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**Original Article**

# Forecasting percentage contribution of plankton biomass towards increase in fish yield under composite culture conditions

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**Abstract**
Seven triplicate groups of fish (67 fish group$^{-1}$) designated as $T_1$, $T_2$, $T_3$, $T_4$, $T_5$, $T_6$ and $T_7$ were reared in fertilized (0.17 g N $100^{-1}$ wet fish weight daily) earthen ponds (0.012 ha) for 365 days. There were five different fish species in each of the triplicate group viz. *Labeo rohita*, *Catla catla*, *Cirrhina mrigala*, *Ctenopharyngodon idella* and *Hypophthalmichthys molitrix* in the ratio of 27:10:10:07:13, respectively. Each triplicate group of fish $T_1$ to $T_6$ were fed supplementary diets at varying protein level *viz.,* 22, 24, 26, 28, 30 and 32% digestible protein (DP), respectively @ 2% of their wet body weight daily. However, control fish ($T_7$) although had an access to plankton; but were devoid of the availability of any supplementary diet. Data on dry weights of plankton biomass and increase in fish yield were collected on monthly basis and subjected to regression analysis in order to estimate the percentage contribution of plankton biomass towards increase in fish yield. The correlation for plankton productivity v/s increase in fish yield was positively significant ($p<0.01$) under all the treatments, showing the direct dependence of fish yield on plankton productivity. The order of percentage contribution of plankton productivity towards increase in fish yield is $T_3 \geq T_4 > T_1 > T_6 > T_7 > T_5 > T_2$. Regression model developed for $T_1$, $T_2$, $T_3$, $T_4$, $T_5$, $T_6$ and $T_7$ illustrated 63.40, 51.60, 64.50, 64.00, 52.20, 58.70 and 54.00% dependence of increase in fish yield on plankton productivity, respectively.
**Key words:** Earthen ponds, composite culture, supplementary diets, plankton biomass, fish yield, regression models.

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## INTRODUCTION

Pond fish culture is an enterprise left to developing countries, through which these nations may improve their economy and existing aquatic food resources. Fisheries sector of the developing world is largely pond based; where mostly planktivorous fish with non-overlapping ecological niches are inducted owing to their lower input requirements and effective utilization of all ecological zones of a pond ecosystem (Rahman *et al*., 2006). The yield of fish in a pond is largely dependent on the availability of plankton food organism that are augmented in pond system through fertilization (Soliman *et al*., 2000). Availability of nutrients in pond systems are limited due to their losses in pond sediments, requiring the exploitation of fertilizers in ponds to compensate for such losses and to build-up adequate nutrient status that could mediate plankton production (Al-Ghanim *et al*., 2015).

Large turnout of wastes from poultry, piggery and livestock sector has become a menace and require effective abatement (Adewumi *et al*., 2011). Carp culture has a great potential for the utilization of such wastes. Therefore, many wastes from poultry, livestock and piggery are efficiently utilized to enhance the production of natural food for carps and many other species (Sehgal and Sehgal, 2002). Fertilization of pond water with such wastes is the most cheapest and economical way to enrich the pond water with plankton production to secure high fish yield (Mahboob and Al-Ghanim, 2014). Poultry droppings contain better concentrations of nitrogen, phosphorous, and potassium as compared to any other animal manure used in fish ponds (Kangombe *et al*., 2006). Sustained natural food production in the pond ecosystem is an important indicator that determines fish yield; and is a major reason for success in semi-intensive pond culture system (Liang *et al*., 1999; Singh *et al*., 2013). Plankton acts as a natural means of promoting available carbon and supplying a higher flux of energy in water (Valencia *et al*., 2003). Optimum phytoplankton and zooplankton abundance can

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be attained through heterotrophic pathways in pond systems (Al-Ghanim *et al*., 2015). Phytoplankton variability in an aquatic environment influences biogeochemical cycles that are precious to the occurrence and continuity of life (Behrenfeld *et al*., 2006). Phytoplankton and zooplankton through their utilization by carp species promote their growth indices and thus enhance fish production per unit area (Dhawan and Kaur, 2002).

