Plankton Management for Fish Culture Ponds

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Introduction

In the culture of larval fish of various species, e.g., walleye (*Stizostedion vitreum*), hybrid striped bass (*Morone saxatilis* X *M. chrysops*) and sunfish (*Lepomis* spp.), management of the zooplankton forage base is critical to successful transition of larvae to the fingerling stage. In addition, information regarding the relative status of plankton (zooplankton and phytoplankton) communities gives insight into water quality parameters and the possible success or failure of the culture season.

The dynamic characteristics of zooplankton populations have led researchers to use particular fertilization techniques and species-specific zooplankton inoculations in culture ponds (Colura and Matlock 1983; Geiger 1983a; Farquhar 1984; Turner 1984; Geiger et al. 1985). The intent of these management techniques was to maintain high densities of desirable zooplankton species in culture ponds until fish were harvested or able to consume commercial feeds.

Population Characteristics of Zooplankton Prey

Zooplankton important to larval fish are classified as either rotifers, cladocerans (water fleas) or copepods. The ability of rotifers and cladocerans to reproduce asexually (parthenogenetically) enables them to react quickly to unfavorable and favorable environmental conditions (Pennak 1989).

Rotifers have the shortest life span (12 days) and can reach their peak reproductive level in about 3.5 days (Allan 1976). At 20° C (68° F), the egg-to-egg span is 2-3 days and 15-25 young are produced by an adult throughout its life span.

Cladocerans and copepods have similar life spans of approximately 50 days, but with different peak reproductive periods. To reach theis peak reproductive capacity, cladoceans require 14-15 days while copepods require

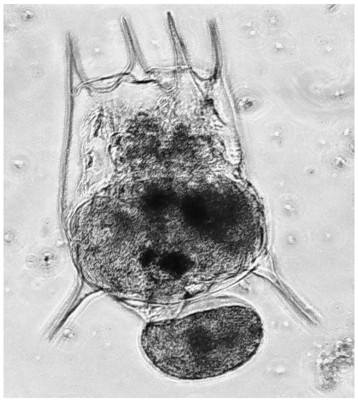

Figure 1. *Brachionus* spp. is one of many types of rotifers found in fish culture ponds.

Figure 2. *Ceriodaphnia* spp. are important cladocerans found in culture ponds.

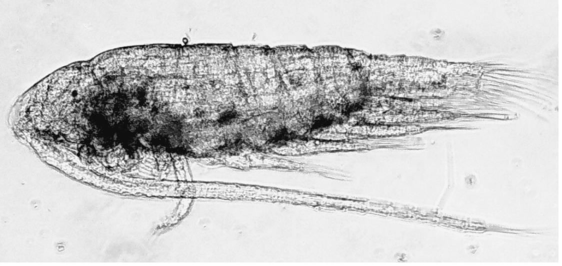

Figure 3. Calanoid copepods can be a key component of the zooplankton forage base.

24 days (Allan 1976). Copepods, which have only sexual reproduction, require longer periods to increase their population levels.

Cladocerans are desirable fish prey since they have high energetic caloric value, assuming that they can be consumed by fry. However, cladoceran populations usually decline rapidly when subjected to predation by larval fish in culture ponds (Geiger 1983b; Geiger et al. 1985). Conversly, copepods, because they are swift, powerful swimmers, are better able to maintain their populations during the later stages of a culture season (Geiger and Turner 1990).

Egg-to-egg generation times are slower for copepods (13-15 days) than for cladocerans (7-8 days) at 20°C (68°F); however, life spans are similar (approximately 50 days at 20°C [68°F]) (Allan 1976). The total young produced per adult lifespan is 400-600 for cladocerans compared to 250-500 for copepods at this temperature.

Although rotifers are the first zooplankters to reach large numbers in newly filled culture ponds, they are soon dominated by cladocerans and copepods through competition for available food. There is also a difference in filtering rates for these animals. Cladocerans have the highest filtering rates, followed by copepods and then by rotifers (Allan 1976). The high filtering rates and total young produced per adult life span give cladocerans a definite ecological advantage over rotifers and copepods. However, increased predation by fish on cladocerans does reduce these ecological advantages.

