Biomass Increase in Plankton Populations Induced by Organic Fertilizers Applied during the Reproduction of Common Carp

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Abstract
Artificial fertilization of nursery ponds used for nursing postlarvae to fry is a common procedure used in hatcheries to enchance productivity. A 2 ha nursery pond at the Martinesti hatchery was fertilized with 500 kg fermented manure to stimulate phytoplankton, and consequently zooplankton production. A sharp rise in nutrient levels was imminent. Nitrate and phosphate levels has rised tenfold from 0.5 to 2 and 5 mg l^{-1}, respectively from 0.05 to 0.5 mg l^{-1}. Altough nutrient levels kept rising, phytoplankton biomass remained steady, then fell from 0.6 to 0.1 g m^{-3}, while zooplankton biomass has increased from 5 to 14 and 64 g m^{-3} during the first 4 weeks of postlarval developement.

Keywords: artificial fertilization, nutrients, phytoplankton, primary productivity, zooplankton

1. Introduction

Artificially controlled natural reproduction of common carp (*Cyprinus carpio*) is still a standard procedure in Europe. During this process, different ponds are used for fish spawning, egg incubation, hatching and rearing the hatchlings to postlarval stage and nursing postlarvae to fry and fingerlings. The larval and postlarval stage are the most important in the production process. Larvae and postlarvae are sensitive to changes in water parameters and require appropriate quantity and quality of food. Naturally occuring food is preferred in this stage of developement and mortaliy rates can be reduced significantly if naturally occuring food is aviable. Organic fertilizers, like manure, are often used to fertilize nursery ponds to stimulate primary productivity. If applied correctly, these kind of fertilizers induce slight increases in nutrients, enchancing primary productivity. In the absence of zooplanktivorous fish, large zooplakton populations can develop, providing different size of food particles for carp postlarvae and fry. Food size is crucial, because ingestion capabilities are limited in the first stages of developement, consequently the adequate quantity of food particles in the 50-100 µm size range is crucial (Moata et al., 2005) [2], (Horvath, et al., 2002) [3], (Bud, 2004) [1].

2. Materials and methods

A nursery pond with a 2 ha surface area was filled up with water 2 weeks before stocking. The mean depth of the pond was 1.5 m, with a 6 l s^{-1} water supply, the retention time or the residence time of the pond was 11 days. The 500 kg manure was spread along the shore and covered with earth, providing a gradual leak of nutrients. NH_4, NO_2, NO_3 and PO_4 concentrations were measured with a high precision Merck Aquacant water test kit. A weekly phytoplankton monitoring program was estabilished to understand and manage the ecological functioning of the water body. Subsurface samples were taken at 0.5 m from 2

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*Corresponding author: Levente Vass, Tel: 0742296381, Email: vassdlevi@yahoo.com sampling sites. These 2 samples were pooled at equal volumes into a composite sample. Depth-integrated sampling was not applied here because stratification was only temporary (diurnal overturns). Transparency was measured weekly with a Secchi disc to determine the euphotic zone wich is 2.5 times the Secchi depth and can indicate the trophic state (Megard et al., 1980) [4]. Samples were preserved for later counting with Lugol's solution at a ratio of 1:100. Samples were concentrated before counting by sedimentation (4-5 days), then subsamples were taken for microscopic analysis. Phytoplankton cells were identified and measured with a stage micrometer, using an upright Muller light microscope (400x-800x magnifications). Cell volumes were calculated based on these measurements. Phytoplankton cells were counted with a Lund cell (Lund, 1959) [5]. Zooplankton was sampled with a 50 µm mesh size net by filtering exactly measured amounts of water from the same sampling sites. Phytoplankton and zooplankton wet biomass was calculated based on microscopic analysis of cell volumes.

