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Fertilizing Fish Ponds

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Ponds are commonly fertilized to develop a desirable plankton ‘bloom’. Fertilizers provide necessary nutrients used by aquatic plants to grow and increase their density in the pond. Healthy phytoplankton blooms are important in fish culture for several reasons. A desirable phytoplankton bloom will provide turbidity which shades the pond bottom preventing rooted aquatic weed growth and may reduce bird predation. Healthy phytoplankton blooms will provide oxygen to the water and remove nitrogenous wastes and toxins. Proper phytoplankton blooms can also lead to increased fish production by enhancing the food web and increasing natural food (phytoplankton and zooplankton) in the water. Several species of fish fry feed primarily on zooplankton, so fertilizing the pond to maximize appropriate zooplankton production is important to successful fish culture.

When implementing a fertilization strategy, the goals are to use low-cost fertilizers, quickly establish a phytoplankton bloom, and to produce the greatest number of appropriate zooplankton community for the cultured fish species.

Variables limiting fertilization effectiveness

Adding proper nutrients at the suitable rate and frequency will not necessarily be effective if other conditions are not right. Water quality variables (pH, total alkalinity) can influence the fertilizer nutrient availability to phytoplankton. Other factors (temperature, turbidity, weeds, excessive water flow) affect phytoplankton growth.

Optimum pH range for most aquaculture species is 6.5 to 9.0. Low pH in bottom soil may reduce the abundance of benthic organisms that may serve as natural food. Ponds with low alkalinity can have wide daily fluctuations in pH, stressing natural food organisms and the culture species. Reduced carbon dioxide availability in ponds with low alkalinity may limit phytoplankton abundance. In low alkalinity water, phosphate is strongly adsorbed by acidic soils making it unavailable to phytoplankton. Therefore, ponds with acidic soils and low alkalinity (<20 mg/L (ppm) $CaCO_3$) water will be naturally low in productivity and will not respond well to fertilization.

Ponds with low alkalinity can be limed to increase fertilization effectiveness. Typical application dosage for agricultural or dolomitic limestone are from 1 to 3 tons/acre (2 to 7 tonnes/ha), and the recommended dose is based on the lime requirement of the bottom soil, as determined by soil testing.

Increasing water temperatures accelerate chemical and physiological processes associated with pond fertilization. When water gets warmer, fertilizers dissolve faster, nutrients are adsorbed more quickly by phytoplankton, and facilitate phytoplankton growth rates. Phytoplankton do grow over a wide temperature range, but growth rate is slowed below 60°F (16°C). Therefore, beginning fertilizer additions is most effective in the spring after the water temperature reaches about 60°F (16°C).

Turbid or muddy ponds should not be fertilized until the turbidity is reduced, because turbidity prevents light from entering the water and inhibits phytoplankton growth, regardless of nutrient availability. Weedy ponds should never be fertilized, because the established weeds will take up the nutrients instead of phytoplankton, leading to an even greater weed problem. Ponds with excessive water flow (overflow or seepage) will not respond well to fertilization, because the nutrients are constantly being diluted.

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Fertilizer types

Fertilizers are grouped into two main types—organic and inorganic. Organic fertilizers can be directly consumed by zooplankton, but require time to decompose before releasing nutrients for phytoplankton use. Inorganic fertilizers are man-made, have more concentrated nutrient content, and have nutrients readily available for phytoplankton.

Organic fertilizers

Organic fertilizers can either be manures or plant-based. Manures are used to fertilize ponds in many countries, but the Food and Drug Administration in the United States has classified farmyard manures as filth. Also, there could be consumer perception problems associated with fish grown in ponds fertilized with manures. Plant-based organic fertilizers are therefore more commonly used in the U.S. Commonly used plant-based organic fertilizers and their nitrogen and phosphate content are listed in Table 1.

Table 1. Commonly used organic fertilizers and approximate nutrient content (percentage).

Fertilizer	N	P_2O_5
Alfalfa meal	2.9	0.4
Cottonseed meal	6.6	2.5
Rice bran	2.0	1.5
Soybean meal	7.0	1.2

Organic fertilizers have been recommended as pond fertilizers—either alone or in combination with inorganic fertilizers. However, organic fertilizers have many disadvantages. Unlike inorganic fertilizers, organic fertilizers have low nutrient content (Table 1 and 2), which causes them to be more labor intensive to apply compared to inorganic fertilizers. On an equal nitrogen basis, it would require adding 290 pounds/acre (325 kg/ha) cottonseed meal to equal the nitrogen added with only 58 pounds/acre (65 kg/ha) ammonium nitrate. The nutrients contained in organic fertilizers are not readily available and require the material to decompose before releasing nutrients. When adding large amounts of organic fertilizers, an additional oxygen demand is enforced in the pond. Significant reductions in dissolved oxygen in ponds receiving organic fertilizers are common. Organic fertilizers are also often in a fine powder form easily blown by the wind causing applicator discomfort.