Models of zooplankton succession patterns and species composition in large reservoirs and lakes may not be applicable to intensively fertilized culture ponds (Parmley and Geiger 1985). In a study of fertilized culture ponds without fish Parmley and Geiger (1985) found that copepod adults and nauplii, and the cladoceran (*Daphnia* spp.) populations reached maximum mean densities in an average of 23.5 days. Rapid population declines of copepod adults and nauplii occurred in 5.3 days, while cladoceran (*Daphnia* spp. and *Bosmina* spp.) populations decreased significantly within 7.3 days after reaching maximum densities.

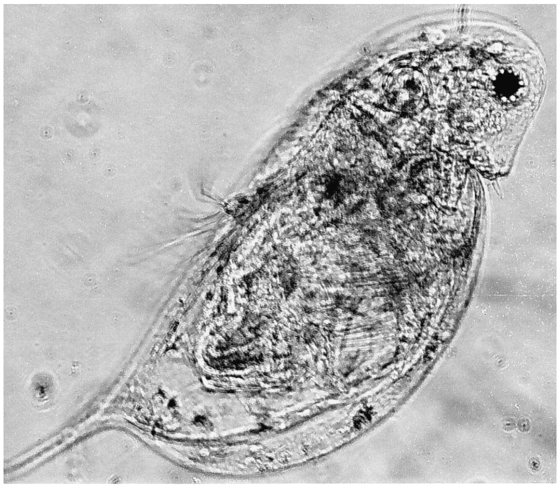

Figure 4. *Daphnia* spp. or 'water fleas' are easily recognizable cladocerans among the zooplankton.

Researchers have differed in their recommendations concerning the time between filling the ponds and fry stocking. Geiger (1983b) recommended that culture ponds be filled 2-3 weeks prior to hybrid striped bass (*Morone saxatilis X M. chrysops*) fry stocking to allow time for maturation of zooplankton populations. However, Cross (1984) found that hybrid striped bass fry stocked into ponds filled the shortest time before stocking had the greatest survival rate. The discrepancy may relate to Geiger's ponds being filled with well water, while ponds in Cross's study were filled with water from the Pearl River, Mississippi. Culver et al. (1992) also compared filling ponds seven days or 30 days before fry stocking. The ponds filled 7 days before stocking had 64% survival while those filled 30 days before stocking had 14.5% survival of walleye and saugeye (*S. vitreum* X *S. canadense*).

Not all fish species require the same size of prey at the onset of feeding. For instance, reciprocal cross hybrid striped bass (*Morone chrysops* X *M. saxatilis*) have very small mouths that require them to consume small prey, such as rotifers and the early instar stages of cladocerans. Improved fish production may be acheived by stocking these fry into culture ponds filled just prior to stocking.

Predator and Prey Interactions

Direct relationships between fish ingestion rates, larval size, or fish larval density to prey density appear to exist (Eldridge et al. 1981). Several studies have documented the size-selectivity of fish for their invertebrate (Brooks and Dodson 1965; Dodson 1974; Zaret 1980; O'Brien 1987). Fish have been observed to consume larger prey as fish length increases. Size selectivity of prey was demonstrated for small bluegills (*L. macrochirus*), 70-80 mm (2.8-3.2 in) total length (TL), presented with four size classes of *Daphnia* spp. (Werner and Hall 1974).

Zaret (1980) noted that prey size selectivity generally was not displayed by most fish, except during the youngest stages. In these fish, their mouth gape restricted them to consume appropriately size prey. Miller et al. (1988) noted the similarities among different fish species concerning the importance of fry size upon feeding, starvation, activity and searching ability, and risk of predation.

Zaret (1980) showed that planktivorous fish were highly discriminate feeders of particulate matter, and that filter feeding was rare. Drenner and McComas (1980) noted the correlation between gill raker spacing and size of prey consumed. In addition to size of prey, predators also key in on different visual cues such as eyespots and pigmentation patterns (Zaret 1980; O'Brien 1987).

