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Fertilization of Fish Fry Ponds

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Fish farmers fertilize fry ponds to increase the amount of suitable natural foods for young fish. Applying fertilizer stimulates the production of organisms that serve as the first foods for many species of fish and increases fry survival and growth. Fertilization also causes the water to develop a “bloom,” a turbid, green to brown color caused by microscopic organisms called phytoplankton (plants) and zooplankton (animals). The bloom shades the pond bottom and helps prevent the growth of aquatic weeds.

Fish fry feed primarily on zooplankton. Natural foods may also include large bacteria, protozoans and phytoplankton. Fry of most fish species feed primarily by sight, and target individual food particles. Ideal food particle size is directly related to fry size. The size of the most abundant natural food organisms generally increases with time, as the plankton bloom develops. To ensure that available natural foods are of the appropriate sizes for fish fry, proper timing of fry stocking after filling and fertilizing a pond is very important.

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The ideal fertilizer would provide a rapid, reliable and appropriate response from a single application. Unfortunately, there is no single recipe for obtaining abundant natural foods every time in every pond or location. Soil and water characteristics profoundly influence fertilizer requirements and responses. For example, hill ponds that receive runoff from fertile watersheds may require little or no additional fertilizer. Waters with high calcium hardness typically require higher levels of phosphorus per fertilizer application, because calcium in the water will precipitate the phosphorus. While row crop farmers expect differing fertilizer recommendations depending on soil type, fish farmers usually do not have such information for ponds, except in general terms. Many different fertilizer types, forms and rates have been used with varying degrees of success. In the absence of site-specific information, farmers must experiment and use their experience to adjust fertilization practices to get satisfactory results. Table 1 suggests a fertilization schedule to use as a starting point. Fish culturists will need to adapt these recommendations to meet the specific conditions of individual locations, farms and ponds.

Pond preparation

To prepare a pond for stocking fry, begin with a dry pond bottom. If possible, disk and roll the pond bottom before stocking unless the pond has a history of leakage, in which case the pond bottom is best left undisturbed to avoid breaking the seal. If weather or other factors prohibit disking, leave ponds empty as long as possible before stocking. If the pond cannot be dried, apply an approved chemical to the remaining water to kill all existing fish and other organisms, such as predaceous insect larvae, crayfish, etc., that would affect the fry. If the pond has aquatic vegetation, it must be eliminated before stocking.

Check the water supply for new ponds before fertilizing. One important parameter of the water is the alkalinity. Alkalinity stabilizes pH and facilitates the uptake of nutrients by phytoplankton. If the water has less than 20 mg/l total alkalinity, liming is necessary. Waters that have between 20 and 50 mg/l alkalinity would benefit from the application of lime, while waters above 50 mg/l alkalinity do not require lime. If ponds receive runoff water from watersheds with acidic soils, supplemental liming will probably be necessary. The initial liming rate is

Table 1. Suggested fertilization schedule. Use this as a starting point and modify for your pond conditions by adding more or less of the two types of fertilizer.

Organic fertilizer		+ Inorganic fertilizer		
rice bran, cottonseed meal, or alfalfa pellets		liquid 10-30-0 or similar	OR	powdered 0-49-0 or similar
day*	**pounds/acre**	**gallons/acre**		**pounds/acre**
1	250	2 to 4**		16 to 32**
8	50	1 to 2		8 to 16
If needed:***				
14	50	1 to 2		8 to 16
21	50	1 to 2		8 to 16
28	50	1 to 2		8 to 16

* Day 1 is the first day the pond is being filled.

** For ponds with calcium hardness below 50 mg/l, use the lowest rate. For each additional 75 mg/l of calcium hardness, add an additional 1 gallon/acre of liquid or 8 pounds/acre of powdered fertilizer. For example, if the calcium hardness is 200 mg/l, use 4 gallons/acre of liquid or 32 pounds/acre of powdered. For repeat applications, use one-half of the initial rate.

*** Continue fertilization if the secchi disk reading is greater than 18 inches. Do not add more fertilizer if the dissolved oxygen reading is less than 4 ppm or if the secchi disk reading is less than 9 inches. If this schedule does not produce an adequate bloom, add fertilizer more often rather than increasing the amount per application.

based upon the pH of the pond bottom soils. Your state Cooperative Extension Service can help you check your soil and water for this value and recommend the amount of lime needed.