Inorganic fertilizers

Inorganic fertilizers are readily available from farm supply stores. The grade of inorganic fertilizers is expressed as three numbers giving the nutrient percentage of the product by weight. The first number is the percent total nitrogen (N), the second number is the percent phosphate (P_2O_5), and the third number is the percent potash (K_2O). Thus, 100 pounds (45 kg) of 37-11-5 fertilizer would contain 37 pounds (17 kg) nitrogen,11 pounds (5 kg) phosphate, and 5 pounds (2 kg) potash. The remaining 47 pounds (21 kg) would consist of other inert elements.

Table 2. Commonly used inorganic fertilizers and approximate nutrient content (percentage)

Fertilizer	N	P_2O_5
Ammonium nitrate	34	0
Calcium nitrate	15	0
Urea	45	0
Superphosphate	0	18–20
Triple superphosphate	0	44–54

Choosing the nitrogen source depends on the fertilizer effectiveness to increase desirable phytoplankton and zooplankton concentrations, cause few deleterious effects on water quality (e.g., changes in ammonia and nitrite concentrations), cost per pound nitrogen, and local availability. Calcium nitrate (12 percent N), sodium nitrite (20 percent N), ammonium chloride (26 percent N), ammonium nitrate (34 percent N), and urea (45 percent N) were compared as nitrogen sources for pond fertilization, and few differences were seen. Any nitrogen form used for pond fertilization should perform similarly without causing substantial water quality deterioration. Ammonium nitrate and urea contain a higher nitrogen percentage than other nitrogen sources, so less fertilizer would be required. Urea and ammonium nitrate are generally similar in cost/unit N; however, ammonium nitrate can be more difficult to acquire and may require extensive record-keeping because of its potential use in explosives. If urea and ammonium nitrate are available, the one with the least cost/pound N should be used. If urea is $17.50/50 pound (23 kg) bag and ammonium nitrate is $14.75/50 pound (23 kg) bag, one would buy the urea This is because urea is 45 percent N, so 50 pounds (23 kg) * 45 percent = 22.5 pounds (10 kg) N contained in the bag. Taking $17.50/22.5 pounds (10 kg) = $0.78/pound (0.4 kg) N. Ammonium nitrate is 34 percent N, so 50 pounds

(23 kg) * 0.34 percent = 17 pounds (8 kg) N contained in the bag. Taking $14.75/17 pounds (8 kg) = $0.87/pound (0.4 kg) N.

Fertilization strategies

There are three main ways to fertilize ponds:
1) frequently manipulating pond nutrient ratios,
2) using algal bioassays to determine nutrient requirements, and 3) fixed-rate fertilizer applications. The strategy choice will depend on what species is being cultured, the number of ponds being fertilized, and fertilizer and labor costs.

Pond nutrient ratio manipulation

Early studies on nutrients showed the ratio of nitrogen to phosphorus (N:P) contained in phytoplankton was 7:1 by weight, and various studies have shown manipulating that ratio can regulate phytoplankton competition. High N:P ratios (>20:1) tend to suppress blue-green algae and favor small, edible phytoplankton species. Appropriate algal species development, such as planktonic green algae and diatoms (most edible for zooplankton), is required for successful fish production. Inedible large filamentous algae and blue-green algae can lead to deteriorating water quality, reduce zooplankton abundance, and reduce fish growth and survival. Therefore, manipulating nutrient ratios by restoring the needed nutrients to a 20:1 ratio should favor a more desirable phytoplankton community than just adding a set amount of one nutrient.

Implementing a nutrient ratio manipulation strategy requires measuring ammonia, nitrate, and soluble reactive phosphorus concentrations weekly. After measuring the nitrogen (ammonia + nitrate) and phosphorus concentrations, the amount of nitrogen fertilizer and phosphate fertilizer required to restore concentrations to 0.6 mg/L N and 0.03 mg/L P (20:1 N:P) are calculated. These concentrations of N and P are recommended to give the best combination of water quality, algal species composition, zooplankton growth, and larval fish survival.

