

PLANKTON MANAGEMENT FOR FISH CULTURE PONDS

J. E. Morris
Department of Animal Ecology
Iowa State University

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 sp.*), 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; 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 are classified as either rotifers, cladocerans (water fleas) or copepods. The ability of rotifers and cladocerans to reproduce parthenogenetically (asexually) enables them to react quickly to unfavorable and favorable environmental conditions (Pennak 1978).



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 (68.0°F), the egg-to-egg span is 2-3 days with the total young per adult lifespan being 15-25 days.



Cladocerans and copepods have similar life spans of approximately 50 days, but with different peak periods. To reach their peak capacity, cladocerans require 24 days, (Allan



reproductive periods. To reach their peak capacity, cladocerans require 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 and are readily consumed by most fry. However, cladoceran populations usually decline rapidly when subjected to predation in culture ponds (Geiger 1983b; Geiger et al. 1985). On the other hand, 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 than for cladocerans (13-15 days for copepods compared to 7-8 days for cladocerans at 20°C), but life spans are similar (approximately 50 days at 20°C) (Allan 1976). The total young 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 out competed by both cladocerans and copepods for the available food resources. 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 per adult lifespan give cladocerans a definite ecological advantage over rotifers and copepods. However, increased predation by fish upon cladocerans does decrease 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 *Daphnia sp.* 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, respectively, while *Daphnia sp.* and *Bosmina sp.* populations decreased significantly within 7.3 days after reaching maximum densities.

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 Cross's study ponds were filled with water from the Pearl River, Mississippi. Culver et al. (1992) also compared filling ponds seven days before fry stocking to ponds filled for 30 days. The ponds filled seven 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 early instars of cladocerans. Improved production may be achieved by stocking these fry into culture ponds filled only 2-3 days before stocking.

Predator and Prey Interactions

Direct relationships between ingestion rates, fish larval size, or fish larval density to prey density appear to exist (Eldridge et al. 1981). Also, several studies have documented the size-selectivity of fish for their invertebrate prey (Brooks and Dodson 1965; Dodson 1974; Zaret 1980; O'Brien 1987). Fish have been observed to consume increasingly 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) TL, presented with four size classes of *Daphnia sp.* (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 restricts them to consuming appropriately size prey. Miller et al. (1988) noted the similarities among different fish 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 have a multitude of different ways by which they attempt 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 anti-predator mechanisms. *Brachionus calyciflorus* populations may develop various levels of posterolateral spines that decrease predation by *Asplancha sp.* (Gilbert 1967). Drenner and McComas (1980) concluded that the impact of predators upon zooplankton stocks varies with the zooplankton'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 1978). 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 also indicated by the increased number of diapause 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 1978).

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 was a reduction in size specific food intake and egg size (Lynch 1989). However, food concentration did not affect length/weight relationships, instar duration and weight-specific investment of energy in reproduction.

Cladoceran populations also 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 given species have improved chances of escaping predation than larger individuals (based on prey visibility). However, smaller animals can also be selected when predators are other invertebrates, such as midge larvae, *Chaoborus sp.*, or backswimmers, *Notonecta sp.*

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 then eat the phytoplankton. However, it has been shown that large

phytoplankton
necessarily increase
populations;
more fungi and
decaying organic



populations alone do not
zooplankton
zooplankters will eat
bacteria associated with
substances than

phytoplankton directly. In fact, these large populations of phytoplankton often lead to lower water quality through increased pH and low morning dissolved oxygen levels.

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) to 20:1. Improvements in both production and fish survival were obtained by weekly restoration of the culture ponds to 600 $\mu\text{g N/l}$ ($\text{NH}_4^+ + \text{NO}_3^-$) and 30 $\mu\text{g P/l}$ (PO_4^{3-}) levels. 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 μm) (Lampert 1987). Algae larger than 50 μm or algae with spines or in colonies were usually rejected. Bluegill algae in the preferred size range are often toxic and not eaten (Porter and Orcutt 1980). Blue-green algae are often favored in environments where nitrogen becomes a limiting nutrient (low N:P ratios); blue-green algae can 'fix' atmospheric nitrogen.