3. Results and discussion

The nursery pond was filled up with fresh stream water from the Rediu stream wich supplies some of the ponds. Nutrient levels in these streams are typically low with oligotrophic caracteristics. These nutrient levels cannot support large phytoplankton populations, therefore biomass flow in oligotrophic freshwater ecosystems is low. To increase primary productivity artificial fertilization can be used in the previously described conditions. Nutrient leves were measured weekly afer the pond was filled up in the first weeks of may (Figure 1).

Nutrient leves indicating trophic status is one of the key components that influence directly algae growth. Light intensity and temperature is also a key factor. According to biweekly sampling and cell count the most important phytoplankton species found in the nursing pond are shown in Table 1.

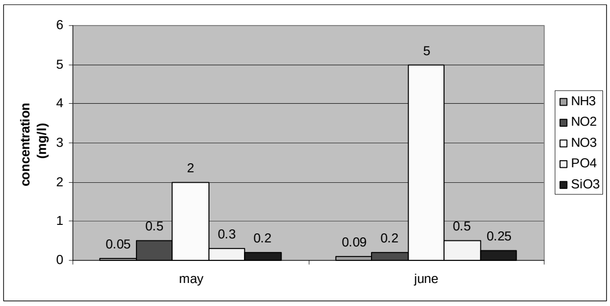

Figure 1. Monthly average nutrient concentrations relevant for algae growth measured in the fertilized nursery pond

Phytoplankton populations sustain the entire natural food chain and serve as food source for herbivorous filter feeding species like zooplankton. Large phytoplankton species (>50 µm) can be consumed directly by carp postlarvae in the very first stage of postlarval developement (Bud, 2004) [1].

Phytoplankton density has a direct influence on water turbidity and Secchi depth, altough after the nursing pond was filled up, some natural turbidity occured in the first two weeks. However, due to weakening grazing perssure over phytoplankton populations, there was a continuous increase in phytoplankton biomass wich resulted in a sharp decrease in water transparency (Figure 2).

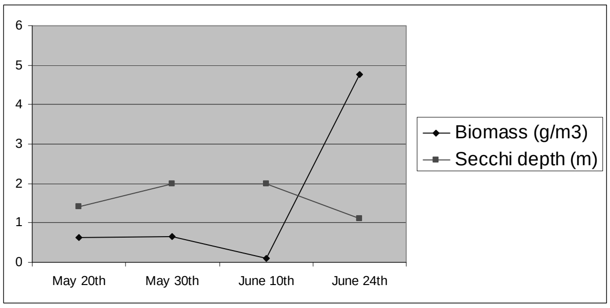

Figure 2. Total wet phytoplankton biomass and Secchi depth in may and july

Table 1. Number and cell volume of dominant phytoplankton species

Phytoplankton species	Average lenght and width (μm)	Biovolume of cells μm^3	Nr. Cells l $^{-1}$			
			may	may	june	june
Ankyra lanceolata	40x1.5	94	128100			
Korshikoviella limnetica	45x1.7	106	3920		2850	
Fragilaria ulna var. acus	65x2	272	6720			
Lepocinclis ovum	100x50	65998	4340	123	356	
Lepocinclis texta	35x25	22457	10640	1200	3385	
Trachelomonas hispida var. acuminata	25x25	8184	3500	120		
Cystomonas actinosphaerii	45x45	33523	1680			
Chlorococcum dissectum	20x20	32100			9900	
Chloromonas bolyaiana	17x17	15603			18150	
Scenedesmus cuadricuata	9x3	150	2800	1650	250	
Spongiochloris spp.	13x13	11214			19200	
Trachelomonas superba	50x35	8529			712	628000
Eudorina elegans	12x12	968		22	891	
Pandorina morum	30x35	16000				76000
Oocystis naegelii	8x14	4200				1300000

Regarding the role of naturally occuring food in postlarval developement the diversity and quantity of zooplankton populations has an exceptionally important role because different species of rotifers, copepods an cladocerans represent the perfect food size for continuously developing carp postlarvae. In the first weeks of developement, the following species could be found in the water of the nursing pond (Table 2).