Algal bioassay

Conducting algal bioassays is a simple, pond-specific approach to identify what nutrient(s) should be added to a pond to stimulate algal productivity. This method does not require measuring nitrogen and phosphorus. The basic premise is to add different nutrients to samples, and based on the algal response; add which nutrient the pond needs.

To conduct the algal bioassay, collect four separate water samples from the pond. Add either nitrogen fertilizer, phosphorus fertilizer, both nitrogen and phosphorus fertilizer, or no fertilizer to each sample. Samples are then placed loosely capped in a well-lit area to incubate. A 2 to 3 day incubation time is typically enough.

After incubation, simply compare the color of the three samples receiving fertilizer to the sample receiving no fertilizer addition. The sample with the darkest color indicates which nutrient(s) (N, P, or both) are required. As with nutrient ratio manipulations, it is recommended samples be collected weekly and ponds fertilized accordingly.

If necessary, carbon can also be added to the test. An additional four samples would be needed (C, C+N, C+P, C+N+P). However, in limed ponds and ponds with already high alkalinity and hardness, carbon would not be a limiting nutrient.

This method does not indicate how much fertilizer should be added, just which fertilizer should be added. If nitrogen is limiting, a good starting point would be about 30 pounds N/acre (34 kg/ha) and if phosphorus is limiting, a good starting point would be about 10 pounds P/acre (11 kg/ha).

Fixed-rate applications

The previous two fertilization strategies take into account specific pond nutrient needs and are probably more ecologically efficient than using a predetermined fixed-rate strategy. However, the majority of available fertilization recommendations are fixed-rate recipes. The major advantage of a fixed-rate recipe is it is simple, routine, and does not require additional labor and equipment for water testing or bioassays.

There is widespread assumption most freshwaters are phosphorus-limited; therefore, fishpond fertilizer recommendations have assumed phosphorus is the key ingredient in fertilizer and have recommended using a fertilizer with three times or more P_2O_5 as nitrogen. However, high phosphorus favors non-preferred blue-green algae and filamentous algae. The recommendation here is to use higher inorganic nitrogen rates.

One recipe working well in production ponds is to fertilize first with 18 pounds N/acre (20 kg/ha) and 2 pounds P/acre (2 kg/ha). After 1 week, fertilize twice a week with ½ the initial rate until a desirable bloom develops. Urea is easy to find and is a good nitrogen fertilizer choice. In many ponds, the P is not needed at all, and good results can be obtained with just nitrogen additions.

Zooplankton

As stated earlier, increasing zooplankton populations is the main reason to fertilize a pond. Zooplankton are the planktonic animals living in the water column. Typical zooplankton range from ¹⁄₁₂₅ inch (0.2 millimeters) to ¹⁄₅ inch (5 millimeters) long. Some larger zooplankton can be seen by taking a flashlight and shining it onto the surface water of a pond at night or putting a water sample in a glass jar and holding it up to the light. The zooplankton observed without a microscope have a characteristic jerky movement.

Zooplankton importance

Zooplankton are often ignored in fish production ponds, especially grow-out ponds. Many fish farmers know the importance of zooplankton for fry and fingerling culture, but for grow-out ponds the importance is not so clear.

Most fry and fingerling fish depend on zooplankton as a food source to some extent. When culturing many fish species, such as hybrid striped bass, walleye, sauger, northern pike and yellow perch, zooplankton are preferred heavily or completely as an initial fry food. The main reason for fertilizing these production systems is to increase zooplankton populations, either by feeding the zooplankton directly or promoting a phytoplankton bloom for them to feed on. With other species, such as catfish, commercial diets are fed to the fry soon after stocking.

These fry consume the commercial diets, but nutrients from the feed are also used by the plankton populations. However, through understanding fish feeding behavior and zooplankton dynamics, more reliance on natural pond production and implementing efficient fertilization regimes could reduce feed costs.

Zooplankton may also be important in grow-out ponds. Larger fish may not necessarily benefit from zooplankton directly by eating them. However, zooplankton are an important part of the pond ecology and are closely tied to phytoplankton populations. As we learn more about the zooplankton—phytoplankton—water quality relationships, it may become important to monitor zooplankton populations in all culture systems.

General zooplankton groups

In fish culture, zooplankton of concern can be grouped into three major categories: rotifers, copepods, and cladocerans. Within each broad category, there are many different genera or species, but generally rotifers are the smallest and copepods (along with a few cladocerans) are the largest.

Rotifers.

