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Zooplankton Succession and Larval Fish Culture in Freshwater Ponds

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Larval fish culture is one of the riskiest phases of freshwater fish culture, but it can be one of the most profitable. Special planning is required to overcome the risk of high mortality during fry culture. Producers must have a dependable larvae supply, a facility appropriate for fry and fingerlings, the right size fry, the right kinds and quantity of food, and fry weaned from natural to prepared foods. They must also take special care in handling fish and preparing the pond. This fact sheet concentrates on the relationship between fry size and the types and sizes of zooplankton found in culture ponds. Zooplankton is required as a first food for many cultured fish; for others it contributes to faster growth and higher survival.

Pond size

Ponds for fry culture and small fingerling production should be smaller than grow-out ponds. Ponds from 0.1 to 3 acres are ideal because they are easier to harvest and will produce more natural food per unit area. There is a higher ratio of pond bottom area to water volume in small ponds than in large ponds, which increases the availability of fertilizing nutrients and resting zooplankton eggs. Increased shoreline to water volume increases the number of small insects being blown into the pond, and they may be a significant source of food for fingerlings. However, ponds with lots of shoreline may have more problems with predaceous wading birds.

Using many small ponds rather than a few large ponds may ensure that at least some fingerlings get to market. Smaller ponds allow the farmer to more easily control the size of the fish by manipulating nutrient (either fertilizer or feed) input. Small ponds also allow the farmer to more easily determine fish size and estimate survival rates because it is easier to locate the fish. With many small ponds instead of a few large ones, farmers can grow fingerlings of different sizes for various markets. Spreading different sizes of fingerlings among different ponds also helps minimize cannibalism. Farmers can rotate the harvest among many small ponds rather than harvesting the same pond over and over; this reduces stress.

Of course, the benefits of smaller ponds must be balanced against the increased costs and decreased pond area per acre of land that result when small ponds are used.

Fry size

Tiny fry eat only tiny prey, but tiny fry are preyed upon by many creatures bigger than they are. It is important to know the size of the fry you are stocking and to make sure that the pond you are putting them into contains plankton of the size that will be their prey and is also void of creatures that will prey on the fry.

The total length of cultured fish fry (Table 1) when they hatch varies from 2 mm for sunshine and white bass to more than 15 mm for muskellunge. In most cases, fry are a few millimeters longer than the values in Table 1 when they are stocked into ponds. Suggested stocking times in the table are based upon the size of the fry and the sizes and types of zooplankton that show up at different times in ponds that have been filled with well water and fertilized. It is safer to stock earlier than the time listed than to stock later. Stocking later increases the chance that predaceous zooplankton or insects will be present.

Plankton types and sizes

Pond plankton is composed of tiny plants called phytoplankton and animals called zooplankton, as well as organisms that are not easily classified into those two groups (such as protozoans and

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Table 1. Total lengths of fry for commonly cultured cool and warm water fish.			
Common name	**Scientific name**	**Fry size (mm)***	**When to stock fry****
Sunshine bass	*Morone chrysops X M. saxatilis*	2-6	5
White bass	*M. chrysops*	3-4	5
Black crappie	*Pomoxis nigromaculatus*	3-5	5
White crappie	*P. annularis*	3-5	5
Goldfish	*Carassius auratus*	3-5	5
Fathead minnow	*Pimephales promelas*	4-6	5
Rosy-red minnow	*P. promelas*	4-6	5
Sauger	*Stizostedion canadense*	4-6	5
Golden shiner	*Notemigonus chrysoleucas*	4-7	5
Common carp	*Cyprinus carpio*	5-7	5
Yellow perch	*Perca flavescens*	5-7	5
Largemouth bass	*Micropterus salmoides*	6-7	7
Walleye	*Stizostedion vitreum*	6-9	7
Grass carp	*Ctenopharyngdon idella*	6-9	7
Silver carp	*Hypophthalmichthys molitrix*	6-9	7
Bighead carp	*H. nobilis*	7-8	7
Striped bass	*M. saxatilis*	7-10	10
Palmetto bass	*M. saxatilis X M. chrysops*	7-10	10
Paddlefish	*Polyodon spathula*	8-10	10
Spotted sucker	*Minytrema melanops*	8-10	11
White sucker	*Catostomus commersoni*	8-10	11
Shovelnose sturgeon	*Scaphirhynchus platorynchus*	>10	12
Channel catfish	*Ictalurus punctatus*	10-12	13
Muskellunge	*Esox masquinongy*	11-15	14

*25.4 mm equals1 inch

**Estimated number of days after pond starts filling at 21 to 27^{o} C (70 to 80^{o} F)

Sources of fry sizes for Table 1:

Becker, G. 1983. Fishes of Wisconsin. University of Wisconsin Press. Madison, Wisconsin.