Table 2. Wet biomass and number of different zooplankton species in may and june

Zooplankton species	Average length and width (μm)	Individual biovolume (mm^3)	Nr. of individuals l $^{-1}$			
			May 20th	May 30th	June 10th	June 24th
Daphnia catawaba	1700x1200	2.199	14	45	88	2
Microcyclops rubellus	1500x1000	0.032	5	30	40	111
Bosmina longirostris	300x200	0.005	8	30	74	685
Cyclopoid nauplius	130x70	0.00036	98	300	190	96
Polyarthra remata	110x60	0.00024	111	330	92	74
Keratella testudo	100x50	0.0002	1	2	14	7

Zooplankton populations continued to increase gradually with rising teperatures due to hefty phytoplankton populations, stimulated by rising nutrient levels (Figure 1).

Altough the density of pelagic unicellular algae hasn't increased in the first two weeks of planktonic developement and started to decrease after a month, their continuously regenerating populations supported a large herbivorous zooplankton population wich served as a food source for zooplaktivorous fish larvae Figure 3 and 4). Due to the sharp rise in zooplankton populations and grazing pressure over the primary producers, a „clear water phase" occured (Lampert, W. Et al., 1986) [6].

Large copepods and cladocerans are capable of intensive filtering and fast reproduction wich can result in depletion of pelagic phytoplankton species. In the absence of zooplanktivorous fishes, these zooplankton species can develop quickly, forming large populations, contributing to total respiration and reducing oxygen levels. With the developement of a large zooplanktivorous fish population in the nursing pond, large cladoceran and copepod species were consumed rapidly.

Altough rotifer populations were not affected significantly, their filtering capacity had no major impact on pelagic algal populations in this case.

In the absence grazing pressure, pelagic phytoplankton populations show an increase in wet biomass from 1 g m^{-3} to 5 g m^{-3} (Figure 3).

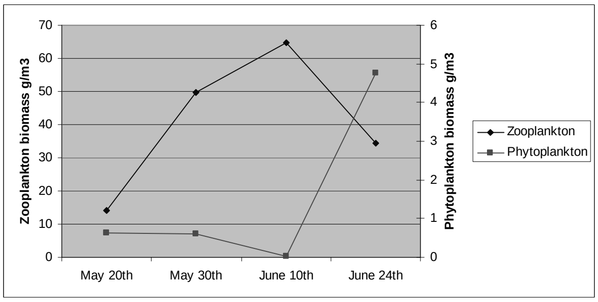

Figure 3. Zooplankton and phytoplankton wet biomass

The most competitive species are the ones with smaller cell size and short reproduction time, like *Oocystis naegelii* (Table 1).

The dynamic changes in phytoplankton and zooplankton populations are shown on figure 4 as well. Planktonic organisms are illustrated as a possible food source for developing fish larvae in different stages of developement. Figure 4 illustrates a month of postlarval developement, based on the changing feeding preferences of fish larvae.