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. However, the use of organic fertilizers may cause dissolved oxygen and ammonia problems during the initial decomposition. Clouse (1991) found that organic fertilizers based on biomass were more effective in producing walleye fingerlings than applications based solely on nitrogen content.

Sampling

While culturing larval fish, the culturist needs to 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 have 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.

Irrespective to sampling technique, zooplankton samples should be obtained in a variety of locations in the pond and at the same time of the day. The reasons for this are that zooplankters are often in clumped numbers throughout the pond and do migrate vertically during the day. Consistency in sampling is paramount to obtaining good quantitative samples.

The number of zooplankton needed for successful culturing of larval fish is affected by the number, age and species of larvae stocked. In general terms, zooplankton populations should be approximately 100 to 500 animals per liter (500-2000/gal). Specific constituents of the zooplankton samples, e.g., size and species, are best determined by the species and the life stage of fish being cultured.

Literature Review

Allan, J. D. 1976. Life History patterns in zooplankton. *American Naturalist* 110:165-180.

APHA (American Public Health Association), American Water Works Association, and Water Pollution Control Federation. 1989. Standard methods for the examination of water and wastewater, 17th edition. American Public Health Association, Washington, DC.

Brooks, J. L. and S. I. Dodson. 1965. Predation, body size, and composition of the plankton. *Science* 150:28-35.

Buddington, R. K. and J. P. Christofferson. 1985. Digestive and feeding characteristics of the chondrostreans. *In North American Sturgeons: Biology and Aquaculture Potential*. F. P. Binkowski and S. I. Doroshov (Editors). Dr. W. Junk Publishers, Dordrecht, Netherlands.

Clouse, C. P. 1991. Evaluation of zooplankton inoculation and organic fertilization for pond-rearing walleye fry to fingerlings. M. S. Thesis, Iowa State University.

Colura, R. L. and G. C. Matlock. 1983. Comparison of zooplankton in brackish water fertilized with cotton seed meal or chicken manure. *Annual Proceedings Texas Chapter American Fisheries Society* 6:68-83.

Conklin, D. E., K. Devers, and R. A. Shleser. 1975. Initial development of artificial diets for the lobster, *Homarus americanus*. *World Aquaculture Society* 6:237-248.

Cross, T. 1984. Turcotte Laboratory ponds fish production. Mississippi D-J project F-68 Annual Report, Mississippi Department Wildlife Commission. 37 pp.

Culver, D. A., J. Qin, S. P. Madon, and H. A. Helal. 1992. *Daphnia* production techniques for rearing fingerling walleye and saugeye. Federal Aid in Fish Restoration Project F-57-R.

Dodson, S. I. 1974. Adaptive change in plankton morphology in response to size-selective predation: a new hypothesis of cyclomorphosis. *Limnology and Oceanography* 19:721-729.

Drenner, R. W. and S. R. McComas. 1980. The roles of zooplankter escape ability and fish size selectivity in the selective feeding and impact of planktivorous fish. *Evolution and Ecology of*
morris.doc

Zooplankton Communities. Special Symposium, American Society of Limnology and Oceanography 3:587-593.