Modern high density pond fish rearing requires the use of supplementary feeds apart from pond fertilization. Fish growth is centered around the production of supplementary feed (Qazi *et al*., 2011). Natural potential of the pond's water and nutritional requirements of cultured species is a prerequisite for the formulation of supplementary feed for fish to be used under semi-intensive culture systems (Stankovic *et al*., 2011).

Offering supplementary feeds to fish means conversion of low valued feed ingredients to high valued fish protein. Level of dietary protein in aquafeeds is of fundamental importance since it significantly influences the economics and yields of fish farming operations (Islam and Tanaka, 2004). Impact of plankton production on increasing fish yield in ponds is an established fact (Garg and Bhatnagar, 2000; Dhawan and Kaur, 2002; Ahmed *et al*., 2005; Al-Ghanim *et al*., 2015). However, scarcity of data indicating the exact percentage contribution of plankton production towards increase in fish yield caused the pursuance of this research project.

## MATERIALS AND METHODS

### *Fish species*

Fingerlings of *Labeo rohita*, *Catla catla*, *Cirrhina mrigala*, *Ctenopharyngodon idella* and *Hypophthalmichthys molitrix* were purchased from Government Fish Seed Hatchery, Satiana Road, Faisalabad and acclimatized for a period of 10 days in nursery ponds at Fisheries Research Farms, University of Agriculture, Faisalabad, Pakistan.

### *Fish rearing and pond fertilization*

Following acclimatization all the above said five fish species were stocked together in the ratio of 27:10:10:07:13, respectively in seven triplicate groups and were reared for a period of 12 months, from May 01, 2013 through June 30, 2014. Poultry droppings were purchased from Ahmad Layer Control Farms, Sumandri, Pakistan and sundried for a period of 15 days and kept in a storage room. Prior to their use in experiment; the dried poultry dropping were chemically analyzed after AOAC (2006).

Dried poultry droppings were found to contain 4.6±0.11% nitrogen, 1.67±0.13% phosphorous, and 1.29±0.10% potassium as major ingredients. Each earthen pond (0.012 ha) was subjected to a preparative phase during which they were sundried, cleaned of weeds/grasses and then limed@2.5kg pond$^{-1}$. Thereafter, each pond was fertilized with poultry droppings@0.17g N/100 g fish wet weight on daily basis between 16:00 and 18:00 hours.

### *Supplementary diets*

Six iso-caloric but hetero-nitrogenous (22, 24, 26, 28, 30 and 32% digestible protein) supplementary diets were prepared in the laboratory through lab extruder (Model SYSLG30-IV, China). Each supplementary diet was chemically analyzed for their moisture, crude protein, fat, ash, carbohydrates and energy following the methods of AOAC (2006). Proximate composition and the formulation of each prepared supplementary diet are presented in Table I.

### *Fish feeding*

Each of the six triplicate group of five fish species (except control group) designated as $T_1$, $T_2$, $T_3$, $T_4$, $T_5$ and $T_6$ were fed supplementary diets *viz.* 22, 24, 26, 28, 30 and 32% DP, respectively at 2% of the wet body weight daily between 8:00 and 10:00 hours through sprinkling method. However, control fish ($T_7$) although had an access to plankton; but were devoid of the availability of any supplementary diet.

### *Fish measurements*

Netting of the fish was conducted on monthly basis, and 50% specimen of each of the five fish species in each pond were caught and weighed through digital weighing balance to the nearest 1 g and the length of each specimen was measured through a specifically designed wooden scale to the nearest 1 cm. Monthly increase in fish yield was calculated by the formula

$$\text{Increase in fish yield (g)} = \text{Monthly average final wet weight (g)} - \text{Monthly average initial wet weight (g)}$$

### *Fish survival*

The survival of each of the five fish species in treated and control ponds was measured through the formula

$$\text{Survival rate (\%)} = \frac{\text{No. of recovered fish} \times 100}{\text{No. of stocked fish}}$$

***Dry weight of plankton biomass***

Water samples from each of the treated and control ponds were obtained on monthly basis between 8:00 and 10:00 hours and brought to limnology lab for the measurements of dry weights of plankton biomass through evaporation method (Javed, 1988), using the formula

Plankton biomass ($mgL^{-1}$) = Total solids - Total dissolved solids

***Statistical analysis***

The data regarding the dry weights of plankton biomass and increase in fish yield were collected on monthly basis and subjected to step wise regression analysis using MINITAB 15®. $R^2$values were developed and used as tools to demonstrate the percentage contribution of plankton biomass (Independent variable) towards increase in fish yield (Dependent variable).