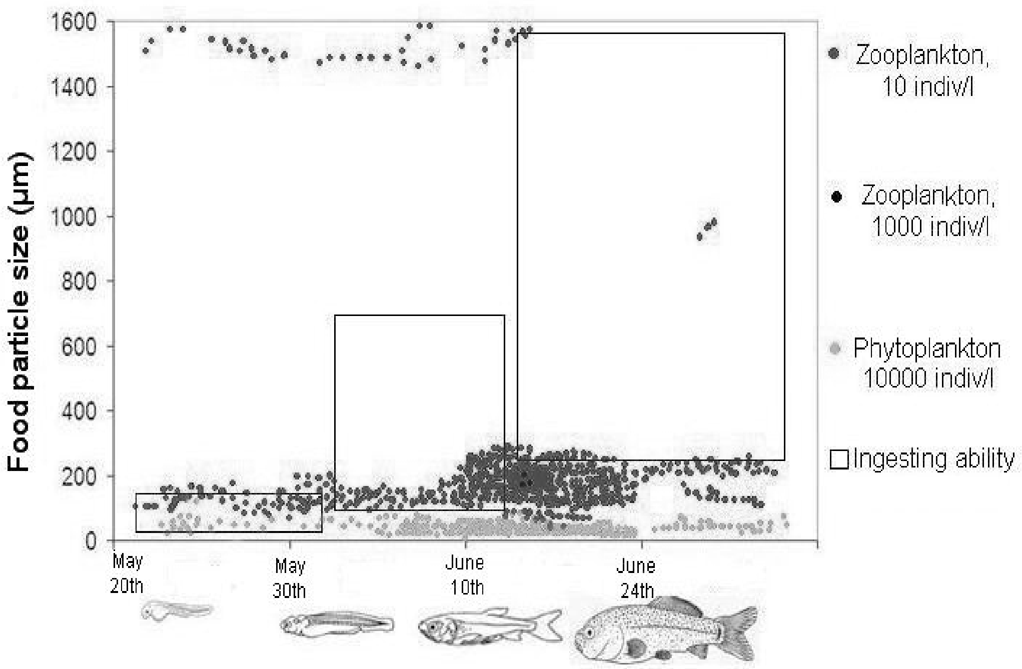

Figure 4. Availability of natural food (zooplankton and phytoplankton) in different developement stages of carp larvae

The red area on figure 4 shows the zooplankton populations between the 100 and 400 µm size range. During the first weeks of larval and postlarval developement this is the appropriate food size, matching the ingesting abilities of fish larvae. In the 1400-1600 µm size area are the larger cladoceran and copepod populations wich are depleted at the end of the first month of postlarval developement. The absence of naturally occuring food in this period was compensated with commercial fish feed.

The chemical analysis, showing the nutrient levels and the biomass calculations are comapred with an another set of data, obtained in similar conditions from a nearby, unfertilized and unpopulated pond. This pond has the same size as the nursery pond, it didn't contain any ichthyofauna and the retention time of the water was high. Nutrient levels were low compared to nutrient levels in the fertilized pond and plankton biomass was also low (Figure 5).

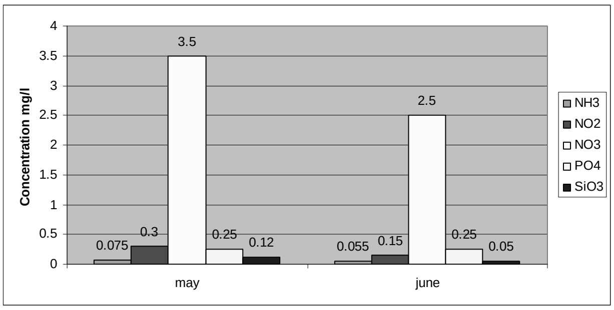

Figure 5. Monthly average nutrient concentrations relevant for algae growth measured in the unfertilized pond

The intensity of trophic interactions is influenced by artificial fertilization, this is why we found a significant difference in zooplankton wet biomass: Statistical analysis with the t-test shows that there is no significant difference betwen the mean phytoplankton biomass in these two pond but the variability, showing the differences between individual measurements is very high (Figure 6).

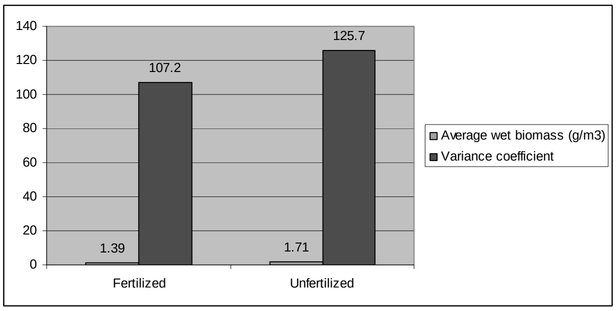

Figure 6. Compared levels of wet average phytoplankton biomass: fertilized and unfertilized water bodies

This means that we can observe a rather usual situation regarding the phytoplankton populations: in natural waters, and in fisheries as well there is a significant oscillation in phytoplankton biomass.
Figure 7 shows a significant difference in zooplankton wet biomass wich explains the relatively low phytoplankton biomass in the fertilized pond.

