle water flow to supply the eggs with oxygen and remove metabolites, e.g., ammonia and carbon dioxide. However, some eggs can die regardless of the amount of physical contact. Fungus will form on dead eggs and quickly spread to adjacent ribbons. The dead and fungus-covered egg sections can easily be identified by their milky opaque color and should be removed as soon as possible.

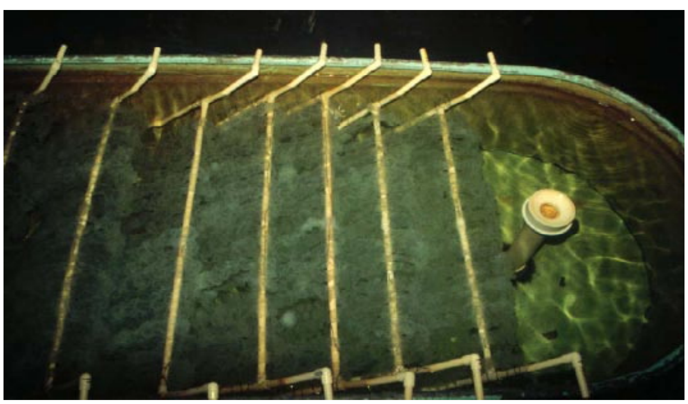
Figure 4.3. In-tank incubation via UW-Madison method (photo by Jim Held).

There are several methods of incubation available to culturists. The method of incubation used by UW-Madison researchers relies on coated wire mesh (chicken wire) submerged in a trough of water and held at an angle so the ribbons are pinned against the wire by water flow (Figure 4.3). Ribbons can be individually teased from a half-submerged bowl and draped over the wire hangers.

Researchers at Michigan State University (MSU) have had success with hatchery trays commonly used in trout and salmonid incubation to incubate yellow perch eggs. Wooden dowels can be inserted into the screens of the trays, and the ribbons can be stretched out and wrapped around these dowels. The overall key for successful incubation is to not allow the ribbons to bunch up on themselves and to allow an even water flow over the entire ribbon.

Yellow perch eggs can be incubated under a rising temperature regimen or at a constant temperature. UW-Madison researchers incubate yellow perch eggs by raising temperatures fom 11 to 15°C (52 to 59°F) over the course of 9 d. By raising the temperature, the length of time required to complete a hatch can be shortened. However, other researchers feel that by increasing temperatures, hatching may be forced to occur too early for some fry, causing developmental problems that may result in high mortalities of yellow perch fry (see Chapter 5). In contrast, fertilized eggs may be placed directly into a constant rearing temperature of 14°C (57°F). Egg incubation is an area that requires more research and development before any single method can be identified as the best for yellow perch production.

During incubation, the matrix holding the eggs together degrades. Its consistency becomes slimy, and the structure of the ribbon becomes very delicate. Contact with the wire hangers or wooden dowels leads to egg death by fungal infection and eventually breaks the strand. Most losses occur during the final stages of incubation when egg strands break and fall to the bottom of the incubation tank or draw in upon themselves in trays. Although the breakage itself is not fatal to the embryos, broken strands should be stretched back out, or the eggs die from low oxygen concentrations.

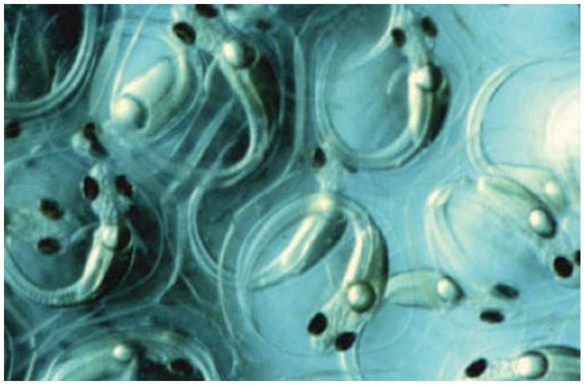

Figure 4.4. Eggs 10–12 d post-fertilization; ready to hatch (photo by Jim Held).

When incubating by using an increasing temperature regimen, eyes become visible (eye-up) about day 8 (Figure 4.5); eyes are not fully pigmented until just before hatch (days 10–12). When incubating with a constant temperature, the length of time to eye-up and hatch depends upon the temperature. For instance, Carlander (1997) notes that yellow perch cultured at 3.3°C (37.9°F) and 13.1°C (55.6°F) hatched at 30.5 and 8–8.5 d, respectively.

Regardless of the method used, as the embryos mature their need for oxygen and cellular waste removal increases. Both increased water flow and direction must be carefully monitored to avoid dislodging or tearing the ribbons. Fungal growth, especially in the last days of incubation, can be a serious problem. Daily formalin treatments have been shown by researchers at Ohio State University (OSU) to provide adequate fungus control. In flow-through incubation tanks, a low dose (25–50 mg/L) is used daily from day 2 until the eye-up stage.

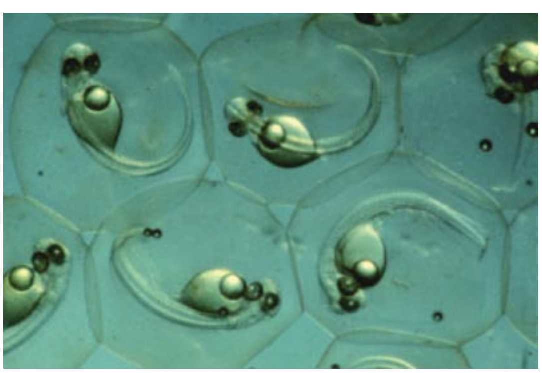

Figure 4.5. Eggs 6 –8 d early eyed stage (photo by Jim Held).

Ribbons also can be incubated in fingerling production ponds. Ribbons are placed into production ponds 1 or 2 d before eggs hatch. Variable hatch rates can occur, unless the ribbons are agitated by wind, waves, or manually during hatch. Although in-pond incubation can be successful on a small scale, the environmental control and improved hatch rates provided by tank incubation make it a more reliable method for large-scale production.

Hatch

Embryological characteristics are used to determine when eggs are ready for hatch. These attributes can be seen when examining the eggs under a dissecting microscope or hand lens. Just prior to hatching, the eye pigment of the embryo is an opaque black when illuminated from below. Additionally, the yolk sac changes from a round or heart shape to a slightly elongated egg shape. Fin buds, sprouting just posterior to the gill slits, become thin flaps (Figure 4.4). The final test for readiness for hatching is to place a few dozen eggs into a beaker of water and stir briskly with a small spatula. If ready, most of the fish in the sample will be released from the eggs and will begin swimming in the water column; this is sometimes called "shocking the eggs."

Eggs can be allowed to hatch on their own, or disturbance can be applied to synchronize hatch. Under laboratory conditions, MSU researchers have consistently achieved 80–90% hatch rates by allowing hatch to occur naturally over a 2- to 3-d span. Newly hatched fry are allowed to flow from hatchery trays into a shallow holding tank (Figure 4.6).

Under laboratory conditions, UW-Madison researchers have found hatching success can be variable unless agitation is provided. Using what

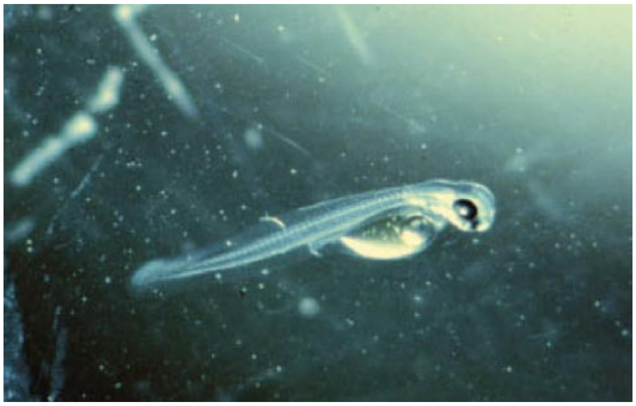

Figure 4.6. Hatched fry (photo by Jim Held).

appears to be a fairly rough treatment to the egg strands, UW-Madison researchers have optimized hatching rates in their laboratory. Once eggs are judged ready to hatch, 20–40 strands at a time are siphoned from the incubation tank into a bucket. The eggs are then stirred briskly using a paint stirrer mounted on an electric drill. The mixing process lasts for 10–15 sec and is repeated two or three times. Hatching success can be judged by observing a subsample of the water/egg suspension. Surprisingly, the mixing process injures only a few embryos. Microscopic observation of hatched fry reveals that <5% show any signs of injury. Apparently, the eggs are ruptured by the shock wave induced by the stirrer; other stirrers may perform differently. Once most of the eggs have hatched, the fry are ready for enumeration.

Further research needs to be conducted to determine whether one method is better than the other. For now, producers should use whichever method works best for them.

Enumeration

Because of their small size and delicate nature, it is not practical to determine fry number by weight or volume. However, by counting the number of fry in small, known-volume subsamples, e.g., 10–20 repetitions of 5-mL (0.17-oz) subsamples of the water/egg/fry suspension, the number of fry per unit of water volume can be determined, and the total number calculated.

Summary

- Environmental changes to induce sexual conditioning are required for manual spawning of yellow perch.
- Milt is easily obtained from ripe males and can be stored for up to 2–3 weeks if extended and kept cool and well oxygenated.
- After stripping eggs and milt, the dry method of fertilization is recommended.
- Eggs can be allowed to hatch naturally or agitation can be provided.
- Survival rates of 60% or higher from fertilization through hatch are considered good.

Constraints

- Ripe brood fish are often limited in number and quality.
- Stripping eggs from the female is more difficult and requires expertise in determining when a female is “ripe”.
- Routine spawning methods can achieve >95% fertilization, but significant losses of embryos and fry can occur during later stages of incubation and upon hatching.

Chapter 5

Fingerling Production

Three methods of producing yellow perch fingerlings have been used: pond culture, tank culture, and tandem pond/tank culture. All three methods can result in highly variable fingerling production rates. The ultimate goal of fingerling production is to provide feed-trained fingerlings for grow out. The feed training methods are described in additional detail in Chapter 6.

Pond Culture

The pond culture method involves stocking larvae into fertilized production ponds where they initially feed on natural food, e.g., aquatic invertebrates. Stocking rates range from 375,000–1,500,000 fish/ha (150,000–600,000 fish/acre) depending on production goals; lower densities yield larger fish for the same culture period. Ponds range in size from 0.04–0.4 ha (0.10–1.0 acre) and are typically <1.83–2.44 m (6–8 ft) deep. Ponds should be dry for at least 24–48 hr to help assure that all gill-breathing organisms (competitive fish and amphibians as well as predatory insects) are dead.

In undrainable ponds, some producers use rotenone to kill all fish prior to stocking larvae. A suitable time (1-8 weeks) should be allowed for decomposition of the rotenone prior to stocking the larvae; the cooler the water, the longer time needed to detoxify rotenone.

Water for filling the culture pond may originate from a well, reservoir, surface runoff, or other surface water source, e.g., streams; filling procedures vary depending on the water source. Although well water will not have problematic pests, a longer pre-stocking period is often needed prior to stocking fish fry. In contrast, surface waters will often have a compliment of natural fish prey, e.g., zooplankton, but they have to be filtered to eliminate all fish eggs and wild fish that may prey on yellow perch fry. Several types of simple filters can be used, with Saran (fine-mesh synthetic fabric) cloth filters being the most common.

In regard to the prestocking period for flooded ponds, some researchers have suggested a short period, 2–7 d, be used to take advantage of the initial abundance of small-sized invertebrates. Longer prestocking periods might allow for larger sized aquatic invertebrates to become established, resulting in a limited number of suitable-size prey for yellow perch fry.

At this time, the suggested actual length of htis pretocking period varies among culturists. Nearly all surface waters naturally contain zooplankton, and, given enough time, less fertile waters, e.g., well water, will be colonized. Because fish usually are cultured at high densities, the densities of their prey, zooplankton, also must be high. Minimum density of suitable-sized zooplankton is 100/L (378/gal).

Fertilizers are commonly added to culture ponds to increase zooplankton numbers by increasing zooplankton food, e.g., organic material, bacteria, and algae. Many different types and application rates are available. There seems to be little indication of an optimal treatment, and success can be highly variable.

Fertilizers are classified as either inorganic or organic. The actual rate is determined by pond fertility as well as maintenance of suitable water quality. Inorganic fertilizers, e.g., ammonium nitrate (52%-N) and phosphoric acid (32%-P_2O_5), may be used. The grade of a fertilizer refers to percentages by weight of nitrogen, phosphorus, and potassium, e.g., 10-35-0 percentages, respectively. These nutrients stimulate primary production (algal growth) and are available in both granular and liquid forms; liquid forms are preferred due to their ease of use as well as faster results.

Although often less expensive, organic fertilizers need to provide adequate amounts of nitrogen and phosphorus (limiting nutrients in aquatic systems) typically in usable forms, e.g., plant and animal materials—alfalfa, soybean meal, bone meal, and manures. Organic fertilizers provide food for the fish by stimulating algal growth as well as serving as a direct food resource, i.e., bacteria and protozoa, for aquatic invertebrates.

Organic fertilizers may decrease dissolved oxygen (DO) and increase ammonia levels in culture ponds. Ponds with intense "blooms" of algae may exhibit low DO in the morning (<2 ppm) and high pH levels in the afternoon. The combination of low DO, high ammonia, and variable pH levels may be lethal. The producer must consider such water quality parameters before initiating a pond fertilization regime. In addition, regular assessment of zooplankton populations allows for identification of harvest times whereby fingerlings are harvested before complete zooplankton population declines, resulting in fewer instances of in-pond cannibalism. More information on nursery pond management can be found in Morris and Mischke (1999).

The actual application rates of both types of fertilizers are highly variable. For example, some culturists add inorganic fertilizers to maintain a constant 0.10 mg/L (ppm) total phosphorus level, whereas others work to maintain a pre-selected nitrogen:phosphorus ratio. Common application rates of alfalfa hay or pellets are 560–1,681 kg/ha (500–1,500 lb/acre) applied in 3–5 portions over the four- to six-week culture period.

A particular regime must be determined for each aquaculture setting. It is important for the producer to first determine whether a fertilization program actually is needed. It also is important to remember that fertilizer applications in the NCR are not determined solely by water temperature, in contrast to recommendations often used in more southern states. If the producer waits for the water temperature to reach 21°C (70°F), as recommended in southern states, yellow perch culture season might never take place.

When the fingerlings reach approximately 17.0–20.0 mm (0.7–0.8 in) TL, they should be fed frequently throughout the day with a commercial trout starter diet. As they grow, the fish should then be fed with increasingly larger food sizes until they are harvested in the autumn (see Chapter 9). These harvested fingerlings are called young-of-the-year (YOY) because they have not yet reached age 1 (all YOY perch are considered age 1 the following spring, regardless of when they were hatched).

In addition to feeding the fish on a daily basis, adding lights has proven to be effective in getting this fish to feed on commercial diets. Yellow perch <50 mm (≈2.0 in) exhibit a strong photopositive (attraction to light) behavior. These smaller perch have ultraviolet (UV)-sensitive cones in their eyes, which suggest they use surface light to find food because UV light cannot penetrate far beyond the water surface. The UV-sensitive cones disappear when yellow perch attain about 50 mm (≈2.0 in) TL; thus, feed training with lights must occur before they attain this size. Automatic feeders can be installed near the perimeter of the pond adjacent to the submerged lights (Figure 5.1). At night, the lights concentrate large numbers of fish in the vicinity of the feeders. The feeders then disperse food frequently throughout the night. This modification increases the percentage of fish that

Figure 5.1. Feeding with lights (photo by Jim Held).

initially accept the formulated food and reduces total food use.

NCRAC investigators demonstrated that using a combination of lights and automatic feeders in small 0.08-ha (0.20-acre) rearing ponds increased total production two- to four-fold. A large part of the increase in production depended on the number of feeders used per pond surface area and the level of attention given to maintaining and supplying feeders with fresh feed.

Fingerling production is often quite variable. Yellow perch can be raised in ponds from eyed eggs to fingerlings having mean weights of 11.0–12.8 g (0.39–0.45 oz) within one growing season at production levels as high as 1,216–1,525 kg/ha (1,085–1,360 lb/acre), although 178–357 kg/ha (159–319 lb/acre) may be more typical using current production methods. This variability is often related to a combination of site-specific water quality conditions as well as fry quality.

Harvesting yellow perch fry or fingerlings from ponds can be problematic because of the delicate nature of the fish. NCRAC investigators have evaluated several strategies of harvesting various sizes of YOY yellow perch (16.0–35.0 mm [0.63–1.38 in] TL) by using light attraction, referred as "light harvest," in various ponds. The "best" size at which to light harvest young yellow perch to minimize physical injury and maximize the number of fish captured seems to be 18.0–25.0 mm (0.71–0.98 in) TL. However, many variables influenced the number of fish captured and the catch per unit effort. Thus, a single night's effort under seemingly similar conditions with the same equipment might yield from 50,000–500,000 fish with no obvious explanation for the differences.

Percentage success of total pond harvest seems to be inversely related to pond surface area, depth, and the steepness of slope of pond banks. Thus, with 0.2-ha (0.50-acre) ponds, harvest percentages as high as 50% can sometimes be achieved, whereas similar harvest success in 0.4-ha (1.0-acre) ponds is rare. Preliminary trials with larger ponds suggest that harvest percentage declines progressively with increasing pond surface area. Given the variable harvest success and the relatively high cost of associated equipment, it is recommended that this harvesting practice be used only by experienced fish culturists for targeted applications, such as the early harvest of very young perch for habituation to formulated feed.