Carlander, K.D. 1977. Handbook of freshwater fishery biology. Vol. 2. The Iowa State University Press. Ames, Iowa.

Ludwig, G.M. 1996. Tank culture of sunshine bass *Morone chrysops X M. saxatilis* fry with freshwater rotifers *Brachionus calyciflorus* and salmon starter meal as first food sources. *Journal of the World Aquaculture Society* 25:337-341.

Halver, J., ed., Horvath, L., G. Tamas and I. Tolg. 1984. Special methods in pond fish husbandry. Academiai Kiado, Budapest, Hungary, and Halver Corporation, Seattle, Washington.

Huq, M.F. 1965. The effect of crowding on the growth of fry of channel catfish *Ictalurus punctatus* (Rafinesque). Scientific Researches (Dacca, Pakistan). 2:112- 117.

bacteria). Planktonic organisms are suspended in the water and are so small that even slight currents move them about. Fish fry eat zooplankton, phytoplankton, and tiny plants and animals attached to objects on the pond bottom.

Most fish fry eat three main types of zooplankton—rotifers, copepods and cladocerans. For the tiniest fish fry, such as the newly hatched fry of sunshine bass or white bass, small rotifers may be the only zooplankton small enough to eat. For larger fry, the smallest rotifers may not provide enough nutrients to make chasing and ingesting them worth the effort. Copepod nauplii, which are just-hatched copepods, are important first foods for larval fish, too. Protozoans may also be eaten, but little is known about their contribution to fry diets.

In general, the smallest of the main zooplankton groups are rotifers (Fig. 1). Body lengths of rotifer species vary from 0.04 to 2.5 mm. This diverse group of animals obtained their name from their “wheel organ,” a ring of cilia that appears to rotate around the mouth. They are often the earliest visible zooplankton to appear in ponds, hatching almost immediately after ponds are filled. Rotifers reach maturity 2 to 8 days after hatching and some species can increase in number very rapidly. Rotifers that show up later in ponds, when larger zooplankton are present, are usually much larger than the first that appeared. The first rotifers hatch from “resting eggs” that survived on the pond bottom during inclement weather or while the

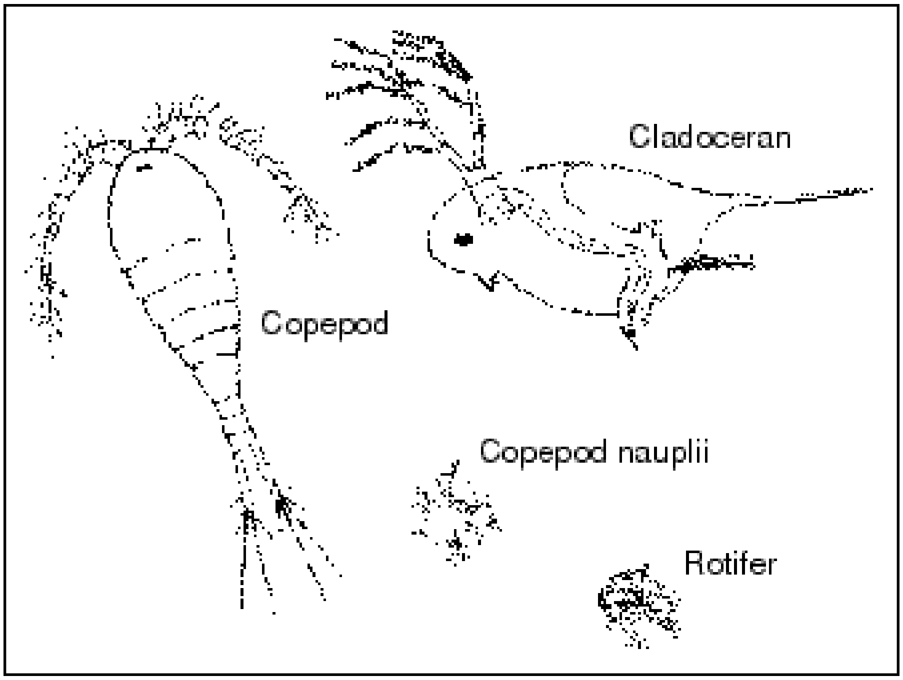

Figure 1. Common zooplankton in fish culture ponds. (Drawings from Taxonomic Keys to the Common Animals of the North Central States, 1982. Burgess Publishing Co. Minneapolis, Minnesota, used with permission from James C. Underhill.)

pond bottom was dry. Most of them hatch into females that reproduce asexually until pond conditions become harsh. Then sexual reproduction occurs and resting eggs are again produced.