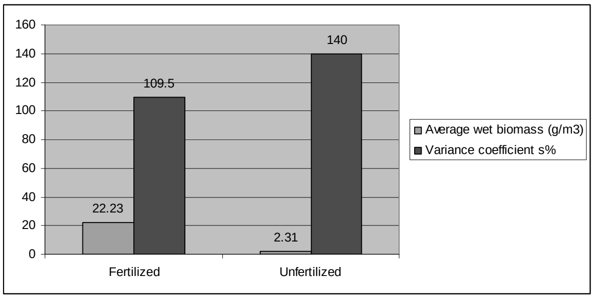

Figure 7. Compared levels of wet average zooplankton biomass: fertilized and unfertilized water bodies

The effects of artificial fertilization can be ovserved in different trophic interactions and different biomass transfer patterns.

4. Conclusions

Primary production is directly influenced by nutrient concentrations and it involves biomass production by photosynthetic algae followed by a succession of grazing and ingestion. The flow of biomass through these trophic interactions is responsible for the productivity of the given aquatic ecosystem. The artificial boosting of primary productivity can be an efficient process used in hatcheries to provide dense populations of phytoplankton and zooplankton, serving as live food for fish larvae. As long as zooplanktivorous consumers are not present in these artificially desingned foodchains, zooplankton populations develop uncheked and suppress pelagic phytoplankton. The flow of biomass can be very effective through these throphic interactions, altough unwanted algae species can develop wich are not consumed by zooplankton, because most zooplankton species feed selectively on phytoplankton (Sarnelle, O., 2007). Water flow (and retention time) through artificially fertilized ponds can be a crucial factor, flushing out algae wich are not integrated in the food chain and preventing the accumulation of nutrients. In these controlled conditions high densities of planktonic populations can develop. When algal populations are low, photosynthetically produced dissolved oxygen concetrations are also low, total respiration by intensively stocked fish and zooplankton populations can be high, resulting in low oxygen levels. In these conditions measures has to be taken to stabilize oxygen levels and PH fluctuations.
If artificially stimulated primary production is performed in a controlled environment, high densities of phytoplankton and zooplankton can be achieved. These planktonic organisms are consumed by fish larvae in different stages of developement, reducing mortality rate and increasing fish production in hatcheries.

References

1. Bud, I., Diaconescu St., Mudure M., Creşterea crapului şi a altor specii de peşti, Editura Ceres, Bucuresti, 2004

2. Moata, J. El., Ghmari, A. El., Droussi, M., Latrache, H., Sajieddine, M., Omoregie E., Bouadili A. El., Growth performances of common carp fry (*Cyprinus carpio*) in semi arid and semi intensive conditions: Deroua Fisheries Station (Béni Mellal, Morocco) Journal of Aquatic Sciences, 2005, 20, 1, 39-42.
3. Horváth L., Tamás G, Seagrave, C., Capr and pond fish cultrure, Blackwell, 2002.
4. Megard, R. O., Settles, J. C., Boyer H. A., Combs, Jr., W. S., Light, Secchi disks and throphic states. Limnology and Oceanography, 1980, 25(2), 373-377
5. Lund, J. W. G., A simple counting chamber for nanoplancton. Limnology and oceanography, 1959*,* 4, 57 – 65.
6. Lampert, W., Fleckner, W., Rai H., Taylor B. E., Phytoplankton control by grazing zooplankton: A study on the spring clear-water phase.Limnology and Oceanography, 1986, 31, 3.