Seine construction for harvesting 51-mm (2-in) fish consists of 3.2-mm (1/8-in) "ace" or "king" type mesh. When fish are 70.0–76.0 mm (2.75–3.0 in) TL, use 6.4-mm (0.25-in) mesh of #9 twine size. By early fall, when fish are 127–178 mm (5–7 in) TL, use 12.8-mm (0.5-in) mesh and #15 to #21 twine size. Successive attempts may be needed to ensure a large percentage of the fish are harvested. Fish should not be harvested when water temperature exceeds 24°C (75°F); <21°C (70°F) is better for fish harvests. Also, do not hold fish less than 51 mm (2 in) TL for more than 3 d in holding tanks or starvation may occur. All of the other management measures are useless if the fish are stressed and die at harvest or later because of subsequent diseases.

At harvest, fish should be weighed and three or four sample counts taken from each pond to determine total number and size of the fish. Size of fingerlings is usually presented as the number of fish/kg or fish/lb, although determination of harvest success is often based on percentage of return, fish condition, and total production.

Advantages of the pond culture method are that large numbers of fingerlings can be raised at a relatively low cost. Separate pond and tank systems are not needed, and labor costs remain low throughout the growing season.
However, there are several disadvantages to the currently used pond culture methods. First, survival rates in fingerling production ponds have shown significant variation, ranging from 0 to nearly 100%. Typically, 35–50% is considered excellent survival. Correspondingly, yellow perch fingerlings harvested in autumn show tremendous variation in size, which may result in significant cannibalism. Second, total fish production averages 785–897 kg/ha (700–800 lb/acre), although 178–357 kg/ha (159–319 lb/acre) may be more typical under some conditions. Third, fingerlings reared in ponds for an entire growing season can be difficult to habituate to tank systems.

Tank Culture

The tank culture method has focused on feeding yellow perch fry a combination of live and commerical foods. Many combinations of different live food types have been used, including organisms such as protozoans, rotifers, vinegar eels, copepods, cladocerans, and brine shrimp. Commercial diets also have been used independently and in combination with live feeds. Live feeds are cultured indoors under controlled environmental conditions that allow for optimum production. As the fish reach approximately 15.0–20.0 mm (0.6–0.8 in) TL they can gradually be weaned onto a formulated fry diet, e.g., a commercial trout fry diet. Similar to walleye culture, tanks used in this method (Figure 5.2) are 150.0 L (39.6 gal) or larger.

Figure 5.2. Tank culture (photo by Jim Held).

Although success has been achieved on a laboratory scale, tank culture has not been developed to the point of being a viable source of yellow perch fingerling production for commercial operations. When using tank culture, most researchers and commercial producers have been unable to consistently attain high fry survival. The inability to achieve significant survival of perch fry is thought to be associated with a combination of factors, including inexperience with appropriate feeding and handling practices for larval fish, a failure to meet basic nutritional needs, and poor swim bladder inflation. Other problems associated with tank culture, compared to pond culture, include the higher costs associated with more intensive labor and producing live food organisms. Research to date on improving tank culture has focused on identifying the nutritional requirements of yellow perch fry, developing acceptable diets, and evaluating different physical properties of rearing tanks to enhance survival and swim bladder inflation rates.

Tank culture could be the most desirable method of producing perch fingerlings if techniques can be developed to make it more viable. Some research has suggested survival rates of >70% can be achieved using tank culture; unfortunately, methods for achieving survival rates this high have yet to be published.

One method that may be of commercial interest is "green tank" culture. Green tank culture is the attempt to make available sufficient quantities of small, appropriately-sized live food in a single culture tank by growing algae, zooplankton, and larval yellow perch together. Researchers at University of Wisconsin-Milwaukee (UW-Milwaukee) have consistently had success using green tank culture. They feed green tank water

(GTW) from days 0 to 4 (all days are posthatch), GTW plus *Artemia* (BSN) from days 5 to 12, BSN only from days 12 to 22, BSN plus beef liver mash (BLM) from days 22 to 25, BSN plus BLM plus formulated starter diet (FSD; Biodiet Starter, Bioproducts, Inc., Warrenton, Oregon) from days 25 to 28, BLM plus FSD from days 28 to 49, and FSD from day 49 on.

During the GTW phase of rearing, flow is less than one exchange per day. Beginning with the addition of BSN, water flow is increased to 7–10 volume exchanges per day. During the early feeding phases involving GTW and BSN, the fish are reared under 16-hr light:8-hr dark.

On about day 28 after first feeding, fish are switched to a 12-hr light:12-hr dark photoperiod. Researchers at UW-Milwaukee have shared unpublished data describing the preparation and management of GTW systems as well as providing on-site consultations to producers. Although these researchers have been successful in producing 2,000–4,000 fingerlings/m^3 (8–15 fingerlings/gal) using this technique, producers have not had similar success.

Laboratory studies using 208-L (55-gal) culture tanks completed at MSU during spring and summer 2004 suggest that larval growth and survival can be increased by reducing handling. The researchers made the following suggestions:

1. Incubate eggs inside fry culture tanks to reduce handling stress.
2. Use either a gentle upwelling of water, e.g., 2.0–4.0 Lpm (0.5–1.0 gpm) piped directly to the bottom of the tank or consider no flow with a 10% water exchange daily by adding Artemia (see # 5) and green water (see # 6).
3. Apply salt, e.g., high-quality Instant Ocean® (Aquarium Systems, Mentor, Ohio) to reduce the effects of stress on the fish (see # 5).
4. Use multiple feedings (five feedings every 4 hr) spaced evenly throughout the day between 8:00 AM and midnight of *Artemia* and green tank water.
5. Feed 24-hr-old *Artemia* cultures through AT LEAST day 14 and preferably through day 28 with a relatively high density of fish/L. Add the *Artemia* with 2.0 L (0.5 gal) of the saltwater culture medium.
6. Supplement the *Artemia* with 2.0 L (0.5 gal) of green water at each feeding. Researchers used a mixed culture of protozoa, rotifers, and ostracods.
7. Use gentle aeration to keep feeds suspended and to break the water surface tension and oil and protein surface films released from decaying feeds and waste to enhance air bladder inflation
8. Use gentle tank cleaning methods such as a peristaltic pump set at a low pumping volume rather than using traditional siphoning methods.

Tandem Pond/Tank Culture

The tandem pond/tank rearing method is currently the most widely used method for the commercial production of yellow perch fingerlings. In this method, yellow perch larvae are initially stocked into fertilized production ponds where they feed on natural food in the ponds. Once the fish reach approximately 17.0–51.0 mm (0.8–2.0 in) TL, usually within 4 to 8 weeks posthatch, they are harvested and stocked into tanks where they are trained to accept conventional feeds, e.g., trout starter diets.

The principal advantages of this method are that large numbers of fish can be produced in ponds (typically >123,548/ha [50,000/acre]) at a size of 38.0 mm (1.5 in) TL at low cost compared with the tank culture method. Normally, 70–90% of the fingerlings of this size harvested from ponds can be habituated to formulated feeds and tank culture conditions. Skeletal and other deformities associated with nutritional deficiencies or imbalances often observed in tank-cultured fry and early fingerlings are rarely observed in yellow perch reared initially in ponds.

Recent studies have demonstrated that by using a combination of high fry stocking densities (>500,000/ha [>200,000/acre]) and early pond harvest, the number of fingerlings produced in ponds can be increased by 100% or more compared to only stocking lower densities of fry and culturing them longer. Between 50–70% of the harvested fish can then be habituated to formulated food and tank culture conditions.

There are some disadvantages associated with the tandem pond/tank method. First, separate pond and tank systems are required, thereby increasing expenses compared with single-system methods. Second, fingerlings subjected to excessive harvesting stress can be difficult to train to formulated diets and are more susceptible to disease. Finally, the tank rearing stage of the tandem strategy requires frequent feeding, tank cleaning, and other animal husbandry, leading to labor costs that continue to escalate the longer the fish are held indoors.

Summary

- Three methods of yellow perch fingerling production can be used:
  - Pond culture
    - Simplest method
    - Larval yellow perch are stocked into fertilized ponds and fed frequently with common diets after they reach 17.0–20.0 mm (0.7–0.8 in) TL.
    - Lights have been used to attract the fish to feeding stations at night, which can increase production.
  - Tank culture
    - Successful on a laboratory scale but needs further development before it is ready to be widely used on a commercial scale.
    - Relies on raising live food organisms initially, and then weaning the fish to formulated feeds after they are 15.0–20.0 mm (0.6–0.8 in) TL.
    - Producers have more control over production.
  - Tandem pond/tank
    - Most widely used method for producing fingerlings. This method uses ponds for the first phase of production and tanks for the second phase.
    - Large numbers of perch fingerlings can be produced with lowered incidence of nutritional deformities compared to tank culture.

Constraints

- Pond culture
  - Reliable pond fertilization techniques to ensure appropriate-sized live feeds have not been developed.
  - Pond- and tank-reared survival of 35–50% is often accepted as excellent.
  - Difficulty in fry and fingerling and fingerling harvest from ponds.
- Tank culture
  - Successful on a laboratory scale but needs further development before it is ready to be widely used on a commercial scale.
  - Size variation is reduced, but the method is management-, labor-, and capital-intensive.
- Tandem pond/tank
  - Expenses are increased with having both pond and tank systems, and fish have additional harvesting stress.

Chapter 6

Habituating Pond-Reared Fingerlings to Formulated Feeds in Ponds and Tanks

One of the difficulties associated with the production of yellow perch fingerlings is habituating (feed training) pond-raised fingerlings to formulated feeds. To raise perch intensively as a food fish, fingerlings must be trained to take commercial feeds. The availability of feed-trained fish is often a limiting factor to producing food fish.

For both pond and pond/tank culture, researchers at UW-Madison and several commercial producers have found a transition feeding period and size-grading can significantly improve feed training. Freeze-dried krill mixed with a conventional feed as a transition between live and commercial feeds have been used. Size grading to a very uniform size also has improved feed training success.

Habituating in Ponds

In fingerling pond culture, fry first feed on natural, live food organisms. After an initial period of relying completely on natural production of live feeds, a commercial feed is then added several times throughout the day. As the fry grow, larger feed sizes are offered until the fingerlings are harvested in the fall. Using this method of habituating fingerlings to commercial feed produces variable results. The fingerlings tend to exhibit large variation in size, and many do not habituate to the commercial feed. A primary reason for the variation in results is because the fish are widely scattered throughout the pond, which makes it difficult to present the food efficiently.

Because of the photopositive responses of perch fingerlings (see related information in Chapter 5), research has been done to use this reaction for feed-training perch. UW-Madison researchers produced perch fingerlings at 593,000/ha (240,000/acre) with >95% of them readily consuming formulated feed by harvest. Automatic feeders are installed near the perimeter of the pond adjacent to submerged lights, 30-45 feeding stations/ha (12-18 feeding stations/acre) with submerged lights (75 watt, 12 volt) and vibrating feeders attached to floats. The lights were turned on at night to concentrate the fingerlings around the feeders. After 10–15 nights of feeding, the fingerlings were aggressively consuming the formulated feed.

Habituating in Tanks

Fingerlings habituated in tanks can either be harvested from ponds and transferred to tanks, i.e., pond/tank culture, or reared entirely in the tanks. Tank habituation involves preventing access to natural sources of feed while offering fingerlings commercial feeds. Many producers have found that the use of krill as an initial diet greatly enhances the transition of fingerlings from live to dry commercial feeds. One hundred percent freeze-dried krill is offered to fingerlings for the first 1–3 d in tanks, and then over the period of several days it is blended with a traditional dry starter feed.

As with pond habituation, lighting has been used to successfully habituate fingerlings to commercial feeds; both in-tank (see Figure 5.2) and overhead lighting has been used successfully. In-tank lighting concentrates fingerlings under the feeders and may improve feed training success by as much as 25%. Researchers did not find significant differences in the habituation success of fingerlings 16.9, 32.5, or 42.6 mm (0.7, 1.3, or 1.7 in) TL; however, habituation did occur faster with the smaller fish. Also, in-tank lighting had a higher habituation rate than those reared using overhead lighting. This difference was probably because in-tank lighting reduces the disturbances that result from shadows and movements.

Another method used for habituating tank-cultured fingerlings has been used by MSU researchers. They have habituated fingerlings transferred from pond culture to tank culture by adding 3–5 feed-trained fingerlings per approximately 100 non-feed trained fingerlings resulting in rapid feed training to commercial diets. This observation is related to the inherent schooling behavior of these fish. Although unpublished, this method has worked on a laboratory scale and may help lower costs associated with purchasing tank lights.

Summary

- A challenging problem with yellow perch production is habituation of fingerlings to commercial diets. Just adding commercial feeds to ponds or tanks has not produced satisfactory results.
- Habituation success can be greatly increased using the photopositive responses of yellow perch fingerlings, either in ponds or tanks.
- Yellow perch <50 mm (≈20 in) exhibit a strong photopositive response behavior.
- The use of krill has been found to dramatically aid in the success of habituating fingerlings, regardless of initial fingerling culture method, to commercial feeds.
- Another method for habituating fingerlings in tanks is the addition of a few feed trained fingerlings to a group of non-feed trained fingerlings, which has led to some successful feed habituation in laboratories.

Constraints

- Availability of feed-trained yellow perch is often a limiting factor to food fish production.
- Some feed-trained fish may not accept commercial diets after being stocked into culture systems; reasons may include:
  - Not all fish obtained are feed trained.
  - Stress associated with harvest, transport to culture site, and acclimation or changing feed types may cause fish to go off feeds for prolonged periods.

Chapter 7

Grow-Out Methods

Yellow perch have been raised for grow-out production in the NCR by using flow-through systems, recirculating technologies, net pens, and ponds.

Flow-Through Systems

Flow-through aquaculture uses water in a one pass system, meaning water passes through a tank or series of tanks only once before being discharged. Past research funded by NCRAC has demonstrated that yellow perch can tolerate and thrive at the high loadings and densities needed for the economic production of fish in flow-through systems. Investigators at MSU demonstrated that the optimum loading rate for intensive culture of yellow perch is between 1.1 and 1.4 kg of fish/L/min water flow and that about 3.5 mg/L of DO is necessary to maintain optimal growth. The maximum rearing density of yellow perch is at least 85 kg fish/m^3 rearing space.

One advantage to using flow-through systems for perch grow-out is that they offer the potential of year-round growth if water can be maintained at constant temperatures near 20–22°C (68–72°F) and controlled lighting is used to maintain a photoperiod of 16-hr light:8-hr dark. If these conditions can be maintained, yellow perch can be expected to grow, on average, from a starting size of 10.0 g (0.35 oz) to a final size of 130.0 g (4.6 oz) in 1 year, or an average of about 0.33 g/d (0.01 oz/d). Another advantage to flow-through systems is that constant water temperatures do not permit normal reproductive development (see Chapter 3), which is advantageous because yellow perch normally mature sexually before they reach a marketable size, and the gonadal growth that occurs with sexual maturity results in a 10–25% decline in fillet yield.

Figure 7.1. Raceways (photo by Chris Starr).

In the NCR, ground water temperatures normally range from 4–7°C (39–62°F), which is too cold to permit good yellow perch growth. Therefore, flow-through systems for yellow perch in this region require a cost-effective method for heating large volumes of water, e.g., thermal effluent from power plants.

Presently, there are no commercial yellow perch operations in the NCR using a flow-through system incorporating power plant effluent. The most successful of these ventures was Bay Port Aquaculture, Inc., which was in operation for more 10 years in Michigan. However, nearly all fish died when the power plant operators incorrectly applied a chlorine treatment to sanitize their cooling systems. There have been other attempts to use water sources from power plants in the U.S. but for a variety of reasons, including the consequences of periodic plant shutdowns, such systems have not been successful.

Another problem associated with flow-through aquaculture is obtaining an effluent permit to discharge water into streams or lakes. The United States Environmental Protection Agency and/or state natural resource agencies set limits on nutrients and solids that can be discharged into public waters. Many waters have already reached or passed these limits; thus, obtaining a discharge permit into these bodies of water is nearly impossible.

Recirculation Systems (RAS)

Recirculating systems are fully-contained systems; water is only added at about 10% of the total volume per day. Typical RAS include aeration, sedimentation, mechanical filtration, biological filtration, pH control, and water sterilization. The capability of raising yellow perch to market size in RAS was demonstrated more than 20 years ago. Like flow-through systems, RAS offer the potential of year-round fish growth and limited reproductive development. Unlike flow-through systems, however, there is no need to continuously heat large volumes of flowing water.

The growth of yellow perch in RAS is similar to that in flow-through systems (see above). Yellow perch are moderately tolerant to low levels of DO (levels as low as 3.5 mg/L do not impact growth) and high levels of ammonia (this topic is discussed in further detail at the end of Chapter 9). These factors are major determinants of the production levels that can be expected in a recirculating system.

Other important factors that determine production levels are specific to the system components being used. The major system-related factors that limit the productivity of yellow perch RAS are the ability of components to remove fine particulates (suspended solids), ammonia, and nitrite. The temperature requirements of yellow perch allow for adequate but not optimal nitrification by using standard biological filtration for the removal of ammonia and nitrite, i.e., biological filtration is temperature sensitive and is more effective at temperatures higher than those tolerated by yellow perch. Presently, the production levels that can be expected from various RAS operations are not known.

Initial capital investments for RAS have been high because of the considerable costs associated with system design and construction. Studies have shown that small-scale recirculating models are not profitable, whereas historically, large-scale systems have not been economically feasible for yellow perch producers. High start-up costs, system operation costs, labor costs, competition from foreign markets, high cost of available feed trained fingerlings, and inefficient farm operation have all been reasons why commercial producers using RAS are a challenge for RAS operators. Thus, economically feasible techniques using large-scale RAS need to be developed for perch aquaculture.

In the 1970s, more than 10 yellow perch farms using RAS became operational. All of these eventually closed because they were not economically viable. In the past 15 years, more than 20 new operations began production, but many of these have already closed for similar reasons.

Net Pens

Net pen culture consists of rearing fish confined in a pen in an open body of water. By using this method, culturists can gain some of the benefits of both pond and tank culture. Ambient environmental conditions can be used to provide light and heat to the water, saving the commercial producer the cost of providing these resources. The pens allow for fish to be segregated into different size classes for better management.