Rotifers are the tiniest zooplankton and are of many forms. They generally range from ¹⁄₅₀₀ to ³⁄₁₀₀ inch (60 to 800 µm). Some common rotifer genera in culture ponds include: *Branchionus* (Fig. 1), *Keratella* (Fig. 2), *Polyarthra,* and *Asplanchna.*

Rotifers are generally the first zooplankton to reach large populations in newly filled ponds; rotifers have the ability to reproduce quickly and reach their maximum reproductive peak earlier than the other zooplankton groups. However, because they have a short life span (5 to 20 days) and produce few young (2 to 4 eggs per brood), they are soon replaced by the other zooplankton groups.

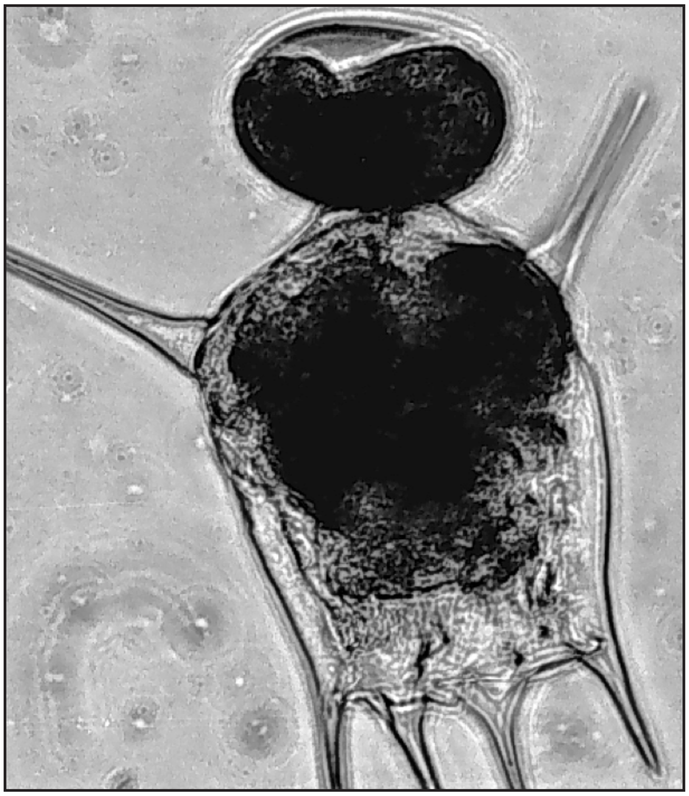

Figure 1. *Branchionus,* a relatively large rotifer, is common in culture ponds.

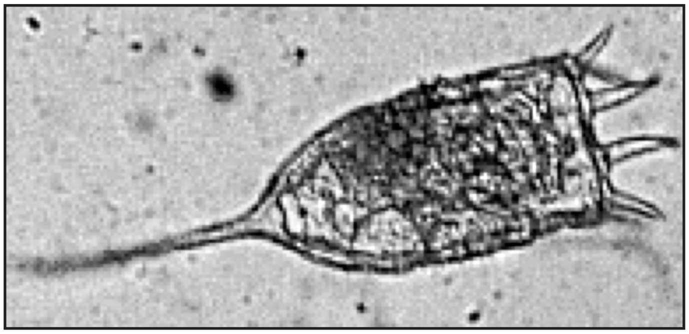

Figure 2. *Keratella* is another common rotifer in culture ponds.

Because of their small size, rotifer diets are generally limited to small particles. They will consume small algal cells and diatoms, periphyton, and detrital particles along with bacteria and protozoans. Their population sizes are strongly associated with the amount and quality of food available.

Rotifers (Figs. 1 and 2) reproduce primarily by asexual reproduction. However, sexual reproduction will occur when the environment is unfavorable. Through sexual reproduction, resting eggs are produced. These thick-walled eggs are resistant to poor conditions, especially desiccation; they will lay dormant in the pond mud until the environment improves. In culture ponds, environmental improvement is usually when ponds are refilled in the spring.

Cladocerans.

The cladocerans (Figs. 3, 4, and 5) are mid-sized zooplankton, ranging from ¹⁄₁₀₀ to ¹⁄₁₀ inch (300 to 3000 µm). Cladocerans are commonly called “water fleas” and are probably the most recognized zooplankton group. In culture ponds, some common cladoceran genera include: *Daphnia* (Fig. 3), *Ceriodaphnia, Moina* (Fig. 4), and *Bosmina* (Fig.5).

The cladocerans are primarily filter feeders and will consume a wide variety of food particles from small algae and diatoms to organic detritus. Even though they are filter feeders, they have the ability to selectively filter different types and sizes of food. Because of this selective filtering ability, the cladocerans are more efficient at feeding than other zooplankton.