Copepod nauplii are the next largest zooplankton to appear after ponds are filled and fertilized (Fig. 1). They hatch from resting eggs that were dormant on the pond bottom. Resting eggs are produced in the fall by sexual reproduction. At other times reproduction may be sexual or asexual. After hatching, the young copepods grow by shedding their exoskeletons up to 12 times in stages called instars. They reach maturity about 18 days after ponds are filled. As they grow they provide larger and larger food for larval fish. The largest freshwater copepods may reach 2 to 3 mm. Only large fry, such as those of channel catfish, have mouths big enough to eat adult copepods initially.

Although copepods may be prey for larger fish fry, sometimes the roles are reversed. Introducing small fish fry into a pond full of large copepods can be disastrous. One group of copepods, the cyclopoids, is predaceous. They feed on smaller zooplankton and even on fish fry. When cyclopoid copepods are prevalent, they may eat all the fish fry stocked.

Cladocerans, often called water fleas because of their shape and “hop-sink” type of locomotion, are the third major group of zooplankton found in freshwater ponds (Fig. 1). Larger fry and even adults of some fish species often selectively prey on these crustaceans. Cladocerans 2 to 3 mm long are commonly found in culture ponds several weeks after the ponds are filled. Often only female cladocerans are found, except in early spring and late fall. Like some other zooplankton groups, cladocerans hatch from resting eggs when ponds are filled. Later, eggs are held in the females before hatching. Cladocerans compete with rotifers and calanoid copepods for phytoplankton.

Pond preparation

Ponds that are drained, dried, and then filled with well water are much safer for culturing fry than are ponds filled with surface water. Starting with water that does not contain zooplankton makes it much easier to predict when the right size zooplankton for the fry will appear in the ponds. It also helps to ensure that zooplankton, fish predators, parasites, diseases, and a variety of fry-eating insects are not abundant in the ponds when fish are stocked. If surface water must be used, it should be filtered through a filter fine enough to prevent even small copepods from passing through (125-micron mesh).

Ponds should be properly fertilized as they are being filled. If fry will depend on zooplankton for food, a combination of organic and inorganic fertilizers is best. Organic fertilizers are the basis of the food chain that nourishes bacteria, protozoans, zooplankton, and eventually the fish fry. (Some organic fertilizers, such as rice bran, are fine enough to be directly consumed by zooplankton). As organic fertilizers decompose, their nutrients are used by phytoplankton, which is consumed by some types of fry. Or, the phytoplankton is eaten by protozoans or zooplankton before they are eaten by fry. Nutrients from organic fertilizers are released over time, so they produce less drastic changes in plankton populations than do inorganic fertilizers.

Inorganic fertilizers add nutrients to the pond instantly. A phytoplankton-based food chain can develop very rapidly without the need for bacterial action. However, the nutrients are often used up very rapidly by the tiny plants, and the risk of a bloom “crash” is greater than it is with organic fertilizers.

Using a combination of organic and inorganic fertilizers results in a greater diversity of plankton than if either fertilizer type is used alone, and reduces the potential for a dangerous bloom crash.

Fertilizer nutrients are used quickly in the pond environment. Some nutrients are trapped in the bottom mud or otherwise lost from water. Therefore, nutrients should be replenished often. Frequent applications of small amounts are more effective than a single large application for maintaining a supply of fry food organisms. Additional information can be found in SRAC Publication 469, "Fertilization of Fish Fry Ponds."

Timing of fry stocking

The proper timing of fry stocking, in relation to filling and fertilizing the ponds, can make the difference between having an abundant harvest or a complete crop loss. Proper timing is also important for optimum growth of the fry. Ponds must contain the appropriate type and size of food when fry are stocked. Large fry stocked into ponds with very tiny zooplankton may grow slowly because the fry must expend so much energy to catch an adequate amount of food. Likewise, if the zooplankton are mostly too large for the fry to eat they may starve, or become prey of cyclopoids or insects.

When ponds are filled and fertilized, the plant and animal populations that invade or hatch from within the bottom mud pass through somewhat predictable changes in sizes and species (Fig. 2). This process is called succession. At first there are usually a few small species in large concentrations. Later there will be many species in an array of sizes, but each in moderate concentrations. The average size of organisms also gets larger with time. The early community is unstable and great changes can occur quickly; later, the greater diversity of organisms makes the community more stable.