## RESULTS

***Monthly variations in plankton biomass***

The average dry weights of plankton biomass varied significantly among various months of the study period. However, significantly higher plankton biomass was recorded in the month of May (66.67±9.58 mg/L) whereas it was significantly the lowest during the month of June (7.17±0.09 mg/L) at the beginning of the experiment (Table II).

***Monthly variations in increase in fish yield***

Increase in fish yield, under all the supplementary feeding regimes and a control were determined and are presented in Table II. A concomitant trend between augmentation of plankton biomass and increase in fish yield was observed.

**Table I: Formulation and proximate composition of supplementary feeds at varying digestible protein levels**

| | Digestible protein (%) | | | | | |
|---|---|---|---|---|---|---|
| **Ingredients** | **22** | **24** | **26** | **28** | **30** | **32** |
| Wheat flour | 13 | 13 | 13 | 13 | 9 | 11 |
| Starch | 2 | 2 | 2 | 2 | 2 | 2 |
| Rice polish | 20 | 18 | 12.5 | 5 | 3 | 0.5 |
| Wheat bran | 15 | 9.5 | 5.5 | 5 | 2 | 0.5 |
| Canola meal | 1 | 5 | 10 | 12.5 | 16 | 25 |
| Rape seed meal | 1 | 1 | 5 | 4 | 9 | 7 |
| Sunflower meal | 0.5 | 2.5 | 4 | 5 | 7.5 | 10 |
| Corn gluten 30% | 22 | 22 | 21 | 22 | 18 | 5 |
| Soybean meal | 0.5 | 2 | 2 | 6 | 7 | 12 |
| Fish meal | 20 | 20 | 20 | 20 | 20 | 20 |
| DCP | 1.5 | 1.5 | 1.5 | 1 | 1 | 1 |
| Soya oil | 1 | 1 | 1 | 2 | 3 | 3.5 |
| Vitamin & Mineral Mixture | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 |
| **Proximate Composition%** | | | | | | |
| Moisture | 7.30 | 7.04 | 6.85 | 6.86 | 6.90 | 6.89 |
| Crude Protein | 22.24 | 24.00 | 26.08 | 28.17 | 30.00 | 32.00 |
| Total Fats | 7.25 | 7.43 | 7.48 | 7.37 | 7.91 | 8.33 |
| Total Ash | 7.13 | 6.92 | 6.66 | 6.19 | 6.29 | 5.32 |
| Carbohydrates | 56.08 | 54.61 | 52.93 | 51.41 | 48.90 | 47.46 |
| Energy (Kcal/kg) | 2517 | 2530 | 2500 | 2515 | 2525 | 2513 |

Note: Each kg of Vitamin-Mineral mixture contains: Vitamin A 3,000,000 I.U.; Vitamin E 6000 I.U.; Vitamin $B_1$ 600 mg; Nicotinic acid 12,000 mg; Calcium d. pantothenate 2400 mg; Vitamin $B_{12}$ 8 mg; Biotin 10 mg; Dl-Methionine 30,000 mg; B.H.T. 12,500 mg; Zinc sulphate 48,000 mg; Copper sulphate 6,000 mg; Vitamin $D_3$ 6000000 I.U.; Vitamin $K_3$ 600 mg; Vitamin $B_2$ 1400 mg; Vitamin $B_6$ 800 mg; Folic acid 300 mg; Choline chloride 50% 160000 mg; L-Lysine 15000 mg; Manganese sulphate 51600 mg; Ferrous sulphate 40000 mg; Potassium iodide 400 mg. Carbohydrates were calculated by difference as 100 - (protein + lipid + ash). Energy was determined by Bomb Calorimeter (Parr Instrument Company Moline, USA).