Fertilizer types

Fertilizers are divided into two main types, inorganic (e.g., 11-37-0, N-P-K) and organic (e.g., cottonseed meal). Usually it is best to use both inorganic and organic fertilizers because a combination provides a broad food base to a variety of zooplankton that are consumed by the fish fry. In some circumstances, organic or inorganic fertilizers alone have been reported to provide comparable or even superior results. For most fish species, there are no compelling, consistent research results to indicate which type or combination of fertilizer is best, so local availability and cost are the most important factors in selecting fertilizers.

Inorganic fertilizers

Inorganic fertilizers are man-made, directly or indirectly, through chemical reactions, and are readily available at farm supply stores. These compounds provide plant nutrients in a concentrated form and stimulate the growth of phytoplankton that serve as food for zooplankters. Zooplankton in turn are consumed by fish fry.

The grade of a fertilizer indicates its content of nitrogen, phosphorus and potassium as a percent by weight. Thus an 11-37-0 fertilizer has 11 percent nitrogen (N), 37 percent phosphorus (as P_2O_5), and 0 percent potassium (as K_2O). Phosphorus is the most important plant nutrient for bloom development. Some nitrogen may be needed as well, especially in new ponds or in combination with organic fertilizer to hasten its decomposition. Potassium is rarely required.

Several studies have concluded that phosphoric acid is the best form of phosphorus to use, and that urea is the best form of nitrogen. However, local availability, cost, solubility and farmer experience are most important in deciding which type to use.

Inorganic fertilizers come in granules, powders and liquids. Each form has its proper application method and this is critical to obtaining the best results. Liquid fertilizer can be applied by dripping the product into the prop wash of an outboard motor while the boat is being driven around the pond, or by mixing the fertilizer with 10 parts water and spraying it over the pond surface. Since liquid fertilizer is heavier than water (12 pounds/gallon versus 8.3 pounds/gallon for water), it must be diluted before it is sprayed to prevent it from sinking to the pond bottom.

Powdered fertilizer is very soluble and can be blown out over the pond surface.

Granular fertilizers generally do not dissolve quickly, and when the grains hit the pond bottom, much of the phosphorus in the fertilizer is adsorbed by the mud and is lost. For this reason, granular fertilizers must be dissolved in water first (which is impractical for large ponds) or kept above the pond bottom. Granules may be poured onto a shallow wooden platform that is positioned1 foot below the surface where wave action will help the fertilizer dissolve. Or, bags can simply be slit open and placed in shallow water, taking care not to spill the fertilizer.

Inorganic fertilizer is usually applied at a rate of 6 to 8 pounds of phosphorous per acre per application. For a liquid fertilizer with a formula of 11-37-0, this is approximately 2 gallons/acre. The equivalent in powdered 12-49-0 or granular 0-46-0 formulations is 12 to 16 pounds/acre.

Heavy phytoplankton blooms can result in high pH levels during the day, so use inorganic fertilizers sparingly when culturing fish species that are sensitive to high pH levels. Hybrid striped bass fry, for example, are adversely affected by pH levels above 8.8. Channel catfish fry are more tolerant, but mortalities may occur at levels above 9.4. Crustacean zooplankton, an important fry food, are killed by very high pH levels above 10.5. High pH also makes ammonia that is present more toxic to fish. In addition, high rates of inorganic fertilizer often promote the growth of blue-green algae, a relatively poor food for zooplankton.

Organic fertilizers

Organic fertilizers are manures, plant meals, and other natural products. They provide relatively low levels of plant nutrients as compared to inorganics, but serve as a substrate for the growth of bacteria, protozoans and zooplankters. The important contribution of organic materials is that, while decomposing, they are a rapid and sometimes direct source of food for zooplankton. Organic meals such as rice bran and cottonseed meal are consumed directly by some zooplankton. Organic fertilizers are broken down by bacteria, which in turn are food for many types of zooplankton. In addition, the bacteria release nutrients that the phytoplankton use. The progressive decomposition of organic fertilizers also lengthens the time that nutrients are available in a pond and helps prevent too rapid a bloom development. Common organic fertilizers and their characteristics are listed in Table 2.

Manures are often high in moisture, vary widely in nutrient content and are relatively difficult to apply. Application of manures may also be regulated in some locations. Plant meals, such as cottonseed meal and rice bran, are more consistent products and can be readily applied from a feed wagon. Transportation costs for organic fertilizers are relatively high because application rates are far higher than for inorganics. This favors the use of locally-available materials.