Knowing how succession happens in fry culture ponds will help a producer be more successful. Figure 2 illustrates the successional process in ponds in Arkansas during the spring when temperatures are 21 to 24° C (70 to 75° F) (sunshine bass fry were also present in these ponds). When ponds are first filled with well water, there are few living organisms and few nutrients. The water rapidly gains nutrients from the bottom, particularly when soluble inorganic fertilizers are added. It also gains nutrients, but more slowly, as organic fertilizers are decomposed by bacteria. Phytoplankton and other bacteria rapidly use released nutrients. Within a few days, growing populations of phytoplankton may provide a green tinge or "bloom" to the water. This indicates that there is a growing food base for single-celled protozoans and other zooplankton. In many ponds the water first appears brownish. This happens when the bacterial food levels are large enough to cause huge protozoan or rotifer blooms without much phytoplankton being present.

Although some protozoans may be large enough for tiny fry to eat, it is the next stages in succession that are of greatest importance to fry. Rotifers usually appear first. Rotifers feed on bacteria and phytoplankton, and then reproduce to form huge populations. When water temperature is 21 to 27° C (70 to 80° F), rotifers can go from nearly nonexistent to concentrations in the thousands per liter by the second week after a pond is filled. As rotifers eat their own food supply the population drops drastically. Then copepod nauplii, adult copepods and cladocerans make their appearance. Cyclopoid copepods prey on small rotifers. Calanoid copepods and herbivorous cladocerans out-compete them for phytoplankton. Together, copepods and cladocerans prevent a re-bloom of the smallest rotifers. However, modest populations of larger rotifers may appear after several weeks, particularly when fish fry prey on the rotifers' competitors and predators—cladocerans, copepods and insects.

Because of the ephemeral nature of high density rotifer populations, timing is critical if the fry being stocked are so small that they can eat only rotifer-sized prey. Most fry 6 mm long or less fall into that category. Fry must be stocked just before the rotifer population begins its rapid growth (Fig. 2). If the fry are stocked when rotifer populations are rapidly rising there will be plenty of food and the fry should grow rapidly and be large enough to eat copepod nauplii and larger zooplankton when those organisms appear. The fry will also have a much better chance of being large enough to avoid being eaten by cyclopoid copepods.

Larger fry (more than 6 mm) should be stocked into ponds as populations of copepod nauplii, copepods and cladocerans begin to climb (Fig. 2). That usually happens 2 to 3 weeks after ponds are filled when water temperature is 21 to 27° C (70 to 80° F). The fry will then have the right size food

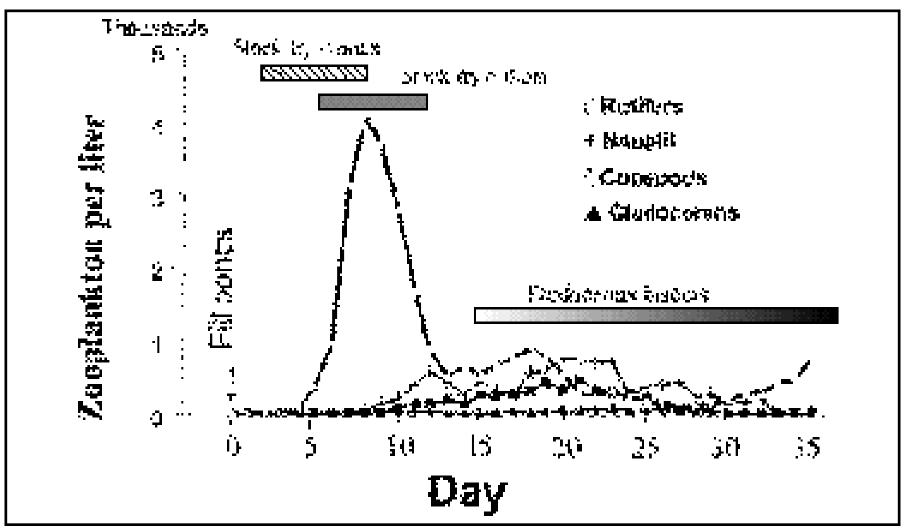

Figure 2. Small fry, those less than about 6 mm long, should be stocked before rotifers reach their initial peak density. Fry longer than 6 mm may be stocked slightly later but before predaceous insect populations are high. This graph illustrates succession of the zooplankton community as it usually occurs in a fish culture pond that has been filled with well water and fertilized. This data was obtained from ponds that contained sunshine bass fry that were preying on the zooplankton.

for rapid growth and can better escape predation from aquatic insects that soon begin to populate the pond.