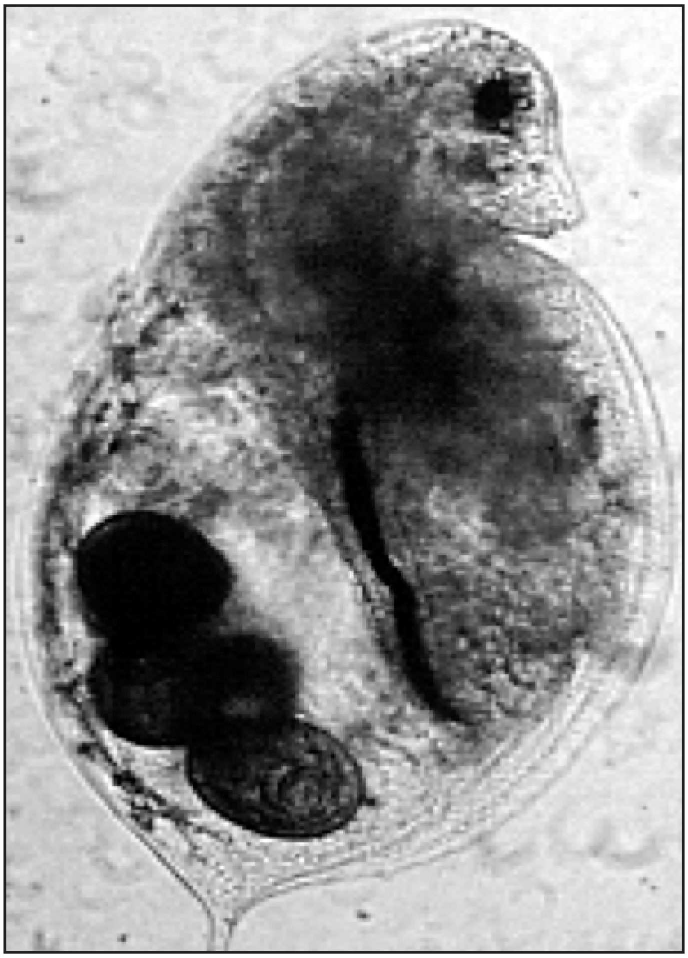

Figure 3. *Daphnia* are an important food source for many fish and are a recognizable zooplankton.

Figure 4. *Moina* are a similar size to *Daphnia* and are also an important food source for many fish.

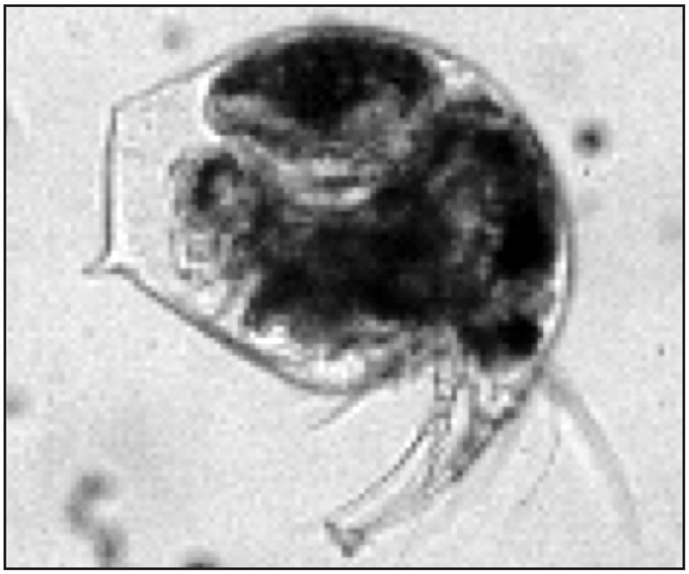

Figure 5. *Bosmina* are a smaller cladoceran and can reach large population sizes in ponds.

Cladocerans reproduce asexually in favorable environments, but will exhibit sexual reproduction when the environment turns poor. Resting eggs result from sexual reproduction and hatch when the environment is favorable. The cladoceran resting eggs are contained in a sac called an ephippium.

Copepods.

Two copepod groups (Figs. 6, 7, and 8) are common in culture ponds: the calanoids and cyclopoids. The copepods are much larger than the rotifers, ranging from 1/50 to 1/5 inch (500 to 5000 µm).

The cyclopoids have mouthparts adapted for biting and seizing; they eat a variety of food items including algae, detritus, other invertebrates, and some species will eat small fish fry.