Decomposition of organic materials releases carbon dioxide, a plant nutrient, but the process also consumes oxygen. The rate of decomposition is related to the ratio of nitrogen to carbon in the material. Organic materials with a higher N:C ratio break down faster than those with a low N:C ratio. Organic fertilizers with a higher percent crude protein contain greater amounts of nitrogen. Adding inorganic nitrogen fertilizer can help speed the decomposition process of organics with a low N:C ratio. Small particle size is also desirable, since it results in a faster rate of decomposition as well.

Organic fertilizers are usually applied initially at rates of 100 to 300 pounds/acre. New ponds benefit from higher rates of up to 500 pounds/acre (prior to stocking fish), which can be spread over the dry pond bottom.

Applying too much organic fertilizer can lead to low dissolved oxygen (DO), and fry of many fish species are particularly sensitive to low DO. For this reason, after the initial application to a pond, it is better to make multiple applications of smaller amounts (i.e., 50 pounds/acre). Organic fertilizers can cause waters to clear as a result of the settlement of clay particles. This favors the growth of filamentous algae (especially if the pond water is cool) and its associated problems.

Timing of stocking fry after fertilization

Pond filling, fertilization and fry stocking have to be properly timed. Failure to do so will often result in reduced growth or partial to complete mortality of the fry. Stocking fry, even large fry, into a pond that has been filled for more than 3 to 4 weeks during warm weather can have disastrous effects on fry survival. By that time, a variety of fry predators have usually invaded the

Table 2. Common organic fertilizers.

Type	Crude protein	Approximate cost*	Description
cottonseed meal	36-43%	$190/ton $5.35/50-lb. bag	Used as an animal feed ingredient. Available in many locations. Decomposes rapidly if finely ground. A superior fertilizer, particularly in new ponds.
rice bran	12-13%	$80/ton	Available as a powder or coarse pellet. Low risk of toxic ammonia levels developing. Good for older ponds that require less nitrogen.
alfalfa meal	18%	$7.10/50-lb. bag	Limited availability of bulk product.
chicken manure		$15/ton fresh $185/ton pelletized	Widely available in the fresh (loose) form. Softwood (pine) sawdust and rice hulls are common carriers for the manure. Highly variable in composition, depending on age and decomposition. Litter carriers are resistant to decay and undesirable as fertilizer. May also contain drug residues and various pathogens. Inferior to cottonseed meal.

*1997 prices in central Arkansas.

pond and reproduced. These include insects such as backswimmers and diving and whirlygig beetles in adult and immature stages. Populations of backswimmers can reach phenomenal levels. Other insects that prey on fry, and even larger fish, are water scorpions and the larval stages of a variety of dragonflies and damselflies.

Invasions of insects start as soon as the pond is being filled with water if the weather is warm enough for adult insects to move into the pond, but it usually takes several weeks for their populations to increase enough to become a major threat to small fish. It is important to stock fry before predaceous insect populations become dangerously high.

More secretive, but often much more abundant than insects, are predaceous cyclopoids, one of the three types of copepods. Many of these tiny (<3 mm) zooplankton prey on fry until the fry are large enough to eat the cyclopoids. These creatures show up in ponds after about 1 1/2 weeks when water temperature is above 70 degrees F. There is no legal means of controlling undesirable zooplankton, so it is important that fry, particularly small fry, be stocked into ponds as early as possible after ponds are filled.

Ponds must also have the appropriate type and size of food available when fry are stocked. Large fry stocked into ponds that have very tiny zooplankton may grow slowly because of the energy expended in catching small prey, but usually fry will not starve if enough zooplankton are available. However, stocking tiny fry into ponds with zooplankton that are mostly too large for fry to eat usually results in fry starvation or loss from cyclopoid or insect predation. It is important to know the size of fry to be stocked (Table 3)

Table 3. Fry size of commonly cultured cool and warm water fish.

Common name	Scientific name	Fry size (mm)	When to stock fry*
Sunshine bass	*M. chrysops* X *M. saxatilis*	2 - 6	5
White bass	*Morone 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 crysoleucas*	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* *Aristichthys*	7 - 8	7
Striped bass	*Morone saxatilis*	7 - 10	10
Palmetto bass	*M. saxatilis* X *M. chrysops*	7 - 10	10
Paddlefish	*Polydon spathula*	8 - 10	10
Spotted sucker	*Minytrema melanops*	8 - 10	11
White sucker	*Catostomus commersoni*	8 - 11	11
Shovelnose sturgeon	*Scaphirhynchus platorynchus*	>10	12
Channel catfish	*Ictalurus punctatus*	10 - 12	13
Muskellunge	*Esox masquinongy*	11 - 15	14

*Estimated number of days after pond starts filling, at 70 to 75^{o} F.