Zooplankton utilize many different methods to escape capture. Zaret (1980) noted the effectiveness of vertical migration as one type of escape behavior. Additionally, different levels of ornamentation have evidently evolved as predator defense mechanisms. The rotifer *Brachionus calyciflorus* populations may develop various levels of posterolateralspines that decrease predation by another rotifer, *Asplancha* spp. (Gilbert 1967). Drenner and McComas (1980) concluded that the impact of predators upon zooplankton stocks varies with the zooplankter's ability to escape predation, as well as the degree of size selection of prey.

Zooplankton Characteristics as Environmental Indicators

Zooplankton, namely cladocerans, which are colored a deep red are often indicators of low dissolved oxygen conditions (Pennak 1989). This coloration is based on the increased amount of hemoglobin that these animals have to compensate for low oxygen levels in the environment; however, this increased amount of hemoglobin comes at an energetic cost. Landon and Stasiak (1983) found that *D. pulex* quickly become clear when placed into well-oxygenated waters.

Another indication of poor environmental conditions is indicated by the increased number of eggs with delayed development (dispause eggs) in cladocerans. These diapause eggs are often quite large and dark and are produced when these animals are forced to undergo sexual reproduction in preparation of unfavorable environmental conditions (Pennak 1989).

When a cladoceran is food-limited, it matures at a smaller size and produces smaller offspring (total number being similar). The main response of *D. pulex* to low food levels is a reduction in size-specific food intake and egg size (Lynch 1989). However, food concentration does not affect length/weight relationships, instar duration and weight-specific investment of energy in reproduction.

Cladoceran populations consist of smaller individuals in water bodies with large populations of vertebrate predators. Large-bodied species, e.g., *D. pulex*, tend to be fewer in ponds with large predator bases (Zaret 1980). In these situations, smaller species or smaller individuals within a species have better chances of escaping predation than larger individuals (based on prey visibility).

However,smaller animal can also be selected when invertebrate predators, such as midge larvae, *Chaoborus* spp., or backswimmers, *Notonecta* spp. are present.

Fertilization

Concerning the food resources available to zooplankters, culturists often use fertilization to improve their food base. Fertilizers may be either inorganic or organic based. Inorganic fertilizers are those that take the form of granular or liquid fertilizers having a high phosphorus content and, to a smaller degree, nitrogen (phosphorus is often the limiting nutrient in freshwater). The premise behind using inorganic fertilizers is that by applying needed nutrients, phytoplankton populations increase. These increased populations of phytoplankton, often called a 'bloom', will then increase the number of zooplankton in the pond, which eat the phytoplankton. However, it has been shown that large phytoplankton populations alone do not necessarily increase zooplankton populations; zooplankters will eat more fungi and bacteria associated with decaying organic substances than phytoplankton directly. In fact, these large populations of phytoplankton often lead to lower water quality through increased pH and low morning levels of dissolved oxygen.

Some researchers have had considerable success in managing zooplankton populations through phytoplankton management. Culver et al. (1992) were able to successfully increase walleye and saugeye production by maintaining the nitrogen:phosphorus ratio (N:P) at 20:1. Improvements in both production and fish survival were obtained by weekly restoration of the culture ponds to 600 ug N/L (NH_4^+ + NO_3^-) and 30 ug P/L (PO_4^{-3}) using inorganic fertilizers (ammonium nitrate and orthophosphoric acid). This combination of fertilizers allowed for improved species composition of phytoplankton that, in turn, improved the zooplankton forage base. The most important diet component of these animals have been shown to be small algae (1-25 um)(Lampert 1987). Algae larger than 50 um or algae with spines or in colonies were usually rejected. Blue-green algae in the preferred size range are often toxic and not eaten (Porter and Orcutt 1980). Blue-green algae often have a competitive advantage in environments where nitrogen becomes a limiting nutrient, e.g., late summer, (low N:P ratios), because some blue-green algae species can 'fix' atmospheric nitrogen. Applications of nitrogen fertilizers at this time can help decrease blue-green algae populations.