The calanoids are generally filter feeders. Unlike cyclopoids, the calanoids do not have biting mouthparts and are a common food for many young fish. The calanoids look similar to cyclopoids, but they generally have longer antennae and have a characteristic "constriction" where the body and the tail meet.

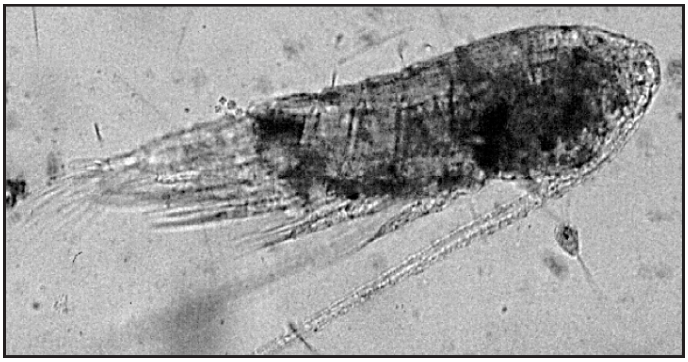

Figure 6. Calanoid copepods are a common food source for many young fish.

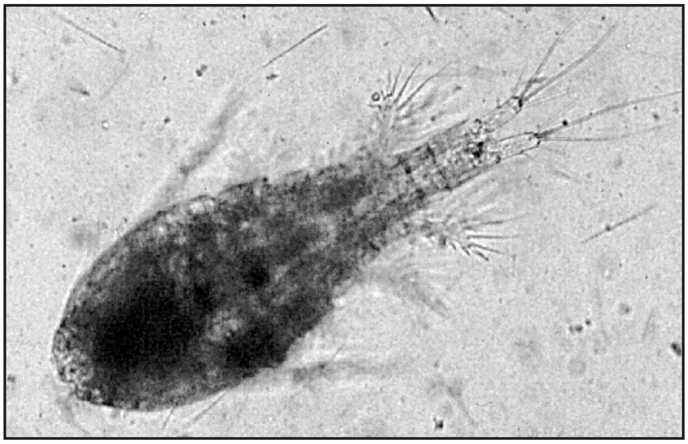

Figure 7. Cyclopoid copepods have biting mouthparts and can prey on small fish fry.

Copepods are bisexual animals. Similar to the rotifers and cladocerans, copepods will produce resting eggs when the environment is unfavorable. Again, the resting eggs hatch when conditions improve. Young copepods do not look like the adults; they go through five or six naupliar stages before taking on the adult form. The naupliar stages are eaten by some fish fry.

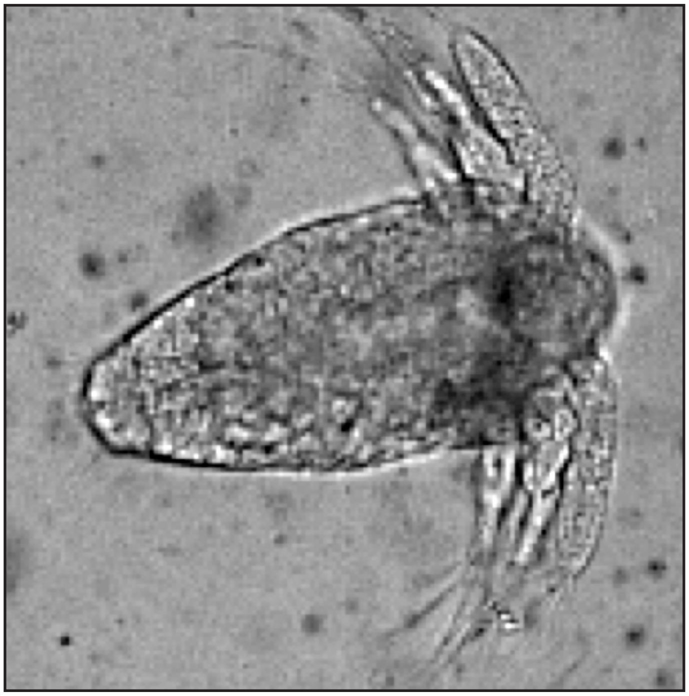

Figure 8. Copepod young go through several naupliar stages before taking on the adult form.

Patterns in zooplankton communities

Depending on the temperature and other environmental factors, one zooplankton group will tend to be favored over the others and attain a greater abundance. There is a natural progression in zooplankton group dominance throughout time (Fig. 9).