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and to time stocking so that zooplankton of the right size for these fry will be present.

When ponds are filled and fertilized, the plant and animal populations that live in them go through somewhat predictable changes in both predominant types and sizes, a process called succession. Understanding succession will greatly contribute toward success in fry culture. When ponds are first filled with well water, there are few living organisms present and limited nutrients. The water rapidly gains nutrients when soluble inorganic fertilizers are added. It also gains nutrients, but more slowly, when organic fertilizers are decomposed by bacteria. The nutrients are rapidly utilized by other bacteria and by phytoplankton. Within a few days the ponds turn a slightly green color as a "bloom" develops. The bacteria and phytoplankton are consumed by slightly larger creatures such as single cell protozoans. Some of these are large enough for fry to eat, but the next stage, the development of blooms of zooplankton (which eat bacteria, phytoplankton and protozoans), is most important to the fry. The major groups of zooplankton are rotifers, cladocerans, and copepods (Table 4 and Fig. 1).

Zooplankton blooms are usually predictable and follow the patterns shown in Figures 2 and 3. These figures show actual zooplankton concentrations found in

Table 4. Major large zooplankton groups in aquaculture ponds.

Name	# of species	Body length	Life span	Peak reproduction	Food size and type
Rotifers	2,500	0.04 - 2.5mm	4 days - 6 weeks	2 - 8 days	0.001-0.02 mm phytoplankton, detritus, bacteria, protozoan. All organic particles that are small enough.
Cladocerans		0.2 - 3.2mm	25 - 100 + days	13 - 26 days	0.001-0.05 mm phytoplankton, protozoans, detritus and bacteria.
Copepods	8,000-10,000	0.3 - 3.2mm	10 days - 3 years	18 - 40 days	Calanoid copepods filter phytoplankton; cyclopoid copepods prey on tiny animals or eat plants or debris.

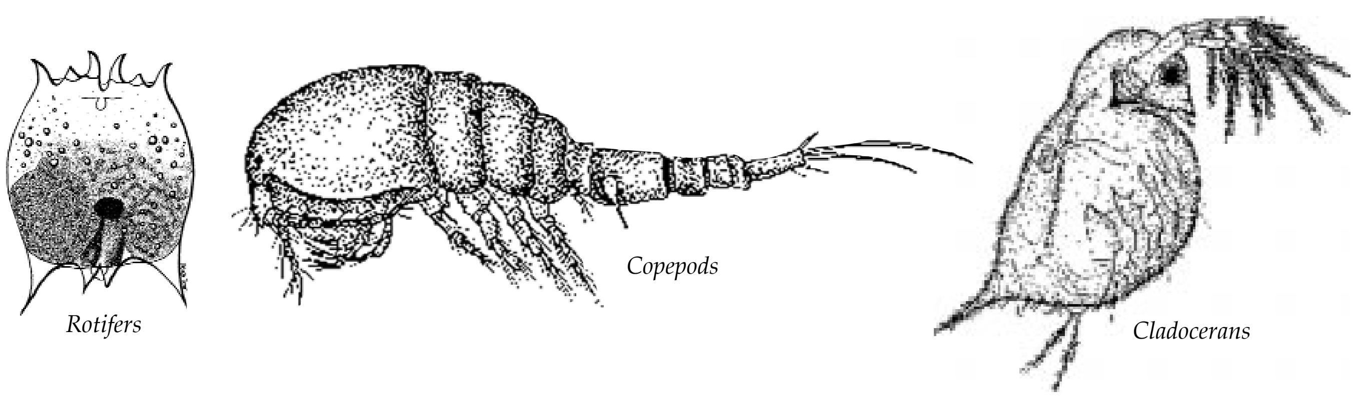

Figure 1. Common zooplankton types found in aquaculture ponds.