Several small-scale demonstration projects have focused on raising yellow perch in net pens. These studies have shown that stress and disease problems become apparent when water temperatures exceed 21–22°C (70–72°F). Accordingly, given the normal surface water temperatures in the NCR, net pen culture of yellow perch may not be feasible except at sites having a large supply of cold, well-oxygenated ground water to reduce maximum summertime temperatures.

Ponds

Pond culture consists of stocking fingerlings into earthen ponds and allowing ambient environmental conditions to provide heat and light. Fish are supplied with a commercial feed and are harvested once they reach market size. Pond culture has been commonly used for yellow perch aquaculture production throughout the NCR. Field trials conducted in ponds at Pleasant Valley Fish Farm, Nebraska, in collaboration with the University of Nebraska-Lincoln, clearly demonstrated that research-based production strategies can be used to culture both fingerling and food-size perch under commercial conditions. Ponds were stocked at high densities (ca. 2,500,000/ha; 1,011,750/acre eyed-eggs or fry) and intensive feeding methods were used. Field trial data collected at Pleasant Valley Fish Farm indicated that yellow perch can be raised in ponds from eyed eggs to fingerlings having mean weights of 11.0–12.8 g (0.39–0.45 oz) within one growing season at production levels as high as 1,216–1,525 kg/ha (1,085–1,360 lb/acre). Age 1 fingerling perch can be raised in one growing season to food-size fish having weights averaging 135 g (4.76 oz), at production levels at least as high as 4,740 kg/ha (4,229 lb/acre).

Pond culture has been popular with yellow perch producers because of low initial investment and operational costs compared to flow-through or RAS. As of 2003, approximately 10 yellow perch culturists in Nebraska and Wisconsin produce food-size fish in ponds; however, it is unknown whether these enterprises are profitable. In recent years, an incrasing number of Ohio producers have cultured yellow perch.

There are possible problems associated with pond culture of yellow perch in the southern portion of in the NCR. For instance, Kansas, Missouri, and Nebraska have an average monthly ambient temperature at 22ºC (72ºF) or higher for a maximum of 3 months of the year. Under high-density conditions (RAS, tank, net pen) yellow perch do best at 22ºC (72ºF) or less. Under typical low density pond produciton conditions, optimum growth occurs at 24–25ºC (75–77ºF), with 27ºC (81ºF) being problematic. Thus, optimum grow-out conditions may only exist 3 months or less per year in these states.

Lethal upper temperatures for yellow perch have been reported to range from 26–30ºC (79–86ºF). States in the southern region, except Kentucky and Virginia, have exhibited ambient temperatures at or above the upper lethal threshold through part of the year, making yellow perch pond grow out in the southern region less feasible. As with all potential aquaculture species; genetics, strains, culture conditions, and feeds alter growth rates under different climates.

Fingerlings stocked into ponds under natural conditions typically have taken 2 to 3 years to reach market size for fish food in the NCR. In addition to questionable growing conditions in southern NCR states, pond-reared fish in southern and northern states are subjected to predation and cannot be efficiently treated for prevention and control of diseases. Additional problems with pond culture include yellow grub infestation as well as other parasites and diseases. These problems may be circumvented with RAS operations. More information on diseases and therapeutants is contained in Chapter 8.

Researchers at OSU have investigated the effects of grading yellow perch by size in the second year of food-fish production. They graded the fish into three size groups (mean initial size): small (5.3 g [0.2 oz]), large (18.3 g [0.6 oz]), and unsorted (11.3 g [0.4 oz]) and stocked them into 0.1-ha (0.2 acre) ponds. Based on the percentage of fish reaching market size among the large (65%), ungraded (53%), and small (35%) groups, the researchers suggest that yellow perch should be selectively graded by at least the end of one year of intensive culture to increase the number of individuals with the potential to reach market size.

In addition to grading, female yellow perch have been shown to grow faster and attain larger sizes than males at the onset of sexual maturation and gonadal development, which can occur in the first year of life. Studies on yellow perch as well as other cultured species such as flatfish and Pacific salmon have shown a strong correlation between sexual maturation and reduced growth, food consumption, and food use efficiency. Methods for developing all-female stocks of yellow perch are currently being studied and are discussed in Chapter 10.

Comparison of Key Grow-Out Parameters and Production Costs Among Grow-Out Systems

In a recently completed NCRAC yellow perch project, one objective was to "develop or investigate reliable, profitable, and sustainable production systems to rear feed-trained yellow perch to market size." Researchers compared key production values and developed cost of production budgets for raising feed-trained fingerlings reared to market size (defined as 150 g or 1/3 lb) in various culture conditions:

- 0.04- to 0.61-ha (0.1- to 1.5-acre ponds in southern Wisconsin over a 1- or 2-yr grow-out cycle (UW-Madison)
- Tanks or cages supplied by the same deep reservoir water source that never exceeded 21°C (70°F) (OSU/Hocking College)
    - o 2,044-L (540-gal) flow-through circular tanks
    - o 3,785-L (1,000-gal) flow-through raceway tanks
    - o 3,028-L (800-gal) net pens placed in ponds
- RAS (UW-Milwaukee)
    - o An in-house RAS (25-m^3 [6,604 gal])
    - o Two commercial RAS facilities (29 m^3 [7,661 gal] or multiple 36 m^3 (9,510 gal]) in Wisconsin

Key production parameters for each of the system types are presented in Table 7.1. Growth per day was lowest in the RAS production facilities, but third highest per year because of year-round growing conditions. As might be expected, growth per year was lowest in ponds because of the seasonal, 170-d growing season. Feed conversion was poorest in fish reared in net pens followed by flow-through circular tanks and RAS.

Table 7.1. Comparison of key production parameters of yellow perch grown to market size in different culture systems in the NCR.

System	Growth		Survival	FC[1]
	g/d	g/yr	%	
Flow-through circular tanks	0.44	87.9	73.0	1.9
Flow-through raceway tanks	0.36	72.4	90.7	1.5
Net pen	0.46	91.1	72.8	2.3
Open pond	0.34	57.2	83.5	1.5
RAS	0.23	83.6	90.0	1.9

[1] FC, feed conversion, feed/gain.

Survival and feed conversion were better in flow-through raceway tanks than in flow-through circular tanks. These data and others were used to compute break-even costs for yellow perch grow out.

Break-even costs for yellow perch production are presented in Table 7.2. Costs were highest for RAS facilities, essentially 2× or 3× that of 1- and 2-yr pond culture. Flow-through and net pen costs were intermediate between the other two systems.

Fingerling costs, which accounted for a substantial portion of the total cost of production per system, were highest for the 1-yr pond (76%) followed by the 2-yr pond (45%), net pen (41%), flow-through circular tanks (32%), RAS (30%) and flow-through raceway tanks (27%); percentage of costs are reflective of relative costs of fingerlings needed for production within that particular system and culture period.

In addition to lower fingerling costs, other costs were lower the pond production. Their economic data were based on a farm consisting of eighteen 0.61-ha (1.5-acre) ponds, stocking densities of about 91,426 fish/ha (37,000 fish/acre) based on survival rates and growth of 3,364 kg/ha/season (3,000 lb/acre/season), which maintained water quality. For 2-yr pond grow out, they stocked 7.5-cm (3-in), 5-g (<0.25-oz) fish purchased at a price of $0.03/cm ($0.07/in) at the beginning of year 1. The fish gained 53 g (1.9 oz) and had 89% survival. After overwinter in ponds, 75% of the females spawned, losing 19% of the total pond weight in the spring. In year 2, fish gained 69 g (2.4 oz) and had 79% survival.

Mean weight at the end of 2 years was 115 g (4 oz). It is important to point out that these data were collected for southern Wisconsin and may vary by location. OSU/Hocking researchers were able to maintain temperatures <21°C (70°F) by using flow-through water from a deep reservoir, which increased costs. Costs associated with RAS facilities also may vary significantly based on system design and operating costs.

Table 7.2. Break-even costs for yellow perch grown to market size in different culture systems in the NCR. Unless otherwise noted, break-even cost for a particular system includes all relevant costs.

System	$/kg	$/lb
Flow-through circular tanks	14.99[1]	6.81[1]
Flow-through circular tanks	11.37[2]	5.16[2]
Net pen	10.74[3]	4.87[3]
Open pond, 1 yr	6.49	2.95
Open pond, 2 yr	5.70	2.59
RAS	15.13[4]	6.86[4]

[1] $10.25/kg ($4.66/lb) + fingerlings @ $4.74/kg ($2.15/lb).
[2] $8.28/kg ($3.76/lb) + fingerlings @ $3.09/kg ($1.40/lb).
[3] $6.35/kg ($2.88/lb) + fingerlings @ $4.39/kg ($1.99/lb).
[4] $12.61/kg ($5.72/lb) + 20% for estimated capital costs.

Summary

- Flow-through grow out may be proven feasible in regions having relatively warm (>18ºC [64ºF]) ground water or geothermally heated water, or in conjunction with power plants or other waste heat producing industries that are operated in a manner that prioritize aquaculture.
- Future development of RAS needs to include cost-effective designs as well as appropriate management guidelines.
- The development of flow-through and net pen systems may be limited in the region by resource management agencies and environmental concerns.
- Presently, pond culture systems seem to be most cost effective.

Constraints

Flow-Through Systems

- Difficulty in obtaining discharge permits

RAS

- Recirculation systems provide more environmental control for commercial operators than pond, netpen, or flow-through culture. However, recirculating systems also have higher start up, maintenance, and operating costs.

Net Pens

- Increased stress and disease issues.
- Limited to waters with a large supply of cold well-oxygenated groundwater to reduce maximum summer temperature.

Pond Culture

- The specific geographic region best suited to raising yellow perch in ponds needs to be determined.
- The documentation of production parameters, e.g., fish growth rates and the biomass per surface acre that can be produced, should be a high priority. Subsequently, testing various strategies known to affect the production efficiency of raising other fish species in ponds, e.g., feed management practices, aeration/water circulation, water addition, frequency of harvest, needs to be conducted.
- Pond fingerling and grow out may meet competition from southern states because of their longer growing season, but high summer water temperatures may limit this expansion.

Chapter 8

Disease and Health Management

It has long been recognized that diseases of cultured fish may impose major limitations toward achieving the full potential of a productive and profitable aquaculture project. If yellow perch are subjected to stressful culture conditions such as extremely high stocking densities, nutritionally incomplete feeds, inadequate feeding regimens, or relatively poor water quality, fish will spend a considerable portion of their energy adapting to suboptimal environmental conditions. As a result, cultured yellow perch are subjected to continuous, yet variably intensive, stressors that can substantially increase their susceptibility to infectious or noninfectious diseases. Indeed, it is impossible to separate disease prevalence, intensity, and impact from poor environmental quality. The situation becomes more complex if the water used in aquaculture is directly or indirectly connected to waters where wild yellow perch are a part of the fauna.

The majority of pathogens affecting yellow perch are endemic to natural waters where, under natural conditions, they typically cause negligible harm. However, when obligate or facultative pathogens find their way into an aquaculture environment, they may cause significant losses. The objective of this chapter is to emphasize important aspects of the fish/pathogen/environment interactions and to provide yellow perch farmers with basic information about diseases of this particular species. This information is needed to develop a strategy to avoid the occurrence of these diseases and to control and minimize losses if a disease emerges. A successful health management plan designed for farmed yellow perch relies upon an integrated approach of disease prevention concepts and sound management practices. Designing a well-balanced health plan requires thorough planning and knowledge of both the yellow perch and its diseases. It is advisable to consider fish health implications when selecting an aquaculture location and facility design. Yellow perch, like all other cold-blooded animals, are vulnerable, often in a fatal way, to extremes in temperature, fluctuations in temperature, excessive or insufficient dissolved gasses, and presence of chemical pollutants. Therefore, the cornerstone of any health management plan is to minimize environmental fluctuations. The second most critical component in the health plan is to prevent the introduction of pathogens, infected or carrier fish, and contaminated equipment into the facility. If disease occurs, the plan should provide means to reduce its severity and prevent its spread. In general, health management of cultured yellow perch involves the following elements:

1. **Choice of Location**
   Selecting the optimal site for an aquaculture facility is paramount to its success. The quality of both soil and water should be the primary factors for location consideration.
   - Soil must contain the proper clay in amounts that prevent leakage in ponds.
   - Pond soil and water sources must be free of toxic chemicals, e.g., pesticides and herbicides.

- Water volume must be commensurate with the size of the operation, because crowded fish are more prone to recurrent infections.
- Water hardness, pH, and other water chemistry-based parameters must be optimal for yellow perch farming operations.
  - General water quality recommendations for aquaculture (concentrations, except pH, are in mg/L) are in Table 8.1.

Table 8.1. Suggested critical culture parameters for yellow perch.

Parameters	Critical level (mg/L or ppm, except pH)
DO	3.5-saturation
Carbon dioxide	<5.0
Total hardness	50-400
pH	6.5-9.0
Calcium	10-160
Phosphorus	0.01-3.0
Hydrogen sulfide	0
Ammonia (NH_3)	<0.0125
Nitrite	<1.0

- It is preferable that the water source does not contain free-ranging fish because they may be a continuous source of pathogens to the cultured fish.
- It also is preferable that snails, fish-eating birds, and other important intermediate vectors of yellow perch parasites be controlled.
- If surface water must be used for indoor systems, it should be disinfected with ozone or ultraviolet light.

2. **Quarantine for New Fish Arrival**

Appropriate fish quarantine practices will prevent the inadvertent introduction of diseases by newly acquired stock into the entire aquaculture facility.

- Fish or eggs should be purchased from farms with a known history and a certificate verifying a disease-free status. This certificate should be signed by a certified fish health professional and should accompany every shipment.
- Newly arrived fish should be isolated from other fish already contained within the facility because they may carry pathogens, even if apparently healthy.
- A quarantine area should be designated in the facility that is separate from other fish-rearing areas. Such isolation also requires a clean water supply.
- The fish should be kept separated for up to 40 days, with observations of their behavior, feeding, and general appearance noted regularly.
- Once fish have been introduced to a quarantine tank, no new fish should be added until the quarantine period is complete.

3. **Know the Fish Health Concerns of Each Life Stage**

Knowing the precautions to take to avoid disease for each life stage, the sensitivity of that life stage to various stressors, and the type of diseases that may occur, enables the yellow perch farmer to substantially reduce a disease's impact. In particular, eggs need to be handled in the following manner:

- Before eggs are brought to the facility for incubation, all involved equipment should be washed with hot water, vigorously scrubbed, disinfected with a mild bleach solution, and subsequently rinsed with clean water.
- Egg disinfection minimizes the risk of pathogen transfer from brood fish to

progeny. Although yellow perch egg ribbons are very delicate and susceptible to breakage, egg disinfection may improve the overall hatching rate. Active iodine (polyvinylpyrrolidone iodine or PVP iodophor) is the disinfectant of choice for eggs of various fish species. It is most commonly used for salmonid eggs, but preliminary tests should be conducted to determine the safe and effective iodophore concentration for yellow perch being cultured. A general treatment follows that should be tested on a small batch of eggs to ensure safety and efficacy under individual conditions.

- The pH of iodophor product solutions must be between 7.2 and 7.4. At a lower pH, the toxicity for eyed and newly fertilized eggs increases, and at a higher pH, the disinfection efficacy decreases.

- Adjust the pH of the solution to between 7.2 and 7.4. If the pH is high, remove a 3.78-L (1-gal) subsample of the iodophor solution and, with a dropper, add 1 N HCl. Count the number of drops necessary to lower the pH into the acceptable range. Then, multiply the number of drops by the total number of gallons of iodophor prepared. This approach provides an estimate of the total number of drops of HCl necessary to lower the pH. Initially, add half the number of drops and mix thoroughly, then retest the pH. Repeat again with half of the remaining drops and repeat testing until the pH is adjusted properly. If the pH is low, add NaOH according to the same procedure as described above. If the alkalinity is low (<75 mg/L), which means that the buffering capacity of the water is poor and rapid changes in pH are possible, add sodium carbonate at a rate of 100 mg/L.

- Iodophor solution should be applied at 100 mg/L for 10 min or 50 mg/L for 30 min. For convenience, these dosages also can be measured as 10 mL/L or 5 mL/L (1.3 fluid oz or 0.6 fluid oz/gal of water, respectively). Keep in mind that 14.8 mL (1 tbsp) equals 0.5 fluid oz. The solution should be used only once.

- Rinse eggs gently, but thoroughly, in clean water after disinfection.

- Arrange the egg handling program to ensure that disinfected eggs do not have subsequent contact with contaminated equipment, water, or personnel.

- Developing eggs are sensitive to light, shock, and fungal infections. Eggs must be checked at regular intervals for mortality and presence of fungus. Ribbons with a large portion of dead eggs should be removed.

• Diluted iodophors also can be used to disinfect work surfaces, utensils, nets, and other equipment used during the egg-taking process. Disinfected items must be subsequently rinsed in clean, uncontaminated water.

• During incubation, eggs are particularly susceptible to fungal infections, the most common of which is saprolegniosis. *Saprolegnia* spp. (also called water molds) grow at temperatures ranging from 0–35°C (32–95°F) but seem to prefer 15–30°C (59–86°F). Poor water quality, high organic loads, and the presence of dead eggs predispose eggs to a saprolegniasis outbreak. Saprolegniasis is manifested as fluffy tufts

of cotton-like material on affected fish eggs.
- A 15-min flow-through treatment of formalin at 25 mg/L has been shown to be very effective in controlling fungal infections on eggshells of fish.

4. Know the Common Diseases of Juveniles and Adults

Yellow perch, particularly under culture conditions, are vulnerable to infection by several pathogenic parasites, bacteria, viruses, and fungi. It is necessary for the fish producer to be familiar with signs of health and disease. Although yellow perch have been cultured since the late 1800s, reports on their diseases are scarce. There alos are many diseases that are caused by noninfectious agents, e.g., skeletal anomalies and gas supersaturation. The following is a synopsis of the major diseases and disease signs observed in yellow perch.