Generally, when culture ponds are first filled, rotifers will be the first zooplankton group to attain high numbers. Peak rotifers are usually seen from 7 to 28 days after filling ponds. Rotifers are able to colonize new ponds quickly because of their short time to reproductive maturity. During this initial rotifer community dominance, copepod nauplii and young cladocerans will begin to appear.

From 14 to 28 days after filling ponds, the copepod nauplii and young cladocerans have had time to mature and produce some generations. Then, because the copepods and cladocerans can out-compete the rotifers, rotifer populations decline and copepods and cladocerans will dominate.

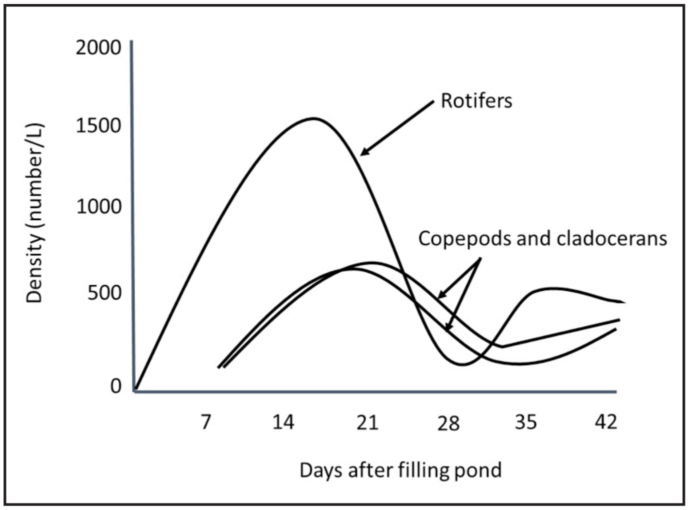

Figure 9. Natural progression in zooplankton group dominance after pond filling.

In culture ponds, as the fish grow and consume more prey items, the zooplankton populations will shift again. Most fish will selectively take the largest zooplankton by 28 to 45 days after ponds are filled. Because of the intense predation by fish on larger zooplankton groups (especially cladocerans such as *Daphnia*), large-bodied cladocerans decline, and zooplankton populations are shifted to non-preferred zooplankton such as rotifers and small cladocerans like *Bosmina*. Copepods may persist in lower numbers even though fish prey on them, because they are adept at escaping predation.

Desirable zooplankton

Regardless of the fish being cultured, it is critical to have the appropriate species and zooplankton size present in enough numbers when the fish are stocked. Most fish fry will consume any zooplankton of the appropriate size; in many cases prey size is more important than species. The prey must be small enough for the fish to eat; if the prey is too small, more energy is used to capture and eat the prey than the amount of energy acquired from it.

Even though many fish fry will eat any prey species if it is the appropriate size, fish do show preferences for certain prey species and have better growth and survival when the preferred species is abundant. It is important to know your specific fish's prey preferences and manage for the optimal zooplankton populations.

Depending on the species being cultured, different zooplankton groups are "desirable". Different fish are different sizes when hatching, which determines the prey size they are able to consume (Table 3). For instance, when culturing catfish, walleye, sauger, and northern pike (fish with large mouth gapes at their first feeding), it is desirable to have large zooplankton groups present throughout culture. However, when culturing species such as sunshine bass, white bass, and yellow perch (fish with small mouth gapes at their first feeding), it is desirable to have many rotifers initially, with a gradual increase in larger zooplankton.

Table 3. Commonly cultured fish and their average size at hatching.

Cultured fish	Fry size at hatching (mm)
Sunshine bass	2 to 6
Green sunfish	3 to 4
White bass	3 to 4
Black crappie	3 to 5
White crappie	3 to 5
Goldfish	3 to 5
Bluegill	4 to 5
Fathead minnow	4 to 6
Sauger	4 to 6
Golden shiner	4 to 7
Redear sunfish	5 to 6
Common carp	5 to 7
Yellow perch	5 to 7
Largemouth bass	6 to 7
Walleye	6 to 9
Grass carp	6 to 9
Bighead carp	7 to 8
Striped bass	7 to 10
Palmetto bass	7 to 10
Channel catfish	10 to 12
Muskellunge	11 to 15

Sampling zooplankton

There are several methods to monitor zooplankton populations. Each method has certain advantages and disadvantages associated with them.