***Rotifers**: Rotifers were named after their "wheel organ," a ring of cilia that appears to rotate around the mouth of most species. About 95 percent of all rotifers inhabit freshwater. Most that are encountered are females; males may appear when conditions are harsh. Reproduction is usually asexual. They hatch from "resting eggs" in the pond bottom or eggs attached to females. Rotifers are capable of very rapid population changes.*

***Cladocerans**: Most cladocerans are found in freshwater. Cladocerans are called water fleas because of their appearance and their "hop-sink" type of locomotion. Often only females are found, except in early spring and late fall. Resting eggs hatch when ponds are filled; later eggs are held by females. Cladocerans shed successive exoskeletons as they grow.*

***Copepods**: A minority of copepods are found in freshwater. Some, such as Lernaea sp. (anchor worm), are fish parasites. Some cyclopoid copepods eat small fish. Reproduction is usually sexual. Eggs are carried by females and hatch into tiny larvae called nauplii. There are up to 12 growth stages, called instars, before maturity is reached. Exoskeletons are shed at each stage. Copepods survive winters as "resting eggs" on the bottoms of dry ponds.*

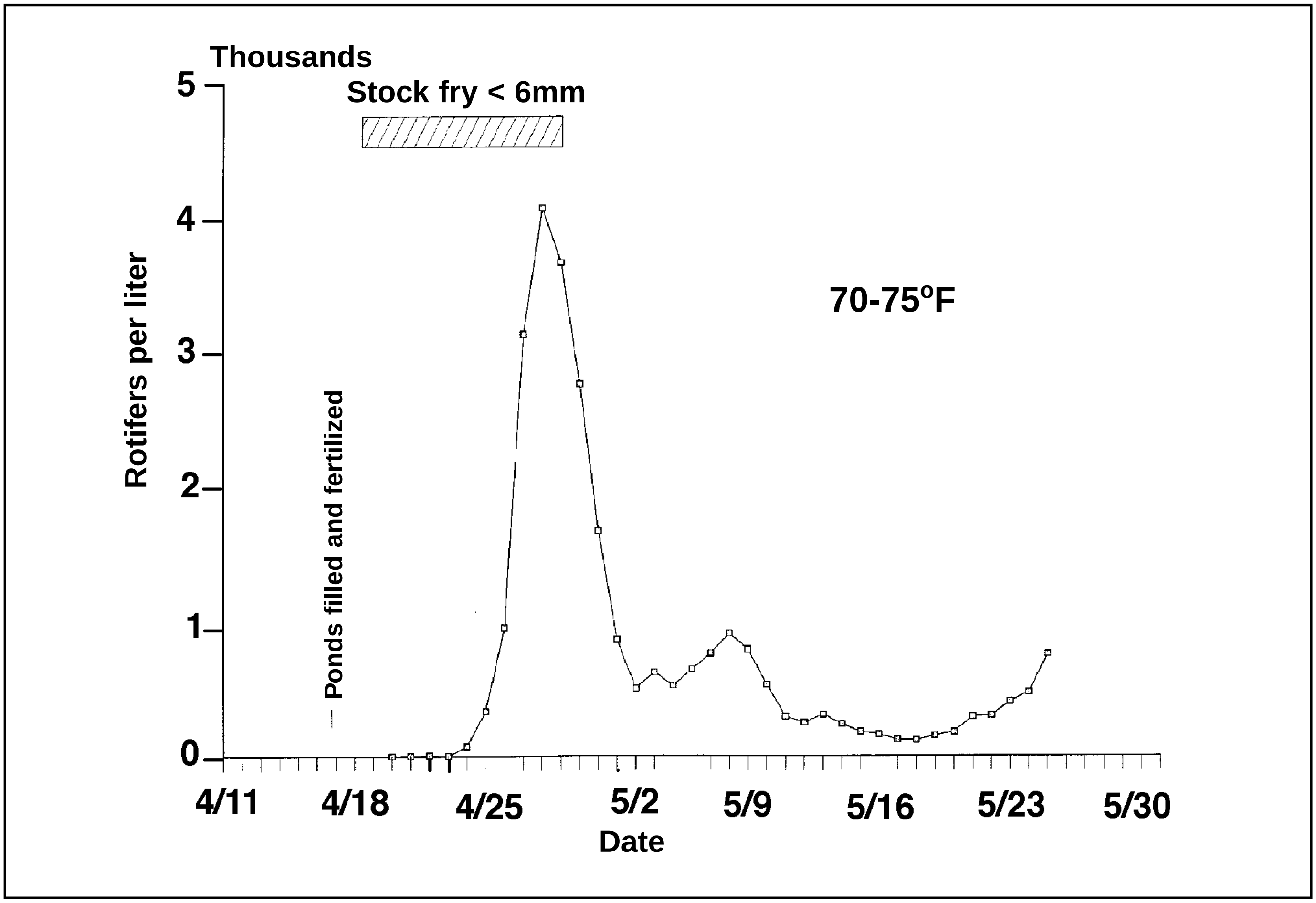

Figure 2. Typical rotifer population levels in a recently filled pond. Stock small fish just when the rotifer population begins to rapidly expand.