Among the 12 months of this study period a unit increase in plankton biomass augmentation caused a unit increase in fish yield and vice versa (Table II). However, significantly higher ($p<0.05$) increase in fish yield was observed during the month of May as 5969.40±163.74g, while the same was significantly lowest during the month of June as 914.58±18.68g at the beginning of the experiment (Table II)

**Table II: Overall monthly variations in plankton biomass ($mgL^{-1}$) and increase in fish yield (g) as influenced by poultry droppings and supplementary diets (Mean±SD).**

| Sr. No. | Months | Overall mean plankton biomass ($mgL^{-1}$) | Overall mean increase in fish Yield (g) | Fish Survival (%) |
|---|---|---|---|---|
| 1 | June, 2013 | 7.17±0.09 l | 914.58±18.68 l | 100.00±0.00 |
| 2 | July | 18.34±3.80 k | 2212.52±54.87 i | 100.00±0.00 |
| 3 | August | 28.05±5.26 j | 3376.88±81.26 f | 100.00±0.00 |
| 4 | September | 41.53±5.64 g | 4551.81±112.09 e | 100.00±0.00 |
| 5 | October | 44.27±6.29 f | 4636.22±109.81 d | 100.00±0.00 |
| 6 | November | 48.65±5.98 e | 3141.40±74.72 g | 100.00±0.00 |
| 7 | December | 39.46±3.97 h | 1402.51±152.64 j | 100.00±0.00 |
| 8 | January | 32.78±3.13 i | 1059.52±105.02 k | 100.00±0.00 |
| 9 | February | 51.40±7.38 d | 2840.48±91.11 h | 100.00±0.00 |
| 10 | March | 55.10±7.55 c | 5029.93±152.70 c | 100.00±0.00 |
| 11 | April | 61.54±8.59 b | 5573.96±123.20 b | 100.00±0.00 |
| 12 | May, 2014 | 66.67±9.58 a | 5969.40±163.74 a | 100.00±0.00 |

Different Alphabets in the same column are significantly different at $p<0.05$.

**Table III: Relationship between increase in fish yield and plankton biomass in different treatments**

| Treatments | | | Final Step Regression Equations (y = a + bx) | r/R | $R^2$ |
|---|---|---|---|---|---|
| $T_1$(22% DP) | Inc. in F.Y. | = | 124.819 + 78.590(Plank. Bio.) | 0.796 | 0.634 |
| | SE | = | (10.249) $^{p<0.01}$ | | |
| $T_2$(24% DP) | Inc. in F.Y. | = | 462.444 + 77.898(Plank. Bio.) | 0.718 | 0.516 |
| | SE | = | (12.949) $^{p<0.01}$ | | |
| $T_3$(26% DP) | Inc. in F.Y. | = | -151.312 + 104.963(Plank. Bio.) | 0.803 | 0.645 |
| | SE | = | (13.349) $^{p<0.01}$ | | |
| $T_4$(28% DP) | Inc. in F.Y. | = | 56.219 + 95.213(Plank. Bio.) | 0.800 | 0.640 |
| | SE | = | (12.246) $^{p<0.01}$ | | |
| $T_5$(30% DP) | Inc. in F.Y. | = | -54.588 + 76.045(Plank. Bio.) | 0.723 | 0.522 |
| | SE | = | (12.472) $^{p<0.01}$ | | |
| $T_6$(32% DP) | Inc. in F.Y. | = | 319.240 + 56.338(Plank. Bio.) | 0.766 | 0.587 |
| | SE | = | (8.105) $^{p<0.01}$ | | |
| $T_7$(Control) | Inc. in F.Y. | = | 343.124 + 55.671(Plank. Bio.) | 0.735 | 0.540 |
| | SE | = | (8.802) $^{p<0.01}$ | | |

$p<0.05$ = Significant $p<0.01$ = Highly significant NS = Non-Significant
SE = Standard error r = Multiple regression co-efficient $R^2$ = Co-efficient of determination
DP = Digestible protein (%) Inc. in F.Y. = Increase in Fish Yield (g) Plank.Bio. = Dry weight of plankton biomass ($mgL^{-1}$)

***Monthly variations in fish survival***

The survival of the fish was unaffected by monthly variations during this study period. Fish remained healthy, gained weight and experienced no mortality indicating the conduciveness of the rearing conditions.