Viral diseases Lymphocystis disease: Lymphocystis disease, caused by an iridovirus, is a chronic, benign, skin infection that is seldom lethal. This disease has been known to affect hundreds of fish species, including wild and cultured yellow perch. Disease signs include whitish nodules on the skin, fins, and eyes (Figure 8.1), which are caused by the enlargement of individual fish cells. These nodules typically slough after varying periods. In severe cases, most of the fish body can be affected. The disease is common during the spawning season and is typically self-limiting. However, epizootics (affecting many fish at the same time) have occurred occasionally.

Figure 8.1. Typical lymphocystis disease nodule (photo by Mohamed Faisal).

Several other viruses have been reported from other perch species in Europe and Australia, but none have been reported that specifically affect the yellow perch.

Bacterial diseases Bacteria associated with fish can be categorized into normal flora causing no harm; primary pathogens that cause disease even in healthy fish; and facultative pathogens that cause diseases only in stressed, immunocompromised fish. Most bacterial diseases affecting yellow perch are caused by facultative pathogens, illustrating that minimizing stress is the first step to controlling the disease and preventing mortalities. In general, fish infected with bacteria can present with one or more of the following forms.

Difficulty in breathing and changes in gill appearance:
This form is often encountered in perch infected with the Gram-negative filamentous bacteria known as *Flavobacterium columnare* (columnaris disease) or its relative *Flavobacterium branchophilum* (bacterial gill disease). Both infections are most common in yellow perch fry and fingerlings. The incidence and intensity of the two infections are affected by water temperatures and are typically highest at 20°C (68°F).

Affected fish typically gather around water inlets, exhibit increased opercular movement, and have copious amounts of mucus covering their head and gills. As the disease progresses, whitish spots become abundant on the tips of the

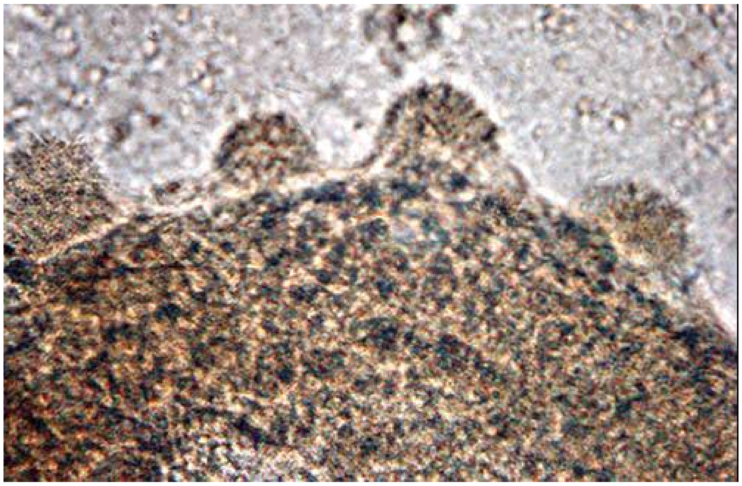

Figure 8.2. Aggregation of *Flavobacterium* spp. on tips of gill filaments of an infected fish (photo by Mohammed Faisal).

gill filaments, and eventually, some of these filaments typically slough off. Fungal masses often grow on the remaining gill filaments, which are usually dull brown. If a smear of the affected gills is examined under the microscope, aggregations of filamentous bacteria can be observed (Figure 8.2).

Figure 8.3. Shallow ulcer caused by Pseudomonas spp. (photo by Mohamed Faisal).

Hemorrhages and ulceration of the skin and fins: Several bacteria can directly cause shallow or deep ulcers (Figure 8.3), scale sloughing, fin rot, or fin erosion.

These bacteria include *Aeromonas hydrophila*, *Aeromonas salmonicida*, *Pseudomonas flourescens*, and *Flavobacterium* species. Skin ulcers and hemorrhages also can be a sign of an overall systemic bacterial infection.

Distended belly and bulging eyes (exophthalmia): These signs are typical of a systemic bacterial infection, in which bacteria can be found ubiquitously in the affected fish. For example, infections associated with *Aeromonas* spp., *Pseudomonas* spp., *Vibrio* spp., and *Flavobacterium* spp. can cause a distended belly because of leakage of blood from blood vessels and the accumulation of body fluids in the abdominal cavity and under the eyes.
Hemorrhages in internal organs: Small, pinhead-sized hemorrhages are found on the surface of internal organs, the swim bladder, or a combination because of systemic bacterial infections. Often, the concurrent enlargement of the spleen and the kidney occurs.

Nodules in internal organs: Minute nodules can be found in the spleen, liver, and kidneys of yellow perch infected with Mycobacterium spp. Several species of this bacterium have been identified in wild yellow perch populations, such as Mycobacterium chelonae. Care should be taken when handling affected fish, because some Mycobacterium spp. that are pathogenic to fish can infect humans as well.

Internal tumors: Most recently, a yellow perch with a large tumor that occupied a major portion of the abdominal cavity was necropsied (Figure 8.4A). Analyses demonstrated that this tumor was caused by a minute, intracellular, rickettsia-like bacterium (Figure 8.4B).

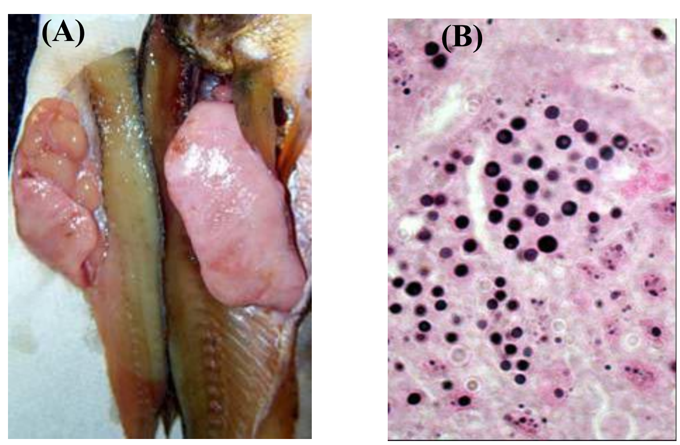

Figure 8.4. Tumor in a yellow perch (A) caused by a rickettsia-like bacteria (B) (photo by Mohamed Faisal).

Water mold infection (saprolegniosis) Saprolegniosis is the most common infection of cultured yellow perch and its eggs. The molds are opportunistic organisms that feed on decayed organic material. Infection occurs if the fish immune system is compromised because of overcrowding, abrupt changes in water temperature, or concurrent bacterial infections causing skin wounds, gill wounds, or both. Water mold infection is primarily characterized by the presence of superficial, cottony growth on the skin, gills, or both. These lesions can progress to involve other areas of the body.

Diseases caused by parasites Many parasites associated with yellow perch are normal fauna that cause little or no harm to the fish. Under culture conditions, however, these parasites may be present in unnaturally high amounts and cause serious damage. In other instances, parasites cause damage to vital organs, such as the eyes, gonads, and heart. Such parasites must be eradicated if found in the culture facility.

Figure 8.5. A *Trichodina* spp. from a skin scraping of an affected fish (photo by Mohamed Faisal).

Parasites, such as some protozoa (single-celled parasites) or monogeneans, have direct life cycles, meaning the parasite spends its entire life in or on one host. Most parasitic worms have indirect life cycles, in which a parasite spends different life stages in different hosts. Hosts in which the sexually mature worms live are called final hosts, whereas immature worms develop in intermediate hosts.

In general, yellow perch affected with parasites can exhibit one or more of the following forms:

- Skin ulcers and fin erosions. Several protozoa cause skin irritation, scale loss, and often shallow ulcers. These protozoa include the motile ciliates *Trichodina* spp. (Figure 8.5), *Chilodonella* spp., and the nonmotile ciliate *Epistylis* spp. In addition to the damage they cause to skin cells, they may disrupt normal skin functions, such as oxygen exchange and osmoregulation. Also, some parasitic copepods anchor themselves to the skin or gills, causing ulcerations at sites of attachment.
- White spots. This condition is caused by the giant ciliated protozoan *Ichthyophthirius multifiliis* (Figure 8.6). The protozoan burrows into the skin and gill tissue and can cause severe losses in yellow perch fingerlings.

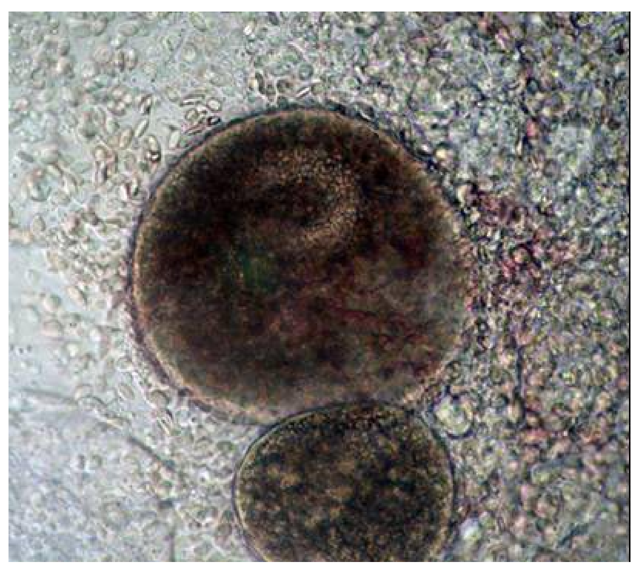

Figure 8.6. *Ichthyophthirius multifiliis* from a skin scraping of an affected fish. Notice the large cell size and the horseshoe-shaped nucleus (photo by Mohamed Faisal).

- Yellow grub and black spot. Digenetic trematodes, whose final hosts are fish-eating birds, e.g., herons and bitterns, or mammals, require two intermediate hosts for their development. Most yellow perch trematodes use molluscs as the first intermediate host, whereas yellow perch are the second intermediate host. The developing worm penetrates the skin and fins of the yellow perch and encysts in the skin and muscular tissue (called encysted metacercariae). When the yellow perch is eaten by a bird, the worms excyst and mature in the throat of the bird. Eggs wash into the water from the bird's mouth when feeding. Encysted metacercariae of *Clinostomum* spp. are known as yellow grubs and are common in both yellow perch fingerlings and brood fish. These metacercariae measure up to 4 mm (0.16 in) in diameter. The skin pigment melanin often surrounds metacercarie of other trematodes, e.g., *Neascus* spp., giving them a black discoloration. Heavy infestations can accumulate, with the fish becoming unsightly and of low market value (Figure 8.7).

Figure 8.7. A yellow perch infected with larval trematodes (black spots) (photo by Mohamed Faisal).

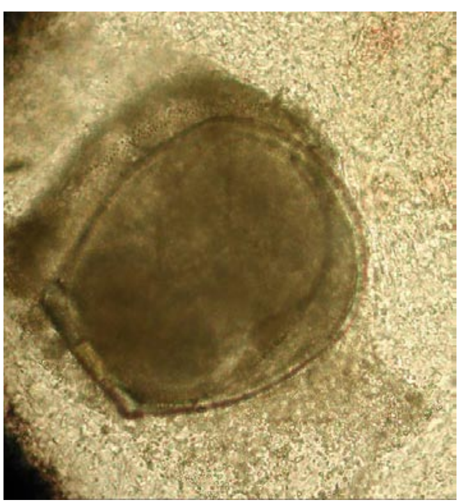

Figure 8.8. Glochidia parasitizing on the gills of a yellow perch (photo by Mohamed Faisal).

- Difficulty breathing. Heavy parasitism with protozoa can lead to damage of gill cells, whose primary function is to extract oxygen from the water. The monogenean *Cleidodiscus* spp. is reportedly able to cause skin and gill irritation in the yellow perch (Muzzall 1995). When gill infections are heavy, respiratory problems due to severe gill tissue damage may occur. Glochidia, the parasitic larval stage of certain clams, encapsulate in the gills of perch, subsequently causing severe damage.

Figure 8.9. Larval nematode (*Eustrongylides* spp.) in the body cavity of a yellow perch (photo by Mohamed Faisal).

- Abnormal erratic behavior and brain cysts: Cysts or abnormal behavior are common in yellow perch in the Great Lakes basin and are primarily caused by the protozoan *Myxobolus neutrophilus*. It is thought that this protozoan requires a tubificid worm to complete its life cycle. In the yellow perch, the protozoan forms aggregations in the brain.

- Cataracts. Larvae of trematodes (*Diplostomum* spp. eye flukes) infect the eyes and lenses of yellow perch. When infections are severe, the lens turns white and sight may be lost.

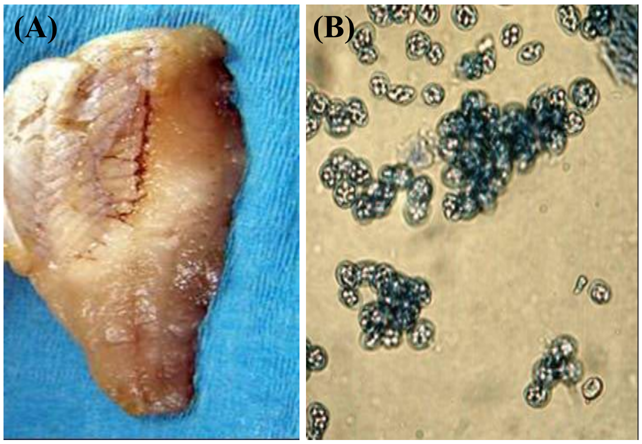

Figure 8.10. (A) Fillet of a yellow perch infected with *Heterosporis* spp. (B) Parasite in tis developmental stages. (photo by Mohammed Faissal).

- Red worms in the body cavity. The larval stages of the nematodes *Eustrongylides tubifex* and *Philometra cylindracea* often encyst in the body cavity of yellow perch. The worms are pink to red and reach up to 10.2 cm (4 in) in length (Figure 8.9). When the fish dies, the worms move out of the cysts and migrate in the body cavity.
- Opaque, whitish areas in fillets. Originally thought to occur only in Europe and Asia, most recently, infection with the microsporidian protozoan *Heterosporis* spp. has emerged in the United States. An explanation as to why the infection has spread has not been formulated. Fillets of infected fish exhibit opaque areas in the dorsal and lateral musculature and around the anus (Figure 8.10A). Affected muscles are stuffed with parasitic stages (Figure 8.10B).

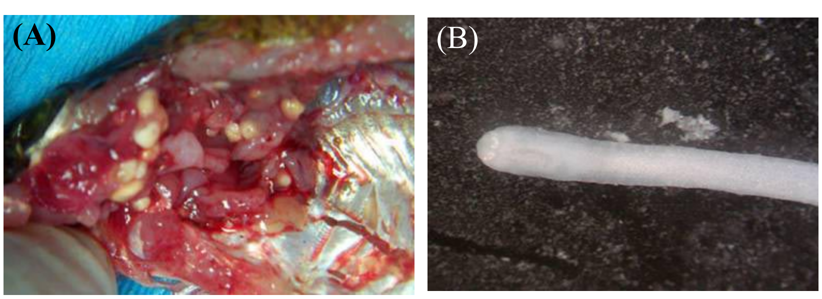

Figure 8.11. (A) Numerous cysts in liver and body cavity. Larval *Triaenophorus nodulosus* extracted from one of the nodules (B) (photo by Mohamed Faisal).

- Liver nodules. Larval stages of the cestode *Proteocephalus* spp. and the spiny worm, *Neoechinorhynchus cylindratus*, form small nodules in the livers of affected fish. Larvae of the cestode *Triaenophorus nodulosus* (Figure 8.11A) form relatively large nodules in the livers of yellow perch that can occupy up to 70% of the liver mass (Figure 8.11B).

Figure 8.12. Radiograph of a yellow perch with vertebral column deformities (photo by Mohamed Faisal).

- Tumors. Over the past five decades, more than 20 tumor types have been identified in yellow perch (Budd et al. 1975). Gonadal tumors often manifest as an epizootic form. Such tumors are very low in prevalence and are restricted to older fish.

Noninfectious diseases These diseases fall under two major categories: nutritional imbalances and environmental disturbances.

- Nutritional imbalances. Nutritional excesses, such as diets high in fat, can cause severe metabolic disturbances known as fatty liver syndrome. Imbalanced diet with regard to quality, quantity, or both can lead to severe skeletal deformities (Figure 8.12).

- Environmental disturbances. High ammonia, high carbon dioxide levels, improper pH, fluctuating temperatures, abnormal oxygen concentrations, and presence of herbicides, pesticides, and insecticides are all capable of causing problems for yellow perch. Gas supersaturation in the culture water may cause chronic stress in the fish or overt clinical signs of air bubbles within the gills, fins, and skin tissue of the fish. In addition, the white-tail syndrome is noted with these fish. This common stress-mediated problem most often is seen where fish (usually fingerlings) are harvested from ponds when temperatures are too high, causing caudal circulatory shutdown and high initial mortalities, followed by what seems to be a permanent inability of survivors to handle subsequent stressors. Presently, a large-scale study has been undertaken in Wisconsin to address this concern.

5. **Know What Should be Done to Prevent Eruption of a Disease**
   The best approach in managing fish health is to implement an efficient prevention program specifically designed for each facility.