Organic fertilizers are often used to promote desirable zooplankton species. Organic fertilizers may be animal manures, alfalfa hay (ground or meal), or soybean meal. Organic fertilizers should have low carbon:nitrogen ratios and have fine particle sizes to allow rapid decomposition (Geiger and Turner 1990). As previously indicated, zooplankters will consume fungi and bacteria associated with decaying organic material. Clouse (1991) found that organic fertilizers based on biomass were more effective in producing walleye fingerlings than applications based solely on nitrogen content. However organic fertilizers may cause dissolved oxygen problems during initial decomposition.

Many types of fertilizers (both inorganic and organic) have been used to increase pond fertility. Table 1 lists some of the more common types of fertilizers used in each category. Application rates and frequencies can vary greatly depending on region and natural productivity of the pond; set rates are difficult to recommend.

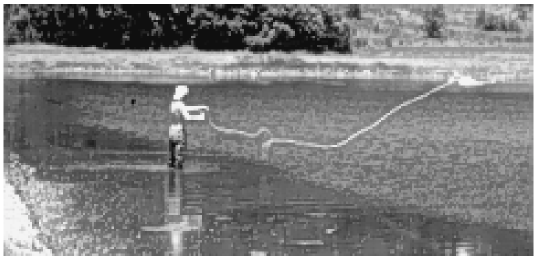

Figure 5. The use of nets is a common way to sample zooplankton populations.

Sampling

While culturing larval fish, the culturist should periodically check zooplankton populations in culture ponds. Sampling equipment ranges from the use of plankton nets being towed at oblique angles to pumps. Sampling tows are often easy to do; however, the main disadvantage is the problem of obtaining good representative samples when the ponds are heavily infested with filamentous algae or vascular plants. Techniques that have shown promise has been the use of pumps and tube samplers. Pumps, such as the one described by Farquhar and Geiger (1984), are often cumbersome and expensive but do give good quantitative samples. Tube samplers may be made of 2.5-cm (1-in) PVC pipe fitted with a 2.5-cm check valve. This tube is then lowered into the water column and the water is removed and filtered through the plankton net. Graves and Morrow (1988) showed that this technique yielded similar results as those used in the more traditional techniques.

Regardless of sampling technique, zooplankton samples should be obtained in a variety of locations in the pond and at the same time of the day. Zooplankters are often clumped in dense numbers throughout the pond and do migrate vertically during the day. Consistency in sampling is paramount to obtaining good quantitative samples.

The number, age and species of fish stocked affect the number of zooplankton needed for successful culture. In general terms, 100 to 500 animals per liter (400-2000/gal) of suitable sizes and species of zooplankton should be present (Geiger and Turner 1990). Desirability of specific constituents of the zooplankton samples, i.e., size and species, are best determined by the species and the life stage of fish being cultured. However, "desirable species" generally include *Daphnia* and *Ceriodaphnia* (cladocerans). In addition, most calanoids and cyclopoids (copepods) are also considered "desirable", although some are parasitic.

Generally, planktivorous fish will preferentially remove the largest sizes of zooplankton (Zaret 1980). Therefore, ponds containing large-bodied zooplankton (yet, small enough for the fish to consume) should be more successful than ponds containing small-bodied zooplankton.

Because larger-bodied zooplankton are preferentially removed, there exists a selective pressure for smaller-bodied populations. As the culture season progresses, there is increasing fish predation pressure on large-bodied zooplankton populations and smaller-bodied species tend to appear. Towards the end of the culture period when small-bodied species (e.g., *Bosmina* and ultimately rotifers) increase in numbers, it is usually an indication that predation pressure by the fish is too great. Therefore, fish need to be either harvested or fed a supplemental commercial diet. At this time, further fertilization is not warranted.

Table 1. Some common types of fertilizers used to increase pond fertility.

Inorganic Fertilizers		**Organic Fertilizers**
Nitrogen Fertilizers	*Phosphorus Fertilizers*	
Urea	Superphosphate	Manures (e.g., cattle, poultry, swine)
Calcium nitrate	Triple superphosphate	Hays (e.g., alfalfa, grass)
Sodium nitrate	Phosphoric acid	Meals (e.g., cottonseed, soybean, bone, blood)
Ammonium nitrate	Orthophosphoric acid	

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