***Plankton productivity v/s fish yield***

Step wise regression models, depicting the contribution of plankton production towards increase in fish yield are presented in Table III. The monthly data regarding increase in fish yield and dry weights of plankton biomass were statistically analyzed to find out relationships between them under each treatment. In all the six treatments (feeding regimes) and a control increase in fish yield showed a significant ($p<0.01$) and direct dependence on the plankton productivity of ponds. The higher values of "R" for each regression equation, computed under all the six treatments and a control, showed a strong relationship between plankton productivity to enhance fish yield (Table III).Regression model developed for $T_1$, $T_2$, $T_3$, $T_4$, $T_5$, $T_6$ and $T_7$ illustrated 63.40, 51.60, 64.50, 64.00, 52.20, 58.70 and 54.00% dependence of increase in fish yield on plankton productivity, respectively (Table III).

## DISCUSSION

Planktons are natural food organisms for carp species reared in ponds that provide the fish with required minimal nutrient supply. In the present investigation the plankton productivity exhibited a bimodal pattern, displaying an initial increase a decrease and again an increase. Winder and Cloern (2010) also recorded similar plankton shifts over a period of one year study and attributed these shifts to fluctuations in environmental conditions that promoted such pattern. Initially the dry weights of plankton biomass were lower, but progression in culture duration and addition of supplementary diets/fertilizers caused them to exalt till November, 2013. However, their concentrations experienced a steady decrease during the following colder months (December and January), and thereafter experienced reoccurrence and a healthy turnover again from February through May, 2014. Sun *et al*., (2010) also experienced an increase in the plankton biomass that occurred due to time and fertilization. Such differential plankton growth dynamics with biomass maxima in summer months and biomass minima during winter months has also been observed by Napiorkowska-Krzebietke *et al*., (2011).Plankton biomass minima in several colder months may be a result of nutrient limitations, plankton cell sinking and utilization by the fish (Winder and Cloern, 2010).

Increase in fish yield also exhibited a bimodal pattern with fish biomass maxima during summer months whereas a minima during the winter months. Present study revealed that the plankton structure of the pond environment seemed to precisely regulate fish yield. Any increase in plankton productivity simultaneously caused an increase in fish yield and vice versa. Ahmed *et al*., (2005) also observed a depression in growth performance of these carp species during the winter months of their study period. Survival of the fish is one of a major aspect in the demographic studies that are important for future fishery ventures. Quantity and quality of the organic manure as well as the seasons influence the survival rate of the fish (Dhawan and Kaur, 2002). In the present study mortality rate remained zero percent and thus seasonality maximally compromised with the survival status of the fish indicating the occurrence of a healthy rearing environment. Neither any of the protein level in supplementary diets nor poultry dropping fertilization caused any ill effect on fish survival.

The present study also revealed that the increase in fish yield was positively dependent ($p<0.01$) on the production of plankton biomass in pond's water. Fish yield increments were significantly correlated with plankton productivity of water under both treated and control ponds (Mehbood and Al-Ghanim, 2014; Al-Ghanim *et al*., 2015). The correlation for plankton productivity v/s increase in fish yield was positively significant ($p<0.01$) under all the treatments, showing the direct dependence of fish yield on plankton productivity. The higher the value of $R^2$ the better is the suitability of the model for the data (Ghani and Ahmad, 2010). In the present investigation the higher values of "$R^2$" for each regression equation, computed under all the six treatments and a control, showed a strong and direct relationship between plankton productivity and fish yield (Table III).

### *Conclusions*

Seasons earned a bimodal pattern for both the augmentation of plankton biomass and increase in fish yield. A concomitant trend between augmentation of plankton biomass and increase in fish yield was observed; with a unit increase in plankton biomass bringing a unit increase in fish yield. Seasonality maximally compromised with the survival status of the fish indicating the occurrence of a healthy rearing environment. Regression model developed for $T_1$, $T_2$, $T_3$, $T_4$, $T_5$, $T_6$ and $T_7$ illustrated 63.40, 51.60, 64.50, 64.00, 52.20, 58.70 and 54.00% dependence of increase in fish yield on plankton productivity, respectively.

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