Arkansas ponds stocked with sunshine bass. Rotifers are the first zooplankton group to appear in culture ponds. They hatch from resting eggs that survive in the pond bottom. When pond temperatures are in the mid-70s, rotifer populations start to explode within 5 to 7 days after ponds are filled. Populations can go from near zero to 4,000 or more per liter within 4 to 5 days. Then, within a few more days, their populations crash to much lower levels. For fry that can only eat rotifer-size zooplankton, a few days difference in the stocking date can mean the difference between harvesting a pond full of fingerlings or none at all. Just as the rotifer populations crash, slightly larger copepod nauplii populations start booming. Nauplii are the small, immature stages of copepods. Larger fry should be stocked at this time.

The nauplii are followed by larger copepods and cladocerans that appear about 2 to 3 weeks after the pond is filled. All of these zooplankton populations start from eggs that survived in the pond bottom soil or were carried in by insects or other means.

This sequence is clearest in ponds freshly filled with groundwater. A similar response is possible if ponds are filled with surface water with an established plankton bloom, as the sudden influx of fertilizer nutrients should stimulate rotifer populations. However, using surface water is not recommended. It gives far less predictable results and can introduce diseases, predators and wild fish.

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 will eat, but the animals must be small enough for the fry to ingest. The smallest fry (Table 3) can only survive on the smallest zooplankton, while larger fry can eat both small and large sizes (Figs. 2 and 3). Usually, protozoans and rotifers are the smallest zooplankton. Most of them are 0.04 to 0.15 mm long. Fry smaller than about 6 mm total length must be stocked at the time that populations of these plankton are starting to rapidly increase, usually within 5 to 7 days after the ponds are filled and fertilized. By the time populations of rotifers decline the fry have grown large enough to consume (or escape from) larger zooplankton. Fry that are larger than about 6 mm can eat slightly larger zooplankton such as copepod nauplii and very small cladocerans. Those foods become available about 10 days