- Eldridge, M.B., J. A. Whipple, D. Eng, M. J. Bowers, and B. M. Jarvis. 1981. Effects of food and feeding factors on laboratory-reared striped bass larvae. Transactions of the American Fisheries Society 110:11-120.
- Farquhar, B. W. 1984. Evaluation of fertilization techniques used in striped bass, Florida largemouth bass, and smallmouth bass rearing ponds. Proceedings Annual Conference Southeastern Association Game and Fish Commissioners 37:346-368.
- Farquhar, B. W. and J. G. Geiger. 1984. Portable zooplankton sampling apparatus for hatchery ponds. Progressive Fish-Culturist 46:209-211.
- Fitzmayer, K. M., J. I. Broach, and R. D. Estes. 1986. Effects of supplemental feeding on growth, production, and feeding habits of striped bass in ponds. Progressive Fish-Culturist 48:18-24.
- Geiger, J. G. 1983a. A review of pond zooplankton production and fertilization for the culture of larval and fingerling striped bass. Aquaculture 35:353-369.
- Geiger, J. G. 1983b. Zooplankton production and manipulation in striped bass rearing ponds. Aquaculture 35:331-351.
- Geiger, J. G., C.J. Turner, K. Fitzmayer, and W. C. Nichols. 1985. Feeding habits of larval and fingerling striped bass and zooplankton dynamics in fertilized rearing ponds. Progressive Fish-Culturist 47:213-223.
- Geiger, J. G. and C. J. Turner. 1990. Pond fertilization and zooplankton management techniques for production of fingerling striped bass and hybrid striped bass. *In* Culture and Propagation of Striped Bass and its Hybrids. R. M. Harrell, J. H. Kerby and R. V. Minton (Editors). Striped Bass Committee, Southern Division, American Fisheries Society, Bethesda, MD. 323 pp.
- Gilbert, J. J. 1967. Asplancha and posterolateral spine production in *Brachionus calyciflorus*. Archives Hydrobiologia 64:1-62.
- Graves, K. G. and J. C. Morrow. 1988. Tube sampler for zooplankton. Progressive Fish Culturist 50:182-183.
- Jennings, T., B. Adair, G. Ackerman, W. Jorgensen, D. Marolf, M. Mason, M. McGee, J. Spykerman and B. Strunk. 1992. 1992 Fish Culture Section Completion Report. Iowa Department of Natural Resources.
- Lampert, W. 1987. Feeding and nutrition in Daphnia. *In* Predation: Direct and Indirect Impacts on Aquatic Communities. W. C. Kerfoot and A. Sih (Editors). University Press of New England, Hanover, New Hampshire.

- Landon, M. S. and R. H. Stasiak. 1983. *Daphnia* hemoglobin concentration as a function of depth and oxygen availability in Arco Lake, Minnesota. *Limnology and Oceanography* 28:731-737.
- Lynch, M. 1989. The life history consequences of resource depression in *Daphnia pulex*. *Ecology* 70:246-256.
- Miller, T. J., L. B. Crowder, J. A. Rice. and E. A. Marschall. 1988. Larval size and recruitment mechanisms in fishes: toward a conceptual model. *Canadian Journal of Fisheries and Aquatic Sciences* 45:1657-1670.
- Morris, J. E. 1988. Role of artificial diets and feeding regimes on the culture of hybrid striped bass fry. Doctoral dissertation. Mississippi State University, Starkville, MS.
- Morris, J. E., P. V. Zimba and R. J. Muncy. 1988. Chlorophyll a determination in aquaculture ponds. Mississippi Academy of Sciences. 52nd. Annual Meeting, Biloxi, MS.
- O'Brien, W. J. 1987. Planktivory by freshwater fish: thrust and parry in the pelagic. *In* Predation: Direct and Indirect Impacts on Aquatic Communities. W. C. Kerfoot and A. Sih (Editors). University Press of New England, Hanover.
- Parmley, D. C. and J. G. Geiger. 1985. Succession patterns of zooplankton in fertilized culture ponds without fish. *Progressive Fish-Culturist* 47:183-186.
- Pennak, R. W. 1978. Freshwater invertebrates of the United States. 2nd edition. John Wiley, New York. 803 pp.
- Porter, K. G., and J. D. Orcutt. 1980. Nutritional adequacy, manageability, and toxicity as factors that determine the food quality of green and blue-green algae for *Daphnia*. *American Society of Limnology and Oceanography Special Symposium* 3:268-281.
- Turner, C.J. 1984. Striped bass culture at Marion Hatchery. *In* The Aquaculture of Striped Bass. J. P. McCraren (Editor) Publication Um-Sg-Map-84-01. University of Maryland Extension Service. College Park, Maryland. 259 pp.
- Werner, E. E. and D. J. Hall. 1974. Optimal foraging and the size selection of the bluegill sunfish (*Lepomis macrochirus*). *Ecology* 55:1042-1052.
- Whitney, D. E. and W. M. Darley. 1979. A method of determination of chlorophyll *a* in samples containing degradation products. *Limnology Oceanography* 24:183-186.
- Zaret, T. M. 1980. Predation and freshwater communities. Yale University Press. 187 pp.