The simplest, least time-consuming method to observe zooplankton populations is to dip a glass jar into the pond and take a water sample. By holding the jar up to the light, the zooplankton density can be observed. Through experience, the number of zooplankton in a jar can be assessed as few, average, or many. This crude method is simple and quick; however, it gives no indication of the plankton community composition. There may be many zooplankton in the sample, but they may be the wrong species or size for the fish to consume. Also, zooplankton tend to be distributed in clusters throughout the pond, so using the jar method, an area with many zooplankton or no zooplankton could be sampled. This would lead to a false assessment of the zooplankton population suitability for fish stocking.

A method of zooplankton population monitoring correcting for the non-random distribution of zooplankton is using a zooplankton net. The common net used to sample zooplankton is called a Wisconsin-style plankton net (Fig. 10). The net is attached to a rope, tossed into the pond, and then retrieved. The zooplankton are concentrated in the bottom of the net and can be rinsed into sample bottles.

Figure 10. A Wisconsin-style plakton net captures a representative zooplankton sample and provides for both qualitative and quantitative analysis.

The best method of retrieving the net is called an oblique tow. An oblique tow provides the best chance of getting a representative zooplankton sample. An oblique tow consists of allowing the net to sink almost to the pond bottom and then retrieving it at a diagonal. This method captures zooplankton at all pond depths.

Samples collected with plankton net will have a good representation of the entire pond zooplankton population. Also, markings can be placed on the net's rope; the net can be pulled for a specific distance. This allows for calculating the total water filtered by the net, and quantitative information about the zooplankton can be obtained. However, a plankton net is much more expensive than a glass jar, and taking plankton tows is more time consuming.

Using a plankton net in conjunction with a good quality microscope provides the most information about the zooplankton community. Both qualitative and quantitative assessments can be made. Identifying various types and numbers of zooplankton in the culture pond will give good insight into the suitability of the pond for stocking and growing young fish. However, zooplankton identification and counting is a tedious and time-consuming endeavor. Also, zooplankton need to be killed and fixed before counting. Zooplankton will decompose beyond recognition fairly quickly, so if counts are not made immediately, the samples must be preserved. The recommended method for preserving zooplankton is by adding a buffered formalin solution. Once preserved, a small volume of water from the mixed sample is placed on a Sedgewick Rafter counting chamber. The chamber is placed under the microscope (50–100× magnification), and all zooplankton are counted.

Managing zooplankton populations

Three zooplankton management methods are practiced: timing of pond filling, seeding with zooplankton, and pond fertilization.

Timing of pond filling

There are different opinions regarding the time between filling a pond and fry stocking. However, the general idea is to fill ponds a set number of days before the fish are stocked. This allows the zooplankton to progress through natural succession. If many rotifers are desirable at fish stocking, then ponds are filled 3 to 7 days (the time for rotifers to begin to reach their peak reproductive capacity) before stocking. If many cladocerans are desirable at fish stocking, then ponds are filled about 14 days (the time for cladocerans to begin to reach their peak reproductive capacity) before stocking. Finally, if many copepods are desirable at fish stocking, then ponds are filled about 24 days (the time for copepods to begin to reach their peak reproductive capacity) before stocking. Temperatures have a significant effect on the time of peak reproductive capacity of each zooplankton group. In cooler water, the time to peak reproductive capacity is longer than in warmer water.

One problem associated with filling ponds an extended time before stocking fish, is predatory insects can establish. These predatory insects will hunt on fish fry and can greatly reduce fish survival. If ponds are filled as fish are stocked, the fish will have a chance to grow to a size too large to be eaten by predatory insects. The longer the ponds are filled before fish are stocked, the more risk there is of predatory insect populations developing, and actions should be taken to reduce predatory insect populations.

Seeding

"Seeding" or "inoculation" is the process of stocking desired adult zooplankton into culture ponds as they are filling. The assertion is by adding desired adults as ponds are filled, natural succession is accelerated. This is because the time for resting eggs to hatch and grow to adults is eliminated by stocking adults directly into the ponds. However, many zooplankton adults would be required to achieve the desired outcome. Finding desired adults in enough numbers would be laborious.

Zooplankton inoculation is probably only feasible if well water is used to fill the ponds, or if ponds are lined with plastic. However, even when using well water or filtered water, zooplankton populations will still become established from the resting eggs and ephippium in the pond soils from the previous production seasons. If zooplankton populations are not present in enough numbers, the problem usually is nutrient related (i.e., there is not a necessary algal bloom for the zooplankton forage base), so inoculation would be a waste of time.

Summary

Pond fertilization is critical to the successful culture of many aquaculture species. Several options are available for fertilization management, and the appropriate fertilization strategy depends on the species being cultured, the number of ponds at the facility, and fertilizer and labor costs.

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