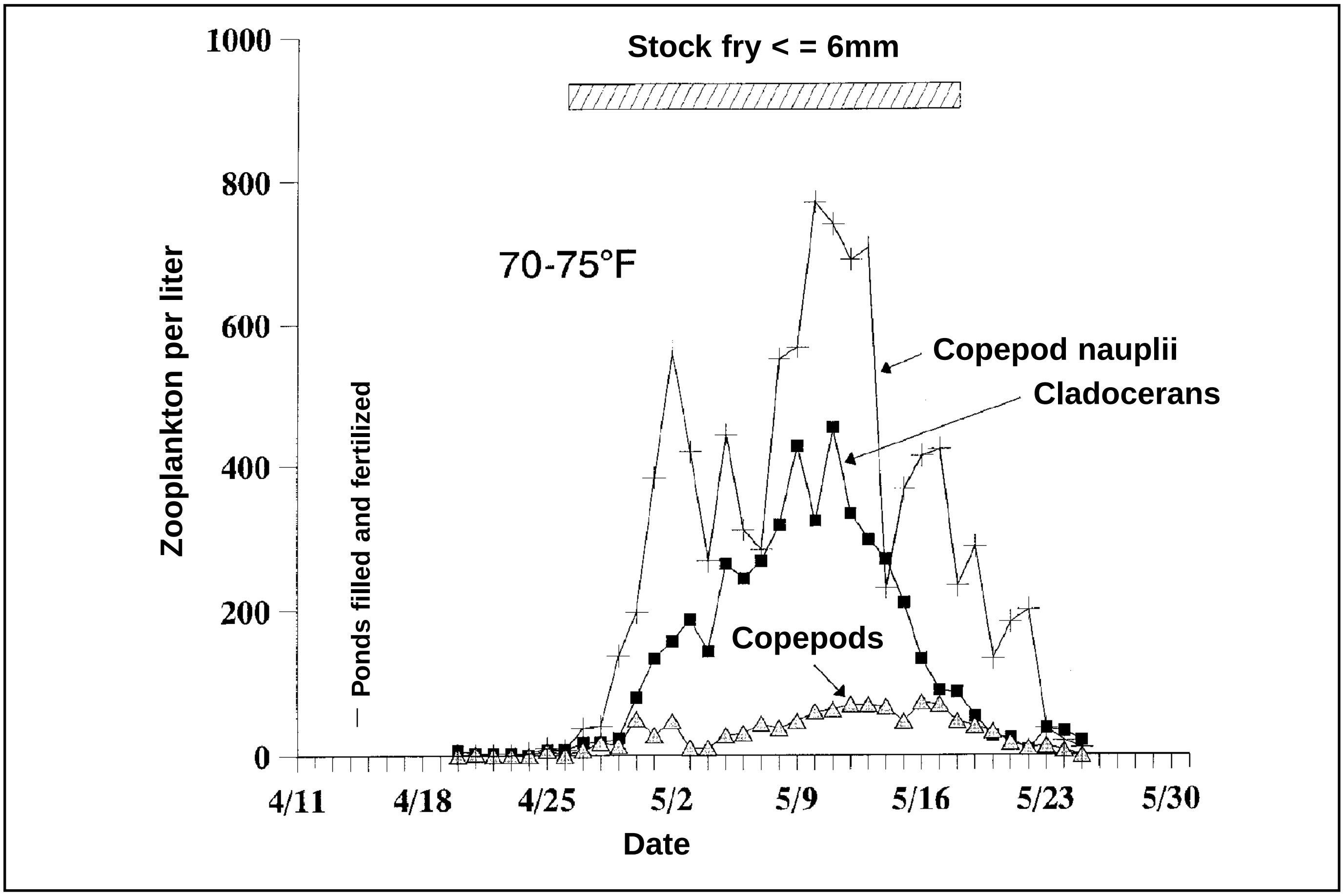

Figure 3. Copepod, copepod nauplii and cladoceran populations in a recently filled pond. Stock larger fry when these zooplankton populations are increasing.

after ponds are filled and are present for several weeks. Fry about 9 mm in length can usually handle all but the largest cladocerans and copepods. As a rule, the smaller the fish fry are, the sooner they must be stocked into the ponds. To maximize survival, it is best to stock any fry just as populations of zooplankton that are small enough for the fry to eat are starting to rapidly increase and before invading insects expand their populations.

The action of fertilizers and the growth of phytoplankton and zooplankton are affected by a variety of physical and chemical factors. The most predictable is the reaction to temperature. The colder the pond water, the longer it takes for nutrients to dissolve or be released by bacterial activity. That alone slows the development of zooplankton populations in a freshly filled pond. In addition, zooplankton are "cold-blooded" and all their activities slow as temperatures decrease. As a result it takes much longer to produce a zooplankton bloom during early spring when water temperatures are cold than after pond temperatures warm in late spring (Fig.4).

When not to fertilize

If the total alkalinity is below 20 mg/l, fertilizing usually will not be effective because the solubility of phosphorus is too low for an effective bloom.

If rooted aquatic vegetation or filamentous algae are present, do not fertilize. The vegetation will out-compete the phytoplankton for the nutrients and the result will be more weeds. Eliminate aquatic weeds or filamentous algae before fertilizing.

Do not fertilize if the pond receives excessive runoff water or is spring fed. Nutrients will be lost with the water leaving the pond.

If the secchi disk reading is less than 12 inches, discontinue fertilizing. The pond may be too rich with plankton. See Figure 5 for a diagram of a secchi disk and how it is used.

Ponds should not be fertilized if the early morning dissolved oxygen reading is below 4 ppm. A low dissolved oxygen reading in the early morning indicates a heavy bloom with a high oxygen demand during the nighttime hours, or a bloom die-off.

If the afternoon pH exceeds 9.5, discontinue fertilizing. Several species of fry cannot tolerate high pH, which often results from a heavy phytoplankton bloom.