- The single most important factor for disease prevention is water quality. Water quality can be achieved by controlling unionized ammonia, nitrites, presence of pesticides or heavy metals, DO, high concentrations of CO_2, rapid changes or extremes in pH or water temperatures, low alkalinity, general hardness, and total suspended solids (TSS).
- Do not handle yellow perch if water temperature exceeds 27°C (80°F).
- Fish with a history of disease resistance should be used when available.
- Only certified specific-pathogen free fish from known sources should be allowed to enter the facility.
- Raceways and tanks should be kept clean by brushing and removing fecal material and dead fish daily.
- All equipment should be disinfected routinely. If the same equipment must be used in several tanks, it should be soaked in an iodophor disinfectant (usually 10 min at 100 mg/L [ppm] and then rinsed for a sufficient time before it is used on different groups of fish.
- Separate equipment, such as nets and brushes, should be kept between raceways, ponds, and buildings to ensure that each culture unit is an isolated unit with respect to disease transmission.
- Infections involving tenacious pathogens, such as *Myxobolus neutrophilus*, require all fish from infected ponds be destroyed. Infected ponds then must be drained, allowed to dry completely, and disinfected with quicklime (calcium oxide) or chlorine (calcium hypochlorite).
- Control of disease is best achieved by reducing the organic load in ponds. Nutrient-rich waters are conducive to algal blooms and large numbers of microorganisms, which serve as the primary food source for many protozoa.
- The most practical way to prevent parasitic worm infections is through the elimination of the snails that serve as the first intermediate host. Elimination can be achieved by the use of approved molluscicides or algaecides (algae are primary dietary items for snails).
- Replacing old brood fish with younger fish for reproductive purposes before they become heavily parasitized can aid in the reduction of parasitic worm infections.

- Segregating fish according to species and age reduces transmission of pathogens.
- It is imperative to have a perch diet that is reliable and of excellent quality. Several researchers have shown that a deficiency of a specific element can increase disease susceptibility.
- Unnecessary handling of the fish should be avoided whenever possible.
- Water flow rate and aeration should be balanced and continuously monitored.
- Fish behavior should be monitored, particularly food intake and swimming behavior.
- Accurate records should be kept of mortalities and if the daily mortality rate exceeds 0.05%, a fish health professional should be consulted.
- Proper biosecurity protocols for all personnel should be established, implemented, and validated regularly.

6. Know the Basics of Disease Control

- First and foremost, a grower should keep accurate daily records for both morbidity (percentage of fish showing disease signs) and mortalities.
- A disease ideally should be recognized before it reaches its peak and mortalities start
- Indeed, morbidity, not mortality, should be used as a primary indicator of fish health. Thus, close, daily observations are a necessary component of proper husbandry practices.
- In addition, regularly scheduled health examinations of the captive stock, even when no health problems are suspected, are highly recommended. Valuable information can be gained from learning what is normal for the particular species and life stage.
- Depending on the size of a facility, a small laboratory can be of great help in monitoring fish health and in judging the efficacy of treatment.

Equipment needed for basic fish health examinations

- Compound microscope
- Microscope slides
- Microscope slide coverslips
- Scissors and forceps

Physical examination procedure

- If possible, fish should be observed alive. Abnormal swimming and other altered behaviors should be noted, because specific behaviors can be associated with particular problems. These noted behaviors can greatly enhance the rate of diagnosis.
- When deciding whether to use anesthetics to keep the fish still for an external examination, it is important to realize that anesthetics may adversely affect the external flora, including any parasites that are present. Please note that there is a 21-day withdrawal period before fish treated with tricaine methanesulfonate (Finquel®) can be consumed.
- External surfaces of the fish, including the fins, mouth, and under the operculum, should be thoroughly examined. Previous observations of normal fish during the production cycle greatly assists in distinguishing pathological changes.
- Gill and skin scrapings using the microscope slide coverslips should be made and smears examined under the microscope for the presence of external parasites.
- A drop of clean water should be placed on the microscope slide. With the coverslip at a 90° angle to the surface of the fish, apply firm pressure and scrape from head to tail, at the inner base of the pectoral and pelvic fins, caudal peduncle, and gills. Alternatively, scrape around areas of external lesions.
- A coverslip then should be placed on the moistened sample.

- To scrape the gills, the operculum (gill cover) should be lifted to facilitate access to the filaments of the gill. Apply the coverslip firmly at a 90° angle to the gills and scrape several times. Alternatively, the tips of the gills can be cut with fine scissors, with the excised gill filaments placed on the slide.
- Under the microscope, one should be able recognize and enumerate most parasites of the skin and gills.

Submitting fish specimens for disease diagnosis
Should the grower notice increased morbidity or mortality in any of the cultured fish lots, the help of a fish health professional should be sought. Disease diagnosis is a challenge not only to fish growers but also to fish health professionals.

Many of the diagnostic assays must be done in a timely manner; otherwise, the pathogens causing the condition will be impossible to identify. It is advisable to first consult a local source, such as an aquaculture extension specialist, state department of agriculture aquaculture coordinator, or the state aquaculture association.

In many instances, fish must be subjected to clinical and laboratory investigations by skilled health professionals. To ensure that specimens arrive at the laboratory in a status that permits accurate diagnosis, it is important that the specimens be handled properly according to the instructions listed below.

Live fish allow the health professionals to observe abnormal swimming behavior, reflexes, and clinical symptoms such as lethargy and pigment anomalies. Live fish also permit the retrieval of blood samples, which facilitates the isolation of pathogens from systemic infections and allows the examination of blood parameters.

Preferred methods for transport of live fish to the diagnostic laboratory involve either the culturist bringing the specimens in question directly to the diagnostic laboratory or the shipment of specimens via "next day delivery," the former being the method of choice. Bringing the afflicted fish to the laboratory personally enables the fish health professionals to benefit from the crucial information often provided by personal conversations with those involved with the fish daily. In addition, meeting with the health professional has the added benefit of providing an opportunity to observe the fish necropsy, thereby increasing the producer's knowledge about his or her fish populations.

To ship live fish, the fish must be placed in a strong plastic bag filled one-third with water. Double bagging is best to reduce the risk of puncture or leaks. Fill the remaining two-thirds of the bag with compressed air or pure oxygen. Pack the sealed bag in a strong, watertight container made of Styrofoam™ or an insulated cooler. Surround the plastic bag with liberal amounts of ice and deliver the specimens in person or ship with next day delivery.

Do similarly for fresh dead fish (not more than 1 hr since death), putting individual fish in separate plastic bags without water, compressed air or pure oxygen. The bags then should be sealed and placed on crushed ice. Shipment should be made in a well-insulated container with liberal amounts of coarse, crushed ice.

Frozen specimens must be placed in separate plastic bags surrounded by liberal amounts of ice. The specimens should be kept frozen and shipped as soon as possible. Deliver the specimens in person or ship with next day delivery.

Generally, preserved specimens are not satisfactory for disease diagnosis because the preservatives kill disease agents. However, if the condition is a tumor or if parasites are seen and you desire an identification, a 10% formalin solution or 70% alcohol (rubbing, isopropyl, or ethanol) preserves tumors or parasites adequately, and the specimens can be shipped in the preservative. Check current carrier regulations on the transport of specimens in flammable solvents before taking them to your local carrier.

Complete records must be made at the time of collection, and a label must be written with soft pencil or waterproof ink and placed in the container with the fish (not directly on the fish, nor in the water with the fish). The label should contain the number of fish, their status at the time of shipment, and bag identification. The form in Appendix 1 must be filled in carefully and sent along with the fish shipment.

7. Know the Treatments for Fish Diseases

- An accurate diagnosis must be made before any treatment is applied to fish. Improper treatment can cause more harm than good. If an antibacterial is necessary, antibiotic sensitivity testing should be done.
- Treatments are divided according to the pathogen present: bacterial or parasitic.

Here are some brief descriptions of commonly used aquaculture chemicals and the precautions/considerations associated with their use. It should be emphasized that the producer must be aware of the legal status of using any chemical. Regulations concerning approved chemicals for use in aquaculture are continuously being updated, and current information is often available through either NCRAC or on the Web at http://www.aquanic.org/. There are many different types of oral antibacterials, but as of September 2005, FDA has approved only two that are available for use in aquaculture species destined for human consumption.

Oxytetracycline is specifically approved as Terramycin for Fish® for the control of bacterial hemorrhagic septicemia, *Aeromonas liquefaciens*, and *Pseudomonas* spp. infections in catfish and ulcer disease, *A. salmonicida*, bacterial hemorrhagic septicemia, and *Pseudomonas* spp. infections in salmonids. It is used as a feed additive at a rate of 3.75 g of drug (active ingredient)/45 kg (0.13 oz/100 lb) of fish weight/day for 10 days. A 21-d withdrawal period is required before the fish may be slaughtered and used for human consumption. A veterinarian would have to prescribe Terramycin for Fish® under extra-label use if oral oxytetracycline were to be used to control any disease listed above or other disease in yellow perch. Because the use of this drug in yellow perch is currently not on the approved label, a facility would need to contact their National Pollution Discharge Elimination System (NPDES) permit writer to request authorization to release oxytetracycline-medicated feed. Thus, veterinarian extra-label use could be restricted based on the facility's NPDES permit.

Data on human food safety, target animal safety, and environmental safety have been developed on oxytetracycline that will allow this drug to be used to control a variety of systemic bacterial diseases in yellow perch once the efficacy data are generated.

Sulfadimethoxine and ormetoprim are specifically approved as Romet-30® and Romet-TC® for the control of Edwardsiella ictaluri infections in catfish and A. salmonicida infections in salmonids. It is used as a feed additive in both cases at a rate of 50 mg drug (active ingredient)/kg of fish weight/day for 5 days. A 42-d withdrawal period is required for salmonids and a 3-d withdrawal period is required for channel catfish before the fish may be slaughtered and used for human consumption. A veterinarian would have to prescribe Romet-30® or Romet-TC® under extra-label use if this drug were to be used to control any disease listed above or other disease in yellow perch. Because the use of this drug in yellow perch is currently not on the approved label, a facility would need to contact their NPDES permit writer to request authorization to release Romet-medicated feed. Thus, veterinarian extra-label use could be restricted based on the facility's NPDES permit.

Florfenicol has been approved as Aquaflor® as a veterinary feed directive, which means it can only be used under the supervision of a licensed veterinarian. The first approval is a label claim for the control of enteric septicemia in catfish. It is applied at a rate of 10 mg/kg of body weight. Extra-label use of medicated feed containing florfenical is prohibited by regulation of FDA. Data on human food safety, target animal safety, and environmental safety have been developed on florfenicol that will allow this drug to be used to control a variety of systemic bacterial diseases in yellow perch once the efficacy data are generated.

Aquaculture chemicals Bacterial gill disease is a potentially acute disease of intensively cultured fish. Affected fish stop feeding, swim near the surface, and orient themselves toward the current to optimize oxygen uptake. It is diagnosed microscopically by observing long filamentous bacteria on gill scrapings. INAD exemptions currently allow the use of chloramine-T and hydrogen peroxide for control of this disease. Chloramine-T® comes as a soluble powder that is dissolved in warm water and applied as a bath treatment at 10–20 mg/L for 1 hour for 2–3 consecutive days. After the 1-h application time, the drug is flushed out with fresh water. Hydrogen peroxide (35%) is used at a concentration of 100 mg/L in continuous flow water supply or as a static bath for 30 min or 50–100 mg/L for 60 min once per day on alternate days for three treatments. Both drugs should be approved by 2007 for use on freshwater-reared salmonids. Once approved, a veterinarian would have to prescribe either drug under extra-label use if these drugs were to be used to control this disease on yellow perch. Because the use of these drugs on yellow perch will not be on the approved labels, a facility would need to contact their NPDES permit writer to request authorization to release these drugs. Thus, veterinarian extra-label use could be restricted based on the facility's NPDES permit. Final approval of hydrogen peroxide and chloramine-T by the FDA is needed to allow their use by the aquaculture community.

Antiparasitics External parasites are a common occurrence in fish on surface water. Fish with parasitic infestations often show signs such as flashing (rubbing on the tank walls) and lethargy. Diagnosis is usually accomplished by microscopic observations of gill and skin scrapings.

Formalin approved as Formalin-F® and Paracide-S® is used for control of several external parasitic infections. It is commonly used as an indefinite pond treatment at 15 mg/L. Formalin removes 1 mg/L DO for every 5 mg/L formalin used as a treatment. Therefore, if DO concentration in a pond is low, aeration must be provided or a different treatment should be used. Formalin must not be stored at temperatures less than 4°C (40°F) because it will form very toxic paraformaldehyde at low temperatures.

Concerns for fish health during formalin treatments:

- Formalin chemically removes oxygen from the aquatic environment. Therefore, while trating fish, supplying a good source of aeration is critical.

- Formalin toxicity is increased at high water temperatures. If water temperatures exceed 21°C (70°F), the volume of formalin used or the time of exposure should be reduced.

- Extemely sick fish may not be able to toleratre high levels of formaline. Any time fish exhibit signs of distress (i.e., darting, gasping, or trying to jump out of the water) during formalin treatment, they should be placed into clean (untreated) water at once.

Formalin application procedure Formalin is applied as a bath treatment, which means fish are placed into the treatment tank for a relatively a short period of time (up to 60 min), and should then be placed into clean (untreated) water.

1. Fill a tank with the same pond water in which the fish live.
2. Provide vigorous aeration (an air stone is ideal).
3. Place the fish to be treated in the tank.4. Have a screen/cover ready to place over the tank.
5. Fill a separate, clean bucket with approximately 1.9 L (0.5 gal) of pond water. This bucket provides a container of untreated water for transfer of fish that may become overly stressed by the treatment.

As with all chemical treatment, follow all label instructions and precautions such as applying appropriate personal safety measures, treatment protocols, and disposal of containers and unused materials.

Summary

- As in other fish species, diseases in yellow perch are almost always the result of outbreaks induced by stress, poor husbandry, poor management, or a combination of those elements.
- Currently, there are few therapeutic agents that are approved for treating disease outbreaks in yellow perch, but there are several drugs nearing approval that will cover most of the disease problems.
- The most important preventative measure is to avoid exposure to pathogens and to heighten the facility's biosecurity.
- Enlist aquaculture health professionals early in your culture operations.

Constraints

- Drug approvals for controlling bacterial, fungal, and parasitic outbreaks for yellow perch are nearing completion, but efficacy data are needed before most of these drugs can be used without an INAD or extra-label use by prescription under a veterinarian

Chapter 9

Nutrition

Although yellow perch and its North American relatives sauger and walleye as well as its European relatives, Eurasian perch (*Perca fluviatilis*) and zander, are all highly prized food fishes and are of significant interest to aquaculturists, very little information is available about their specific nutritional requirements. Yellow perch dietary requirements for crude protein, protein:energy ratio, lipid, lysine, methionine, arginine, and choline are available. The quantitative nutritional requirements and recommended macronutrient concentrations that are available for yellow perch are presented in Table 9.1.

Protein and Amino Acids

Protein is usually the most expensive ingredient in fish diets. It provides the amino acids necessary for fish to grow and to build muscle protein. The essential amino acid levels of the protein must be balanced to meet the needs of the fish. If levels of essential amino acids are too high or too low, the protein may be used for energy instead of building muscle. The protein level also must be carefully balanced with dietary energy levels to reduce the use of protein to meet the fish's energy needs. If protein is converted to energy, excess ammonia will be produced that affects water quality, especially in tank culture systems.

Research done at MSU has shown that the optimal dietary crude protein level is between 21 and 27% of the diet. Although a slightly higher weight gain was observed in fish fed 34% crude protein, the weight gain was not statistically greater than the weight gain of fish fed 27% crude protein. Previous work completed at UW-Madison also indicated that the growth of juvenile yellow perch fed diets containing crude protein levels of 27, 40, or 50% was not significantly different. MSU researchers also reported that the optimum crude protein to metabolizable energy was 20–22 g of crude protein per millijoule (MJ) of metabolizable energy. Rainbow trout metabolizable energy values for feedstuffs were used because the values are

Table 9.1. Quantitative nutritional requirements for yellow perch. Values expressed as a function of dry matter in the diet.

Nutrient	Requirement
Crude protein	21–27%
Protein:energy[1]	20–22
Lipid	6–8%
Lysine	1.1%
Methionine[2]	1.0%
Methionine[3]	0.85%
Arginine	1.4%
Choline	600 mg/kg

[1]Expressed as g of crude protein MJ^{-1} metabolizable energy.
[2] Methionine requirement determined in diets containing 0.03% cyst(e)ine.
[3] Methionine requirement determined in diets containing 51:49 cyst(e)ine:methionine.

not available for yellow perch. The diets were formulated to the minimum dietary crude protein concentration for fish by using the whole-body pattern of essential amino acids. This is a new approach and offers promise of more precise formulations and a rapid method of developing diets for new aquaculture species.

Some of the most important essential amino acid requirements have recently been determined for yellow perch by researchers at Purdue University using diets containing 33–34% dietary crude protein. The lysine requirement of yellow perch is one of the lower lysine requirements reported for fish, whereas the methionine and arginine requirements are more similar to those of other species. The dietary lysine requirement of juvenile yellow perch is 1.1% of the diet. A series of studies also were conducted to determine the methionine requirement of yellow perch at Purdue University. A series of experiments are required because the methionine requirement may be spared by the sulfur amino acid cysteine. In the first study, diets contained 0.03% cysteine, and the methionine requirement was 1.0–1.1% of the diet. In the second study, supplemental cysteine was added to the diet to reduce the amount of methionine required. Fifty-one percent of the methionine requirement was then spared by the addition of cysteine. A ratio of 51:49 cysteine:methionine was used in the third study, and the total sulfur amino acid requirement was 0.85% of the diet. The dietary arginine requirement for juvenile yellow perch is 1.4% of the diet.

Energy: Lipids and Carbohydrates

Lipids (fats and oils) provide essential fatty acids and are an important source of energy for fish. Carbohydrates (starches) also are energy sources, but their value varies significantly between different groups of fish.

Limited work has been published on lipid requirements, and no work has been reported to date on carbohydrate use by yellow perch.

Purdue University researchers fed five lipid sources (menhaden, *Brevoortia* spp., cold-pressed soybean, coconut, or tallow) alone or in combination and reported that juvenile yellow perch gained significantly more weight when fed either menhaden fish oil or cold-pressed soybean oil at 6% of the diet.