In general, fry must have zooplankton to survive, or at least to be healthy and grow rapidly. Most fry are not particular about the types of zooplankton they eat, but the organisms must be small enough to fit into their mouths. To maximize survival, stock any fry just as populations of zooplankton small enough for the fry to eat are rapidly increasing and before invading predators become numerous.

Stocking even large fry into a pond that has been filled for more than 3 to 4 weeks during warm weather can result in high mortality. By that time, a variety of fry predators have invaded the pond and begun to reproduce. These include insects such as back-swimmers, diving beetles and whirlygig beetles. Later, even larger insects such as water scorpions, giant water beetles and the larval stages of dragonflies will appear.

Insects begin to colonize as soon as ponds are filled during warm weather. However, it usually takes several weeks for their populations to reach levels threatening to small fish.

Predaceous cyclopoid copepods are often a much greater threat to fry than insects. Many of these tiny zooplankton will prey upon fry unless, or until, the fry are large enough to prey upon them. Cyclopoid copepods often are abundant in ponds after about 10 days when water temperature is 20 to 25° C (68 to 77° F). Because there are no legal means of controlling undesirable zooplankton or insects, it is important that fry, particularly small fry, be stocked into ponds as early as appropriate after ponds are filled.

The effects of weather must also be considered when stocking fry. Temperature has a profound effect on the successional process. Figure 3 shows that the colder the water the more time is required for rotifers to reach their initial peak population.

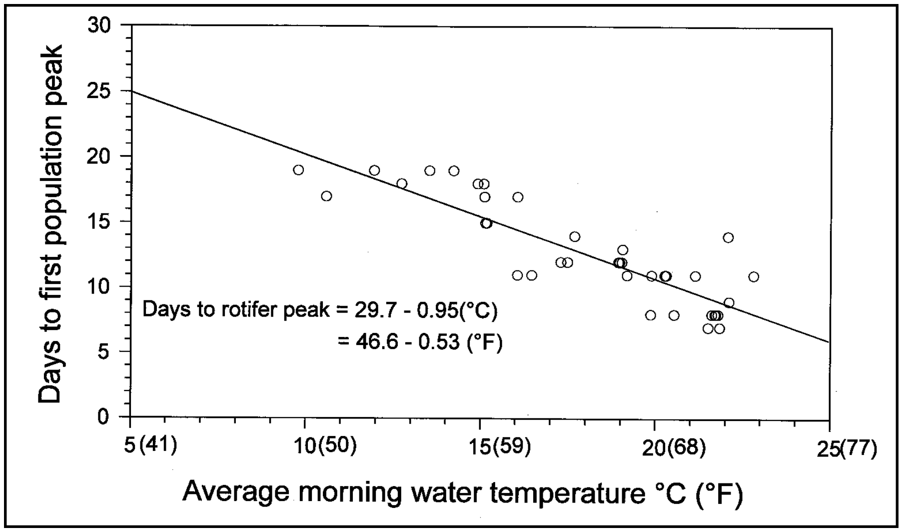

Figure 3. The effect of water temperature on the time to peak rotifer populations in a fertilized culture pond. Cold water slows the development of zooplankton populations.

Researchers are developing methods of predicting when some zooplankton events will occur under different temperatures. Figure 3 shows that the time it takes to reach an initial rotifer peak is related to the mean morning water temperture in the following way:

Days to rotifer peak
= 29.7 – 0.95 (average morning water temperature in °C)
= 46.57 – 0.53 (average morning water temperature in °F).

If you know the average water temperature on a farm for selected dates you can predict how long it will take to reach a peak in the rotifer population. If the fry being rasied require rotifers, they should be stocked several days before the peak.

There is also a relationship between the mean average daily air temperature on days between filling the pond and reaching the peak and the time it takes rotifers to reach their initial peak density (Fig. 4). The relationship is

Days to reach rotifer peak
= 27.4 – 0.89 (mean average daily air temperature in °C)
= 43.22 – 0.49 (mean average daily air temperature in °F)

where average daily air temperature is defined as high daily temperature plus low daily temperature divided by 2.