Muddy water should not be fertilized. Phytoplankton in turbid ponds responds poorly to fertilizer because the sunlight needed for

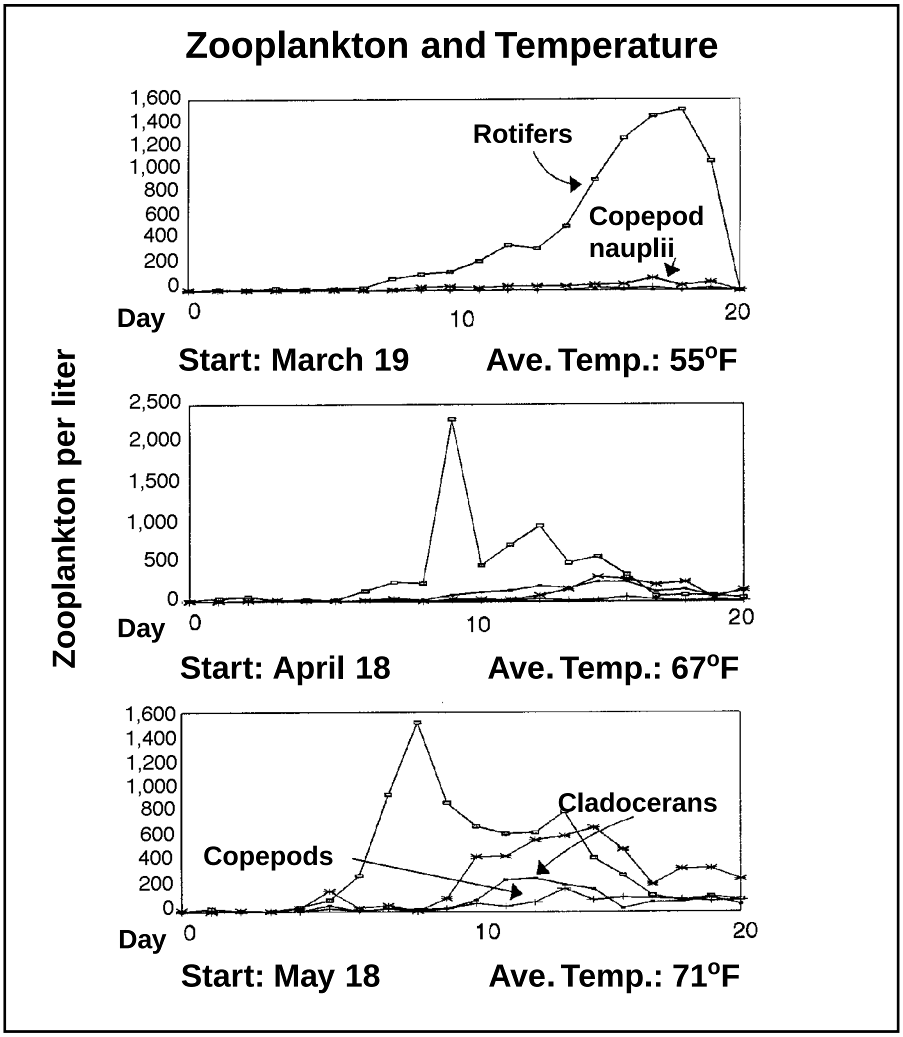

Figure 4. Zooplankton population development in a freshly filled pond is related to temperature. The higher the temperature, the faster populations develop.

growth is blocked by the muddy water. Water must be cleared before fertilization begins.

Associated practices

Bloom seeding is a practice used for starting a bloom in a pond. This is done by pumping water from an adjacent pond that already has a bloom. This method decreases fertilizer costs and begins the bloom much faster. However, this practice may not be useful if the bloom being pumped into the pond is too mature for the fry. For example, if the fry to be stocked are sunshine bass (reciprocal hybrid striped bass), the mature bloom would consist of organisms too large for the fry to eat and that would prey on the fry. Another concern with bloom seeding is introducing predaceous aquatic insects or fish into the pond and the risk of spreading disease. Ponds have been experimentally seeded with zooplankton obtained by filtering pond water. Results are inconclusive, and in any case this is not practical for most commercial farms.

For a pond with a history of producing only a minimal bloom, some producers plant a crop such as rye grass on the pond bottom during early fall and flood the pond the following spring. The flooded crop will decay and stimulate a bloom.

Aeration aids in maintaining a bloom because it keeps nutrients suspended in the water column. This practice will increase production and contribute to better quality fish.

Figure 5. A Secchi disk is a 6- to 8-inch disk of painted wood or plastic, often with alternating white and black quadrants. The disk is fastened to a yardstick or calibrated string. To measure the secchi disk visibility, the disk is lowered into the water until it disappears from view, and the depth recorded. The disk is then raised until it reappears. The depth is again recorded. The average of the two readings is called the secchi disk measurement. The secchi disk cannot be used in muddy ponds, as it will measure mud turbidity rather than plankton abundance.

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