Within each lipid source, weight gain significantly decreased as dietary lipid concentration increased to 12 and 18% of the diet. Additionally, there were no significant differences in weight gain of fish fed a 1:1 mixture of menhaden fish oil and cold-pressed soybean oil at any of the dietary concentrations tested (6, 12, or 18%).

The essential fatty acid requirements of yellow perch have not been determined. However, researchers at OSU have identified docosahexaenoic acid (DHA, 22:6n3) as the predominant fatty acid in phospholipids of yellow perch. They also reported a decrease in DHA as eggs hatched and fry grew. Both DHA and eicosapentaenoic acid (EPA, 20:5n3) were higher in juvenile perch than in their major food item, which was *Daphnia*. This information indicates the long-chain fatty acids may be important in larval diets for yellow perch.

Juvenile yellow perch fed diets deficient in linolenic acid had lowered levels of DHA in polar lipids. This finding tends to support the previous finding that DHA is important in eggs and fry and that phospholipid studies should be conducted on linolenic acid as an essential fatty acid in yellow perch.

Vitamins

Work at Purdue University has shown that the yellow perch choline requirement is approximately 600 mg/kg diet. Choline is a member of the vitamin B complex and is important in liver function and many other metabolic pathways. Results in the same study showed that phosphatidylcholine could be used to meet the choline requirement.

Ohio State University researchers have observed that low dietary ascorbic acid (vitamin C) intake by yellow perch resulted in decreased liver concentrations in 6 weeks, but overt signs of vitamin C deficiency did not develop until 8 months. This finding demonstrated that ascorbic acid is required in yellow perch diets, but the dietary level required was not identified. Spinal deformities have been relatively common in yellow perch reared in tanks from larvae. These deformities may have been caused by insufficient vitamin C in the prey items or starter diets.

Larval Diets and Feeding

Yellow perch are relatively small when they first hatch (4.5–7.0 mm [0.18–0.28 in] TL). Mouth gape measurements indicate yellow perch larvae can consume prey or food particles <130 –190 µm. Practical methods of feeding live or formulated practical feeds to these small larval fish remains difficult. Although several new dry and liquid practical larval diets have been developed in recent years, acceptance of the diets, weight gain, and survival have continued to be highly variable and most often very low compared with other commonly reared fishes.

Recently, in both laboratory studies and production scale studies, the survival rates of larval walleye fed only formulated feeds have been comparable to fish reared in fertilized ponds and then switched to commercial diets. Additionally, developments in larval feed manufacturing methods offer promise for all percids and a variety of small-egged species.

At present, the most common method of mass propagating larval yellow perch used by commercial aquaculturists is in outdoor ponds. These methods are described in more detail in Chapter 5. In ponds, larval yellow perch feed on the available zooplankton. Rotifers and copepods are important prey items at this stage. In tank systems, several types of zooplankton can serve as potential prey items, including some strains of *Artemia* that produce small first-hatch nauplii. Researchers at UW-Milwaukee also have developed green tank culture methods to rear larval yellow perch from first feeding to advanced stages totally in tanks.

Yellow perch are generally large enough to be trained to accept formulated feeds after approximately 30–45 days. This transition can be accomplished in ponds or tanks by simply offering feed on a regular basis, often with an automatic feeder. Feed acceptance may be further enhanced by taking advantage of the photopositive nature of larval yellow perch. Researchers at UW-Madison have developed an automatic feeder that uses lights to atttract fish to the feeders at night.

Production Feeds

Commercial diets fed to yellow perch are usually formulated to meet the requirements for trout and other salmonids. These feeds exceed the nutrient requirements of yellow perch but seem to meet their needs better than practical feeds formulated for other commonly cultured fishes, such as channel catfish, *Ictalurus punctatus*. Feeds initially fed to yellow perch have been either dry or soft-moist diets containing approximately 20% moisture with mostly fish products as ingredients. After yellow perch have accepted soft formulated diets, they can gradually be converted to dry salmonid grow-out diets. Sinking or floating feeds may be used, but yellow perch may not actively feed on floating feeds under high light conditions. In ponds, however, floating feeds may be preferable to observe feeding behavior and not over- or under-feed the fish.

Researchers at Purdue University have evaluated various commercial diets formulated for other species but fed to yellow perch. Their results are summarized in Table 9.2.

Small yellow perch (5 g, 0.2 oz) fed a practical diet formulated for rainbow trout gained more weight than fish fed a similar diet formulated for channel catfish. Both diets contained 36% crude protein. However, the trout diet contained 8% lipid and the catfish diet contained 6% lipid and a higher level of plant proteins.

Table 9.2. Mean weight gain and feed conversion ratio (FCR) of yellow perch fed commercial diets for 10 weeks. Values are means of three replications. Means within the same column for each size group of yellow perch with the same letter designation were not significantly different.

	Weight gain[1]	FCR[2]
Commercial Diets fed to 5-g yellow perch		
Catfish (36/6[3])	127.8c	2.9c
Trout (36/8)	174.7a,b	2.3a
Trout (45/15)	212.1a	2.3a
Commercial Diets fed to 51-g yellow perch		
Trout (33/8[3])	43.3c	5.9c
Trout (38/12)	38.7c,d	6.5c,d
Trout (40/10)	63.4a	4.4a
Trout (50/17.5)	46.3b,c	5.7b,c
Catfish (36/4)	46.0b,c	5.7b,c
Catfish (32/3.5)	10.2e	25.8e

[1] Weight gain expressed as percentage of initial body weight.
[2] Feed conversion ratio calculated as dry weight of feed/wet weight gain of fish.
[3] Values in parentheses are the guaranteed concentrations (%) of crude protein/fat, respectively, supplied by the feed manufacturers.

Feeding higher crude protein (45%) and lipid (15%) concentrations in a feed formulated for trout did not result in higher weight gains. However, higher dietary crude protein and lipid concentrations were effective when fed to larger yellow perch. Larger yellow perch with an initial weight of 51 g (1.8 oz) gained more weight when fed a commercial trout diet containing 40% crude protein and 10% lipid (designated as 40/10) than fish fed diets with 33/8, 38/12, or 50/17.5, similar designation. Weight gain of the larger yellow perch also was generally better when fed diets formulated for trout rather than for catfish.

Feeding Practices

The optimum feeding method depends on the fish's feeding behavior and physiology, and on the characteristics of the production system. Fish culturists have historically emphasized maximizing intake of feed in the hopes of maximizing growth. Evidence suggests this may not be the most effective feeding strategy for fish production. Maximizing intake can lead to excess feed not being consumed, lower feed efficiency, and result in more expensive production. Uneaten feed also reduces water quality, fish health, and performance, especially in recirculating systems that use low water exchange rates.

Feeding rates vary with fish size, water temperature, and culture management practices. The appropriate amount fed is measured as a percent of the average body weight. As the fish's weight increases, the percentage of body weight fed decreases; daily feed ration must be adjusted to compensate for growth.

In laboratory studies, yellow perch have typically eaten less than catfish and trout, generally about two-thirds the amount normally fed to trout. Because feeding rates for trout are available from trout feed manufacturers, a good starting point for yellow perch is to multiple that rate for a specific size (TL) by 0.67. If all feed fed is rapidly consumed (less than 5 min), slightly increase the amount fed. If feed remains after 5–10 min, decrease the amount of feed.

By keeping careful records on the amount fed and water temperature, and fish length and weight, yellow perch farmers can develop their own site-specific feeding rates. A subsample of fish should be tested every 2 weeks to calculate the total weight and average length of the yellow perch in the culture system. The information can be used to calculate feeding rates (rate fed/total weight) and feed conversion (weight gain/feed fed defined as FCR).

Because of their rapid growth, high energy requirements, and small, partially developed digestive systems, fish fry require frequent feeding.

Automatic feeders are almost mandatory when feeding larval and very early juvenile stages of yellow perch raised in tank culture. Depending on feed type, first feeding larvae may be fed almost continuously throughout the entire day. Automatic feeders should be checked frequently and adjusted if necessary to avoid overfeeding, which can degrade water quality.

As the fish grow, the frequency of required feedings should be gradually reduced to every hour throughout the entire day to 8–10 times per day. Juvenile fish larger than 5 cm (2 in) can be fed two or three times per day, and larger fish are usually fed twice each day. More frequent feedings may increase feed consumption but can result in poorer feed use and reduced water quality in the culture system.

Circular tanks with a strong water flow are considered necessary to prevent poor water quality conditions and to facilitate tank cleaning when high feeding rates and continuous feeding are used. Larval culture tanks with a high surface-to-volume ratio and surface sprays to reduce surface films may increase larval survival by promoting increased air bladder inflation. Flat bottom tanks allow the larval fish to rest. Tank color also may affect acceptance of feed by larvae, but more research is needed to verify this factor’s importance. Culture tanks for larger fish may have conical bottoms to more efficiently remove solids from the system.
Grow-out culture systems for yellow perch have included earthen ponds, raceways, cages, and recirculating aquaculture tank systems (see Chapter 6). Yellow perch culture systems are typically small compared with the earthen pond systems used for catfish production in the southern United States or the raceway systems used for trout in the western United States. With smaller culture systems, hand feeding remains the most common method of dispensing feed. Yellow perch are generally slow feeders so feeding by hand also tends to be more efficient.

Feed size is important to help maintain active feeding and to reduce impacts on water quality. Smaller sized feeds break down more rapidly than larger sized feeds because of a higher surface area-to-volume ratio. Because yellow perch and trout have similar body shapes and mouth sizes, the pellet size/TL fed to rainbow trout can be used for yellow perch (Table 9.3). The size should be increased through various sizes of crumbles for fingerlings to various sizes of pellets for larger fish in grow-out systems.

Table 9.3. Feed size per fish TL.

Feed size	**TL (mm)**	**TL (in)**
00 crumble	<25	<1.0
# 1 crumble	25–40	1.0–1.5
# 2 crumble	40–55	1.5–2.2
# 3 crumble	55–75	2.2–2.9
# 4 crumble	75–110	2.9–4.3
(1/8 in [3.2 mm]) pellet	110–160	4.3–6.25
(3/16 in [4.8 mm]) pellet	>160	>6.25

Note: Some of the new, small extruded diets (1.0 mm and 1.5 mm) can be used instead of #3 and #4, respectively

Fish are sensitive to water quality. Feeding should be reduced or stopped if water quality falls below certain critical levels. Shortly after feeding, DO levels decline rapidly and should be maintained above 5.0 mg/L for best growth. At DO levels between 3.0 and 5.0 mg/L feeding should be reduced, and stopped altogether at DO levels <3.0 mg/L.

Ammonia and nitrite are concerns in RAS and should be monitored regularly. Ammonia production is directly related to feeding as well as feed quality, feeding rate, fish size, and water temperature. Ammonia levels begin to rise after feeding. In most species of fish, ammonia production peaks 4–6 hr after fish are fed. Chapter 8 contains additional details related to the role of water quality to fish health.

In water, ammonia exists in two forms, ammonia (NH_3, or unionized ammonia) and ammonium (NH_4^+, or ionized ammonia). The form that is most toxic to fish is NH_3. Both forms are present at all times in the water, but the percentage of each depends on temperature and pH of the system water. Warmer water and higher pH in the system water favors the more toxic NH_3.

Unfortunately, the term ammonia is often used to refer to both the toxic NH_3 (given as mg/L NH_3-N) and the two forms (NH_3 + NH_4^+) added together, which often leads to confusion. Therefore, culturists often refer to (NH_3 + NH_4^+) as the total ammonia nitrogen (given as mg/L-TAN). When measuring or discussing ammonia concentrations, it is important to be clear which term is being used.

The lethal ammonia concentration for most warm-water fish is between 0.6 and 2.0 mg/L NH_3-N. Yellow perch are at the low end of this scale. Unionized ammonia concentrations below 1.0 mg/L NH_3-N decrease growth and performance of most fishes. Generally, smaller fish are more sensitive to the effects of ammonia. Low DO also increases the toxicity of ammonia and lowers the concentration that affects fish. When ammonia concentrations remain elevated, or fish show signs of stress, feeding should be reduced or stopped.

Summary

- Only a few nutritional requirements of yellow perch have been determined on a percentage of dry matter in the diet;
- Crude protein, 21–27%
- Protein:energy, 20–22 g of crude protein MJ^{-1} metabolizable energy
- Lipid, 6–8%
- Lysine, 1.1%
- Methionine, 1.0% in diets containing 0.03% cyst(e)ine
- Methionine, 0.85% in diets containing 51:49 cyst(e)ine:methionine
- Argine, 1.4%
- Choline, 600 mg/kg

Constraints

- To maximize production efficiency and minimize costs of yellow perch production, the following information has to be known:
  - Nutritionally complete diets formulated to meet their dietary requirements.
  - Optimum crumble or pellet size.
  - Optimum feeding rate (percentage of fish body weight).
  - Optimum time intervals based on the size of the fish and the culture conditions.

Chapter 10

Selective Breeding, Sterile Triploids, and New Biological Technologies

Selective Breeding

Some producers and OSU personnel have raised several successive generations of captive yellow perch, but no systematic efforts have been made to genetically select or domesticate yellow perch. There is currently no evidence for the existence of strains that show rapid growth under aquaculture conditions.

Genetic selection has had major impacts on many emerging aquaculture species. The two most successful cultured species of fish in the United States are rainbow trout and channel catfish.

Domesticated brood fish have been developed for both of these species that produce fish with desirable traits for aquaculture. Genetic selection applied to Atlantic salmon, *Salmo salar*, in Scandinavia has resulted in accelerated growth rates that significantly reduce the time to harvest. By selecting for traits that are considered desirable for cultured fish, e.g., fast growth, it also may be possible for yellow perch producers to develop a domesticated strain of yellow perch more suited to aquaculture.

Triploids

Parental fish pass one set of chromosomes on to their offspring via their eggs and sperm. Providing a pressure or heat shock to the eggs at the appropriate moment after they are fertilized causes the egg to retain two sets of chromosomes. With the addition of the paternal set (from sperm), the embryo has three sets of chromosomes, thus creating triploid fish. Triploid fish are sterile and thus will not put as much energy into gonadal development, instead investing that energy into growth. Because yellow perch reach sexual maturity before reaching a market size, a 10–25% decrease in fillet yield occurs in net pen- and pond-reared fish harvested from December through April, the time of active gonadal development.

To minimize this problem, methods to sterilize yellow perch by inducing triploidy have been developed. UW-Madison researchers have produced triploid yellow perch by both subjecting eggs to heat shock of 28–30ºC (82.4–86ºF), initiated 5 min after fertilization and lasting 10–25 min, or by hydrostatic shocks of 9,000 or 11,000 PSI, initiated 5 min after fertilization and lasting 12 min.

Some laboratory studies have shown that triploids may not grow as fast as diploids (normal fish with two sets of chromosomes) either as juveniles and/or when reared under constant temperature conditions. Such a reduction in growth may limit the commercial potential of triploids. Studies evaluating the growth and fillet yield of triploids raised in net pens or ponds, however, have not yet been conducted.

Monosex Populations

One technique is currently being developed to produce faster growing fish. Both in the laboratory and in the wild, female yellow perch grow significantly faster than males. Accordingly, the production of monosex female populations may improve yellow perch growth rates and thereby increase production efficiency. Monosex female yellow perch populations can be produced by feeding small fingerlings a diet treated with an analog of the sex steroid MT, which causes female fish to produce sperm that are " all x" genotype.

The hormone-treated fingerlings are raised to sexual maturity, and the " all x" sperm is collected from the sex-reversed genetic females and used to fertilize normal (xx) eggs. The resulting fry are all female. Two major advantages of this method of producing monosex females are that the cost is almost insignificant and that no yellow perch destined for the market are treated with hormone analogs. Despite the latter point, one yellow perch distributor indicated that he has received negative consumer reaction to monosex female production. Any such reaction, however, has not limited the use of monosex production in other large aquaculture industries.

For example, 100% of the chinook salmon (*Oncorhynchus tshawytscha)* and coho salmon (*O. kisutch*), produced in Canada; >90% of the rainbow trout produced in the United States; and an increasing percentage of the tilapia produced in the United States are monosex.

The use of MT in yellow perch diets is not yet approved by the FDA, but in 1997 and 1998 its use was available to several producers through an FDA INAD exemption. NCRAC has sponsored some of the research that is needed to gain FDA approval for using MT in yellow perch diets as described above.

Out-of-Season Spawning

In 1996, OSU researchers spawned yellow perch out-of-season during September and October by shifting the photothermal condition, light hours, and temperature regimes, by 6 months. The natural spawning of yellow perch occurs in Ohio in April and May at 12–14ºC (54–57ºF) and a 12-hr light:12-hr dark photoperiod. The brood fish were maintained at higher temperatures and longer photoperiods during September through February (18ºC [64ºF] and 13-hr light:11-hr dark). The photothermal conditions were decreased gradually until June. The chill period (10ºC [50ºF] and 11-hr light:13-hr dark photoperiod) was 60 d (June–July) and was followed by gradually increased water temperature and longer daylight (12ºC [54ºF] and 19-hr light:5-hr dark). After this period, 47% of the females were recorded as gravid and 24 were stripped or spawned naturally.

The males produced sperm during the entire shifted spawning period from August to September. The average relative weight of ovulated eggs as percentage of the female weight was 26.6 ± 10.7%. Embryo survival through the eyed stage was 56 ± 24%. Larval skeleton abnormalities (45 ± 15%) and a low frequency of swim bladder inflation (44 ± 34%) were observed.

One area of research funded by NCRAC is to develop methods for inducing out-of-season spawning so that yellow perch eggs would be available at multiple times of the year. The method being tested is to hold groups of adult yellow perch under environmental conditions in which the chill period is shifted to occur at different times of the year.

The successful commercial application of this method has not yet been demonstrated. Researchers recently began studying techniques for spawning perch out of season. Preliminary results at UW-Madison suggest that by holding brood fish under day length and temperature conditions out of phase with ambient conditions, yellow perch spawning can be delayed until July.