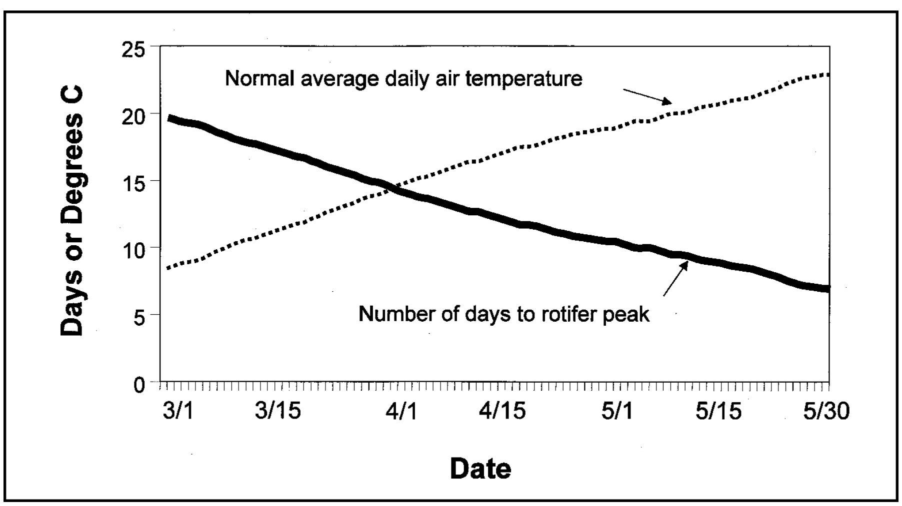

Figure 4. The number of days it takes to reach a peak in the rotifer population in culture ponds at Stuttgart, Arkansas during the spring.

Fish farmers can use this relationship to approximate the time required for rotifer populations to reach an initial peak starting any spring day for any location. To do that, normal, daily average air temperatures for the location are substituted into the equation and a curve is drawn. Figure 4 illustrates this procedure for Stuttgart, Arkansas. Normal daily air temperature data can be obtained from local airports or from the U.S. Department of Commerce, National Climatic Data Center, Federal Building, Asheville, North Carolina 28801. "Local Climatological Data—Unedited" can also be obtained at www.ncdc.noaa.gov.

Weaning fry to artificial feed

Some fry, such as channel catfish, can be grown on artificial feeds alone, but even these fry will grow better and be healthier when zooplankton are present. However, an objective in all fry culture is to train the fry to eat artificial feeds, because fry ponds are stocked at densities so high that natural foods alone cannot sustain good growth of fingerlings. Unless fish are adapted to filter feeding (such as paddlefish) they expend more energy catching zooplankton than they derive from eating them.

At some point, fingerlings will be consuming zooplankton faster than it can be produced in the pond. By that time they should be well on their way to learning how to consume artificial feeds. This learning process should be completed before zooplankton stocks are exhausted.

Sometimes, however, small fingerlings are brought into tanks and trained to eat manufactured feed. This abrupt change from natural feeds can cause high mortality. It is better to wean fish to manufactured feeds by a process called "feeding the pond."

Feeding the pond means spreading finely ground feed across the pond at a rate of about 10 to 50 percent of the weight of fry in the pond. It is hard to determine the weight of the fry, so the typical amount used is 1 to 2 pounds of feed per acre for small fry and 4 to 8 pounds of feed per acre for catfish and other large species. The fish should be fed twice a day for 3 weeks. For small fry, use the finest size feed available. For larger fry, a fine crumble may be used. After the initial 3-week period, increase the amount of feed to 3 to 7 pounds per acre (12 to 24 pounds for large fry) applied twice a day for another 3 weeks. At the same time, increase the size of the feed. After the second 3-week period, check to see if the fry are large enough to eat a crumbled feed.

When the fish begin to take feed at the surface, the amount of feed offered can be adjusted to meet their needs by watching the fishes' behavior. Feed just a small amount more than they immediately consume and later check to see if the additional feed is eaten. Adjust the amount of feed offered accordingly.

Fry feeds have a higher protein content than feeds for larger fish, because fry are growing at a faster rate and must consume large amounts of protein and other nutrients. Fry of fish that are piscivorous (fish eaters), such as striped bass and their hybrids, require a protein content of about 55 percent. Minnows and catfish require feeds with 40 to 50 percent protein. The general rule is that the higher the adult fish are on the food chain, the more protein the fry require.

Most fingerling producers remove their fish from the ponds and sell them, or restock them at lower densities, at the time when natural food in the pond can no longer support the standing crop of fingerlings.

A fingerling operation that is carefully planned and based on what is happening in the pond has the best chance of being profitable.

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