Fry were stocked in newly filled ponds in July and grew faster than fish in ponds stocked in May, possibly because of warmer pond temperatures. The ponds stocked in July produced 50–100-mm (≈2–4-in) fingerlings harvested in September.

If commercially viable procedures for shifting the spawning season are developed, larvae need to be stocked in multiple stockings into production pens (see earlier note) or be accompanied with commercially viable indoor larvae rearing methods. The larvae rearing protocol developed in this project is based on a combination of microalgae and rotifers as the larvae first feed. *Artemia nauplii* were offered from 6 d after initiation of feeding. Weaning period started at 35 d, and the fingerlings were completely weaned from *Artemia* to a dry diet at the age of 45 d. Feeding a mixture of dry diets and *Artemia* as well as coating a starter diet with krill hydrolysate significantly increased growth of yellow perch juveniles.

Summary

- Triploid yellow perch produced by pressure or heat shocks did not grow as rapidly in tank culture as diploid yellow perch; their application in commercial aquaculture may be limited.
- The development of domesticated yellow perch brood fish should be a high priority for the industry.
- The use of MT to produce monosex female populations of yellow perch holds significant promise to improve yellow perch growth rates and thereby increase the production efficiency of producers. Accordingly, efforts aimed at gaining FDA approval for using these compounds should continue.

Constraints

- Replicated and statistically valid studies are needed to document the extent to which monosex females grow faster than mixed sex populations in systems having constant and ambient temperature/photoperiod regimes, i.e., flow-through or recirculation systems, and net pen or pond culture systems, respectively.
- Studies also are needed to document the growth of triploid yellow perch in ponds and to evaluate the extent to which triploidy may improve the fillet yield of pond-raised yellow perch.
- Possible negative consumer reaction to sexually manipulated marketed fish.

Chapter 11

Processing

The commercial harvest minimum size limit for yellow perch has traditionally been 150 mm (8 in); however, farm-raised fish are often processed at smaller sizes. Many producers prefer a 200–250-mm (8–10-in) TL yellow perch; fish are approximately 150 g or 3 fish/lb. Because of their small size, processing yellow perch is expensive compared with other fish species, with total processing costs averaging $3.30–3.60/kg ($1.50–3.00/lb) for fillets. Almost all yellow perch are sold as scaled fillets, and most are scaled by machine and filleted by hand. Presently, machine filleting results in a significant loss of yield.

Yellow perch retain their very high quality when frozen because of their low fat content; nevertheless, there are local markets where fresh product commands a premium price compared with frozen fillets. Unfortunately, some product is illegally sold as fresh when in fact it has been previously frozen. The lack of availability of processing facilities for small-scale yellow perch producers is a significant problem in some areas of the NCR.

Once yellow perch are harvested, they should be kept on ice and out of direct sunlight to prevent bacterial growth. Usually, once fish arrive at the processing facility, they should be eviscerated immediately. However, yellow perch are very difficult to fillet after evisceration (Figure 11.1), so this step is normally not done. Refrigerate to 4ºC (40ºF) or lower as soon as possible. For refrigerated inventories, the first in, first out method must be followed.

Figure 11.1. Fish evisceration.

Most processors ice the whole perch for at least 24 hr to allow rigomortis to set in. The fish are then mechanically scaled. The flesh of fish that are scaled before rigor is subject to severe bruising.Many yellow perch are sold as single or butterfly fillets (Figure 11.2) or less frequently as a headed, gutted product (Figure 11.3).By hand filleting the fish and leaving the belly tissue intact (butterfly filleting), dress-out yields that average 40–50% are obtained. With diligent grading and constant equipment adjustment, machine processing can yield dress outs of 42%; however, 37–40% is more realistic.

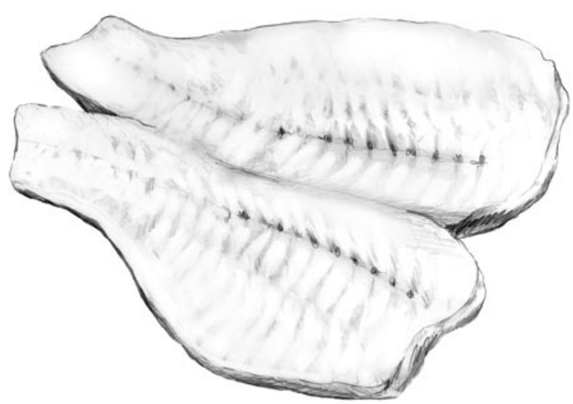

Figure 11.2. Butterfly fillet.

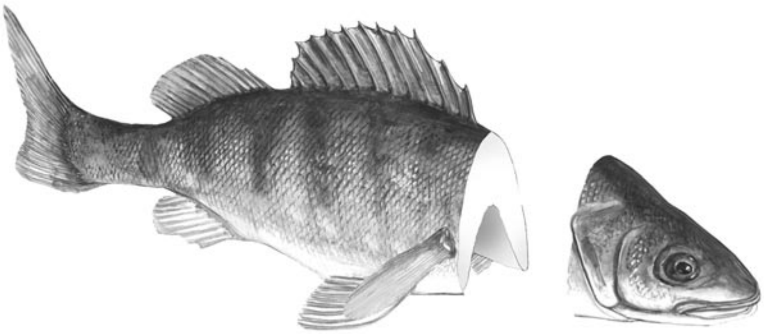

Figure 11.3. Headed, gutted.

For the best quality product, yellow perch should be frozen as rapidly as possible. Use small ice crystals because they cause less damage to the tissue. It is possible to instantly quick-freeze the fish with the use of carbon dioxide or nitrogen. Once the fish is frozen, hold it at -23ºC (-10ºF). To thaw, hold it in a 0–2ºC (32–35ºF) cooler.

Packaging

Plastic or paper is cheap, durable, and requires less knowledge and simple equipment to package the product. Vacuum packaging is more expensive, and it does require product knowledge and complicated equipment. However, it also improves shelf life and is very durable. There are a few cautions in vacuum packaging fish: drip, which is moisture loss from flesh; a maximum shelf life of 4–6 days; possible flavor changes because of oxidation and foreign materials, e.g., ammonia gas or halogen compounds; and fasteners must be avoided to prevent puncturing the seal. Additional concerns about vacuum packing include specific storage and labeling requirements which may be required by some states.

Processing Plant

The quality of the product can suffer if the processing plant lacks a good sanitation program. A sanitation program is all of the activities that keep the product free from germs, chemicals, and foreign objects. The FDA states that a fish processing sanitation program should provide the following:

1. A safe water supply.
2. Cleaned and sanitized food contact surfaces, including equipment, gloves, and utensils, and safeguards against cross-contamination.
3. Properly maintained employee hygiene facilities.
4. Protection of food from incidental contaminants.
5. Properly labeled and handled chemicals.
6. Safeguards against sick employees handling the food.
7. Pest control.

A safe water supply means that the water must be safe for drinking, clean and fresh, from an approved source, and free from harmful chemicals and microbes. When ice is used, it must meet the same requirements used for the water.

A book of Material Safety Data Sheets (MSDS) must be within easy access at all times. This book contains information on all the hazardous chemicals used in the processing plant. There also must be a Sanitation Standard Operating Procedure (SSOP) on hand at all times, and it must be followed. SSOP is a written copy of all cleaning and sanitation procedures used in the facility. Although the SSOP is not required by the FDA, the FDA does require that a processing facility monitor and keep records that demonstrate that the seven sanitation components are both used and effective.

Hazard Analysis Critical Control Point (HACCP)

HACCP is a preventative system for ensuring the safe production of foods. A seafood HACCP was made mandatory by FDA as of December 18, 1995, in that certain enumerated HACCP functions are performed at the processing plant by an individual who has been trained in HACCP. The team developing the HACCP system for the facility should include both managers and workers. There are "over-the-counter" HACCP plans available, but it is a good idea to develop a facility-specific plan.

HACCP has seven principles for a systematic approach to food safety:

1. Conduct a hazard analysis. Prepare a list of steps in the process where significant hazards, such as biological, chemical, and physical hazards, occur and describe the preventative measures to reduce and eliminate them.
2. Identify the critical control points (CCPs). The Seafood HACCP regulation defines CCP in the following way: CCP means a point, step, or procedure in a food process at which control can be applied, and a food safety hazard can as a result be prevented, eliminated, or reduced to acceptable levels.
3. Establish critical limits for preventative measures associated with each identified CCP. If a product is outside of the critical limit, it is considered potentially unsafe.
4. Establish CCP monitoring requirements. Also, establish procedures for using the results of monitoring to adjust the process and maintain control. Monitoring is how an operator checks to see whether a process is in control.
5. Establish corrective action to be taken when monitoring indicates that there is a deviation from an established critical limit. Corrective action tells the operator what to do if something goes wrong.
6. Establish procedures for verification that the HACCP system is working correctly.
7. Establish effective record keeping procedures that document the HACCP system. These records are kept so that the processing facility can prove the product was processed in a safe manner.

Examples of generic seafood HACCP plans can be found at http://seafood.ucdavis.edu/haccp/plans/fillets.htm and http://seafood.ucdavis.edu/haccp/plans/fishwhol.htm.

Fish farmers can be HACCP certified in 3 d with a 2-d on-line training program followed by a 1-d classroom experience. More information about HACCP training and certification can be obtained through state land grant institutions or an aquaculture extension specialist.

Summary

- Hand filleting is currently the preferred method of processing yellow perch because higher yields can be obtained compared with machine filleting.
- Realistic dress-out percentage for yellow perch fillets is 37–40% of live body weight.
- When processing yellow perch, producers need to follow a processing sanitation program, keep and follow an SSOP on hand at all times, and establish a HACCP system ensuring the safe production of foods.

Constraints

- The lack of availability of processing facilities for small-scale yellow perch producers is a significant problem in some areas of the NCR.
- Improvements in fillet machine technology are needed to improve efficiency of fillet processing in yellow perch.

Chapter 12

Marketing

There has historically been a high demand for yellow perch harvested in the Great Lakes region, with almost 70% of the sales occurring within 80 km (50 mi) of the Great Lakes. The predominant states for yellow perch consumption are Illinois, Indiana, Michigan, Missouri, Ohio, and Wisconsin. In this region, where >40 million people reside, there is a large and historical marketing potential for yellow perch that makes it a prime candidate for aquaculture. There also are prime markets available in Canada, such as the cities of Montreal, Ottawa, Quebec, and Toronto, and in states with large retiree communities from the Great Lakes states. Yellow perch have several characteristics that make them valuable to both restaurants and home markets: low fat and phospholipids content extends their shelf life, resistance to freezer damage, and minimal problems with off-flavor and cooking.

As of 2003, other products, such as zander, walleye, and sauger, have been illegally marketed as yellow perch. The practice has become so widespread that the market price for yellow perch in the round has significantly dropped.

When marketing the product, a producer can approach with either a production or marketing perspective. A production perspective means that marketing is seen as only the sale or disposal of the fish to the consumers or any marketing business. A marketing perspective considers all decisions that influence a consumer's perception of fish products. Thus, all production decisions and distribution decisions also are a part of marketing. It is best to have a marketing perspective when marketing a product. It is a more complete view and illustrates how production decisions subsequently influence choices that growers make on how to distribute their fish.

Supply

The Great Lakes fisheries supplied wild-caught yellow perch for many years, and the markets absorbed the peak harvests of >15 million kg/yr (33 million lb/yr) in the 1950s and 1960s. Since then, there has been a decline in the wild harvests to 4.5–5.0 million kg/yr (10–11 million lb/yr) or less, and it is expected that the peak yields of the past will not return. Since 1989, there has been limited recruitment of yellow perch in Lake Michigan, excluding 2005–2006, and regulatory restrictions are in place to limit sport fishermen. This decline has led to the significant closures of commercial yellow perch harvesting in the Great Lakes. This closure allows an opportunity for producers to supplement the demands that the Great Lakes can no longer meet for yellow perch. There are now the beginnings of a perch aquaculture industry, but it currently contributes <226,800 kg/yr (500,000 lb/yr).

The value of the wild-caught yellow perch varies throughout the year and may impact the potential value of farm-raised fish. The value of wild-caught fish is measured as the percentage of edible meat after filleting; yield is highest during the fall run when the fish have more meat on them and lowest in the spring. During the rest of the year, yields fall in between these two extremes.

Cultured fish may have a marketing advantage over wild-caught fish, either perceived or real, in terms of superior freshness, and concerns over contaminants or parasites in wild-caught fish. For example, almost all Wisconsin lakes have a mercury consumption advisory for yellow perch, but fish raised in outdoor commercial ponds in Wisconsin have had mercury levels below the limit of detection.

Demand

Consumers today demand quality, variety, familiarity, and value in their products. Generally, consumers know little about the aquaculture industry, but they also are willing to try new types of farm-raised fish if information about handling and preparation is available to them. A diversity of farm-raised products also encourages consumers to try new products, such as new species or new processing forms.

Within a region, or even a state, the consumer's preference for fish can change. In Michigan, for example, there is a large change of percentage of preference for yellow perch between metro Detroit and the Upper and Lower Peninsula. Also, freshwater fish is preferred to saltwater fish because it is more available, less expensive, and more familiar. Again, familiarity, price, and availability are three important factors to consider with aquaculture of any species.

In an MSU study, consumers indicated their willingness to try aquaculture products because these fish were contaminant-free, they liked fish already, they wanted to support Michigan businesses, and they felt these products would be of a superior quality. They also reasoned that cultured fish were healthy and nutritious, they simply wanted to try them, and these fish would be less expensive and fresher. However, recent reports over the safety of farm-raised versus wild-caught salmon may alter these perceptions.

In the same study, fresh fish was preferred (66%) over frozen fish (4%), whereas 29% stated that frozen and fresh fish were liked equally. Reasons for the preference of fresh fish were that it was thought to have a better taste, consumers liked wild-caught, it had a more mild odor, or the consumer simply did not like frozen fish. Frozen fish was preferred because it was easier to prepare, easier to cook, and tasted better. The consumers prefer mild odor, mild flavor, and a firm and flaky texture. They also prefer a product that looks appealing, is well packaged, and is well displayed.

Consumers prefer fish fillets (68%), although 10% prefer whole fish, 8% prefer breaded fish pieces, and 4% prefer fish steaks. Also, the most popular preparation methods are frying, broiling, and baking. Farm-raised fish are more frequently purchased at a restaurant or grocery store rather than at a fish or seafood market, from commercial fisherman, or at fish farms or specialty stores.

Despite the declining wild supply, the demand for yellow perch remains high. One food distributor, Great Lakes Marketing, Inc., Waukesha, Wisconsin, suggested that the market could easily absorb 23–45 million kg/yr (50–100 million lb/yr). The wholesale price of round (uncut and fresh on ice) yellow perch averages from $5.07–6.61/kg (from $2.30–3.00/lb), whereas the wholesale price for fillets (processed and cut for presentation and sale) average $14.33–19.84/kg ($6.50–9.00/lb). The retail prices for fillets range from $19.84–33.07/kg ($9.00–15.00/lb). It should be noted that these prices were current at the time of publication and that they could range widely in the future.

In surveys conducted in 1996–1997 by Purdue University, the proportions of firms that sold yellow perch in the north central states of the Great Lakes region were as follows:

44% of seafood retailers,
42% of seafood wholesalers,
26% of supermarkets,
17% of restaurants,
16% of food service distributors, and
3% of grocery wholesalers.

Percentages added up to more than 100% because some firms sold to multiple outlets.

Brokers, wholesalers, retail stores, and restaurants can all be involved in marketing cultured fish. Of the mentioned firms, less than one-quarter reported selling frozen culture fish in the Michigan study. Almost all of the retail stores sell cultured fresh fish and about one-quarter of restaurants offer farm-raised fish on the menu. Most marketing businesses prefer the fish to be processed as fillets and, to a small degree, as steaks. There is a demand for fish to arrive whole or gutted for a specific market or for a business that does its own portion control. Businesses also want fish delivered regularly and year-round.

Of the restaurants, 70% were located within 80.5 km (50 mi) of the Great Lakes. In a separate survey conducted by Purdue University of restaurants selling yellow perch as menu items, of the restaurants asked, most indicated they would double their purchases of yellow perch if aquaculture could increase the supply and somewhat reduce the price.

The traditional “Friday-Night Fish Fry” has made Friday the most profitable day of the week for yellow perch sales, and the demand only increases as more and more people eat out every year. If aquaculture can provide a steady supply of high-quality yellow perch to restaurants, and Friday night fish is promoted, the demand will continue to increase for this fish. Restaurants prefer frozen fillets (51% of firms) to fresh fillets (44% of firms), whereas the product forms actually purchased are 65% frozen fillets and 30% fresh. The highest demand months for yellow perch in restaurants seem to be in the spring and summer, with less demand in fall and winter. Restaurants also prefer standardized portion sizes and with aquaculture, this is easier to achieve than for commercial fishermen.

Restaurants sell their product directly to the consumer and the owner or manager of the restaurant usually decides what fish they will sell.

All of the seafood wholesalers and 27% of the seafood retailers surveyed served restaurants. Fifty-six percent of the seafood wholesalers and all of the seafood retailers served consumers. Fifty percent of the seafood wholesalers served supermarkets. Thrity-three percent of seafood wholesalers served other seafood wholesalers, and 12% served other customers.

Wholesalers usually sell to multiple customers, such as retail stores, restaurants, and, to a smaller degree, institutions and consumers. Unless the wholesaler is selling to a restaurant, they are less concerned about the size of the fish. Most wholesalers deal with more than one marketing activity, with retailing and processing being the most common.

Retailers buy primarily from wholesalers, but there are some that buy from commercial fishermen as well. Overwhelmingly, retailers sell their product to consumers directly. Retailers that do not exclusively sell to consumers have small wholesale operations that also sell to other retailers. They vary in the amount of processing they perform, but most fillet and steak their fish. About one-half of retail stores want a variety of sizes of fish to offer a wider selection to the consumer. The others want standardized sizes to simplify purchasing decisions and for display purposes. Seafood retailers purchase 88% of the fresh fish fillets, 47% of frozen fillets, and 18% of fresh whole fish. They sell 87% of their fresh fillets, 50% of frozen fillets, and 6% of the fresh whole fish.

For supermarkets, 56% of those selling yellow perch are within 80.5 km (50 mi) of the Great Lakes, and the greater the distance away, the less likely they are to sell yellow perch. Large business chains are more difficult to deal with because the volume of fish they request may exceed the volume a single aquaculture facility can provide. It might be necessary to work in conjunction with a large retailer or wholesaler as well.

Food service distributors purchase 33% of the fresh fish fillets, 53% of frozen fillets, and 17% of fresh whole fish. They mostly sell all frozen fillets. To maintain a good market for his/her aquaculture product, a grower can:

- Maintain a consistent product.
- Ask a reasonable price.
- Maintain a constant delivery schedule.
- Provide more variety in fish products.
- Create, maintain, and improve communication with marketing businesses.
- Educate customers.
- Assist in product promotion.

Promotion

Promoting yellow perch can increase its demand and it can be aimed at former yellow perch customers to encourage them to return to consuming yellow perch or to entice new customers to try the fish. Increased sales to restaurants may be encouraged with wholesale sales campaigns, extra commissions, or other such methods. Within a restaurant, the menu clip-ons and table tents can be effective in increasing sales. For an increase in retail sales, the fish's low caloric content, sweet flavor, and nutritional value should be highlighted.

Although it may be an emerging industry, there is potential for yellow perch aquaculture because of the large market in the Great Lakes region and high prices. Aquaculture would be able to supplement the demands of the market because natural stocks have never returned to their peaks of the 1950s and 1960s. Markets include seafood retailers, seafood wholesalers, supermarkets, restaurants, food service distributors, and grocery wholesalers. Expansion of this industry is needed, but a lack of production technologies limits this and new producers repeat mistakes of the past.

For more information on making plans for an aquaculture business and selecting a business structure, see the relevant publications noted in the references.

Summary

- There has historically been a high demand for yellow perch harvested in the Great Lakes region, with almost 70% of the sales occurring within 80 km (50 mi) of the Great Lakes.
- Aquaculture would be able to supplement the demands of the market because natural stocks have never returned to their peaks of the 1950s and 1960s.

Constraints

- Markets are limited to Great Lakes states or areas where there are concentrations of Great Lakes retirees.
- To be competitive with other fish products in nontraditional market areas, fillets must be similar in price to other fish products.
- Other fish have been sold as yellow perch, and confuse the consumer.

Chapter 13

Critical Limiting Factors and Research/Outreach Needs

In 2003, a NCRAC white paper was developed by Jeff Malison that identified critical limiting factors and research and outreach needs for the advancement of yellow perch aquaculture. As of March 2000, a large market for yellow perch existed at prices higher than those of most other cultured fish species. By 2003, however, driven by the importation of inexpensive young pike-perch into the United States and its illegal marketing as yellow perch, the price of yellow perch had declined by 50%. This practice must be halted if a yellow perch aquaculture industry is to develop in this country. In addition to this problem, the yellow perch aquaculture industry is limited by the lack of proven, profitable, and sustainable production technologies. Hopefully, research projects currently underway will help resolve this problem.

Regardless of grow-out system, the relatively high cost of fingerlings/lb of market size is the leading factor that constrains the growth of the industry. Research leading to improved fingerling production methods is clearly needed. It is not yet clear which strategies for grow out will prove to be the most cost-effective. The results of a recently completed NCRAC research project suggest that pond culture will prove to be the most cost-effective method for grow out. Accordingly, research and extension activities for yellow perch grow out should be focused on these systems until other systems show more promise. In this regard, the development of flow-through and net pen systems may be limited in the region by resource management agencies and environmental concerns. Flow-through grow out may be proven feasible in regions having relatively warm (>18°C °[64°F]) ground water or geothermally heated water, or in conjunction with power plants that are operated in a manner that prioritizes aquaculture. Pond fingerling production and/or grow out may meet competition from southern states because of the longer growing season there, but high summer water temperatures may limit this expansion.

In addition to yellow perch in the United States, a significant interest is developing for the commercial culture of the European perch. Because these two species are so closely related, the problems constraining their aquaculture development are similar. Since 1995, an international group of scientists has been collaborating on percid aquaculture. The most recent meeting of this group was at Percis III, a conference held in 2003 in Madison, Wisconsin.

Marketing

Riepe (1998) provided a detailed summary of yellow perch markets and marketing in the NCR. Presently, it seems as though the market for yellow perch is both large and capable of considerable expansion if needed. A critical problem that needs to be resolved, however, is the illegal marketing of pike-perch as yellow perch. Studies on contaminants may improve the marketability of cultured fish compared with wild-caught fish.

Biology and Production Technology

Brood Fish Management and Fry Propagation Methods

Presently, there are few problems with gamete quality or quantity. Methods for spawning yellow perch and incubating and hatching eggs are well developed. One possible advancement that could be made in this area is the development of methods for identifying or producing female brood fish with larger eggs. It has been hypothesized that such females may produce fry having increased survival in some rearing systems. Studies to date, however, have not successfully correlated large egg size with other characteristics of female brood fish (e.g., fish size or age) useful for identification purposes.

The development of methods for producing yellow perch eggs and fry at multiple times of the year, especially in midsummer, holds the potential to double-crop fingerling ponds, thereby greatly increasing fingerling production and reducing costs. Such methods also would greatly facilitate research on tank and pond fingerling culture methods. Accordingly, research efforts aimed at out-of-season spawning of yellow perch should be given high priority.

Diseases in brood fish, eggs, and fry are almost always the result of outbreaks induced by stress or poor husbandry or management. Currently, there are few therapeutic agents that are approved for treating disease outbreaks in yellow perch. Efforts should be made to gain approval for existing treatments known to be effective at controlling bacterial, fungal, and parasitic outbreaks for yellow perch. The availability of such agents would be advantageous for not only brood fish management and fry propagation but also for fingerling production and grow out.

Results from NCRAC-funded studies from several laboratories have confirmed that female yellow perch grow faster than males when raised under a variety of aquaculture conditions. Accordingly, the use of MT to produce monosex female populations of yellow perch holds significant promise to improve yellow perch growth rates and thereby increase the production efficiency of producers. Efforts aimed at gaining FDA approval for using these compounds should continue.

Two of the most important factors that currently constrain the expansion of the yellow perch aquaculture industry are that, compared with most cultured species, yellow perch are small and grow slowly. Consequently, efforts aimed at improving the growth rate of yellow perch should be a high priority. There are different possible approaches to meet this goal. Some of these involving grow-out strategies are discussed under grow out below. Others involve brood fish and are mentioned here.

In several cultured species, e.g., rainbow trout and Atlantic salmon, traditional genetic selection has been an extremely useful approach for developing fish strains having markedly improved growth. Accordingly, such an approach would have a high likelihood of success with yellow perch. It should be recognized, however, that such a project demands continual funding for an extended time (e.g., 5–7 yr or more) before tangible results are obtained. In addition to traditional selection, alternative genetic technologies, including but not limited to transgenics and interspecific, e.g., *Perca flavescens* × *P. fluviatilis*, and intraspecific hybridization, may be useful in developing rapidly growing strains of yellow perch.

Regulatory agencies and environmentalists have expressed concerns that the development of genetically selected domesticated strains, hybrids, or transgenic yellow perch for aquaculture may harm wild populations of fish, including yellow perch. Unbiased studies are needed to document the extent of this possible threat.

Fingerling Production

One of the primary factors constraining the expansion and profitability of the yellow perch aquaculture industry is the high price of feed-trained fingerlings to grow-out producers. Compared with other species, food-size yellow perch are harvested and marketed at a small size.

For example, rainbow trout, channel catfish, and hybrid striped bass are usually marketed at 0.7 kg/fish (1.5 lb/fish), whereas yellow perch are marketed at 0.11–0.15 kg/fish (0.25–0.33 lb/fish). As a consequence, 4–6 times as many fingerlings are needed to produce a given weight of yellow perch compared with other fish species. Thus, fingerling purchases represent 35–50% of the total operating costs of yellow perch production, regardless of the method used for grow out (Riepe 1997; Hoven 1998).

Research to develop methods for improving the cost-effectiveness of yellow perch fingerling production should be high priority. Such research could be focused on any or all of the three methods described above (tank culture, tandem pond/tank culture, and pond culture), or on new, innovative methods.

If tank culture research is conducted, it should focus on improving swim bladder inflation and the development of viable feeds for yellow perch larvae, because significant breakthroughs are needed in these areas for this method to have commercial potential. Research on improving the tandem pond/tank and pond culture methods should focus on the continued development of new and innovative culture strategies.

For pond culture, efforts should be directed at increasing the average fish size at harvest, decreasing the variation in the size of fish harvested, improving the overall productivity of ponds, and developing methods that improve the habituation of pond-raised fingerlings to tank culture conditions. For both the tandem pond/tank and pond culture methods, evaluations of the large number of existing formulated starter diets are needed, and the development of diets having increased palatability and acceptance should be high priority (Kolkovski et al. 2000).

Grow Out

Regardless of the grow-out system used, research aimed at developing least-cost diets for yellow perch would decrease production costs and is, therefore, warranted. The growth rate of yellow perch could be improved by the use of dietary growth enhancers (including hormones and hormone analogs), but the likelihood of FDA approval and the impact on consumer acceptance of such compounds should be evaluated before funding such studies.

For RAS, most of the research needed on yellow perch grow out is not unique to one fish species but rather has broad applicability across species. Improvements are needed in filter technology, specifically the removal of ammonia, nitrite, and suspended solids. With suspended solids, the development of diets that reduce fine particulate fecal matter also is a priority.

For pond culture, the documentation of production parameters, e.g., fish growth rates and the kg/ha or lb/acre that can be produced, should be high priority. Also, the specific geographic region best suited to raising yellow perch in ponds needs to be determined. Subsequently, the testing of various strategies known to affect the production efficiency of raising other fish species in ponds, e.g., feed management practices, aeration/water circulation, water addition, and frequency of harvest, needs to be conducted.

Processing

Compared with hand filleting, machine filleting of yellow perch could lead to a significant reduction in the cost of processing yellow perch. Thus, the yellow perch aquaculture industry may benefit from improvements in fillet machine technology.

Economics

Business planning requires significant and reliable economic data that currently does not exist. Economic information that documents the true production costs of raising yellow perch fingerlings is needed. Although price information on fingerlings is readily available, the comparative costs of using different methods to raise yellow perch fingerlings are unknown. It may be difficult to procure such information for tank culture, because little or no commercial production is presently underway. Such information should be attainable, however, for the tandem pond/tank and pond culture methods of fingerling production.

For grow out, there currently exists a divergence of opinion among experts as to which system(s) will prove to be the most cost-effective method of producing yellow perch. The recently completed NCRAC study should be helpful at determining the true production costs by using different systems.

Extension

One critical problem that needs to be resolved is the illegal marketing of pike-perch as yellow perch. A second problem, the lack of practical information on yellow perch aquaculture, will hopefully be alleviated by this guide. In addition, a historical documentation of successes and failures of commercial yellow perch aquaculturists may prevent new producers from repeating past mistakes. Conferences and "short courses" targeting specific areas of yellow perch aquaculture seem to be in high demand and are, therefore, warranted. To date, extension activities have been focused to a far greater extent on RAS as opposed to pond systems; thus, more effort should be aimed at pond fingerling and grow-out methods.

Summary of Research and Extension Priorities

It is difficult to rank research and extension priorities, and there is always the potential for bias. The following prioritized list was presented at the 2000 NCRAC Annual Program Planning Meeting (February 25–27, 2000, Kansas City, Missouri), and a general consensus existed with regard to this list among the commercial producers, researchers, and extension personnel in attendance. The most important research and extension needs for the development of yellow perch aquaculture are ranked numerically into categories in order of priority.

Research

1. Reduce fingerling production costs by improving fingerling production methods.
    - Develop methods for inducing out-of-season spawning.
    - For pond and pond/tank culture: develop methods to increase average fish size and total productivity of ponds, decrease variation in fish size, and improve habituation of pond-reared fish to tanks. Also, develop starter diets having increased palatability.
    - Tank culture: develop larval feeds and methods to increase swim bladder inflation.
    - Document the costs of raising fingerlings using different methods.
2. Develop methods for improving growth rates and fillet yields of yellow perch in ponds and recirculation systems.
    - Use traditional genetic selection between and within families (<u>not simply mass selection</u>) to develop fast-growing strains of yellow perch, recognizing that useful results will take a sustained effort of at least 5–7 yr.
    - Continue efforts aimed at gaining approval for using MT (to produce monosex females) and therapeutics in yellow perch.
    - Test alternative strategies, e.g., feeding strategies, hybridization, and transgenics, to improve growth in yellow perch.
3. Document the production parameters and costs of raising perch to market size in RAS and ponds.
    - Complete the ongoing NCRAC-funded study evaluating different system types.

- Evaluate different geographic regions for raising yellow perch to market size in ponds.

4. Improve recirculation and pond systems for raising yellow perch to market size.
   - Develop least-cost diets and evaluate dietary growth enhancers.
   - Develop improved filters for recirculation systems that remove ammonia, nitrite, and solids, and develop diets that reduce fine particulates.
   - Test and improve on pond management strategies.
5. Develop methods for reducing processing costs.

Extension

1. Stop the illegal practice of marketing other species as yellow perch.
2. Develop an historical record of successes and failures of commercial producers.
3. Conduct conferences targeting specific topics.
4. Increase emphasis on pond fingerling and grow out.

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Appendix 1. Recommended Submission Form for Disease Diagnosis

Date: _______/_______/_______ Facility: ____________________ _____________________
Submitted by: _________________________________
Phone: (_____)_________________
Reason for fish submission:
_____ Increasing mortalities _____ Morbidity_____ Planned sample
_____ Other (Explain) ____

What treatments have been applied to these fish?____

FISH IDENTIFICATION
Species: ____________________Strain: _______________ Lot Code: ________________________
Age: _________________ Sex: ____________ No. of fish submitted______________
Anticipated marketing date: _____/______/______

ORIGIN OF EGG
_____ Wild caught ____ Hatchery

Location/State____
Treated with: _____ Antibiotics _____ Formalin _____ Others

Explain ____

MORTALITIES (if applicable)
Date mortalities began _______/_______/_______
Progression and current status____
____
____
____

MORBIDITY
Describe fish behavior: (e.g., normal, gasping at the surface, lethargic, flashing) _________________________
____
____

Describe recent eating pattern (be specific)____
____
____

Describe abnormal external pathology:
_____ Color change _____ Fuzzy gills/body _____ Dropsy
_____White spots on skin _____ Fin/tail rot _____ Reddened/hemorrhagic fins
_____ Red spots covering body _____ Exophthalmia/bulging eyes_____ Furuncles
_____Other (write in)____

Gill scraping results: ____
____

Skin scraping results: ____

FACILITY CONDITIONS

No. of fish in each culture system of concern: ______________________________________

Density (kg/m^3) of fish in each culture system of concern: ____________________________

Type of water supply: ____________________ Flow rate (L/min): _______________________

Tank volume turnover time (minutes): __________Feeding interval: _____________________

Water conditions: Temperature ________ DO ________ pH ________ NH_3 _________ NO_2^-______

NO_3^-________ Other abnormal conditions (describe)___________________________________
____

Other culture systems that share the same water supply:

Upstream______________________________________

Downstream____________________________________

Parallel_______________________________________

Describe other raceways and/or species with mortality/morbidity? _______________________
____

Describe weather preceding mortalities ____
____

Describe weather during mortalities ____
____

HISTORY

Any recent history of disease at the facility? No_____ Yes_____ Explain__________________
____

Any historical disease problems with this species at the facility? No_____ Yes_____ Explain__________
____

Any historical disease problems with this culture system? No_____ Yes_____Explain______________
____

Appendix 2. List of Abbreviations

×	cross; times
=	equal
>	greater than
<	less than
≈	approximate
AquaNIC	Aquaculture Network Information Center
BLM	beef liver mash
BSN	brine-shrimp nauplii
C	carbon
˚C	degrees Celsius
cm	centimeter
CSREES	[USDA] Cooperative State Research, Education and Extension Service
d	days
DHA	
DO	dissolved oxygen
˚C	degrees Celsius
˚F	degrees Fahrenheit
FCR	feed conversion ratio
FDA	Federal Drug Administration
FSD	formulated starter diet
ft, ft^3	foot, cubic foot
g	gram(s)
gal	gallon(s)
gpm	gallons per minute
GTW	green tank water
hr	hour(s)
ha	hectare(s)
HACCP	Hazard Analysis Critical Control Point
hp	horsepower
HCG	human chorionic gonadotropin
in	inch(es)
INAD	Investigational New Animal Drug
IU	international unit(s)
kg	kilogram(s)
km	kilometer(s)
L	liter(s); length
lb	pound(s)
Lpm	liters per minute
m, m^3	meter, cubic meter
µm	micrometer
mi	mile(s)
min	minute(s)
MJ	millijoule
mm	millimeter(s)
MSDS	materials safety data sheets
MT	methyltestosterone
N	nitrogen
NCR	North Central Region
NCRAC	North Central Regional Aquaculture Center
NH_3	ammonia or unionized ammonia
NH_4+	ammonia or ionized ammonia
NO_2-	nitrite
NPDES	National Pollution Discharge Elimination System
oz	ounce(s)
P	phosphorus
P_2O_5	phosphate
ppm	parts per million
PSI	pounds per square inch
qt	quart
RAS	recirculating aquaculture system
SSOP	sanitation standard operating procedure
TAN	total ammonia nitrogen
TL	total length
UV	ultraviolet
YOY	young-of-the-year
yr	year(s)

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