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RELATIONSHIPS AMONG INCREASE IN BIOMASS, PLANKTONIC PRODUCTIVITY AND PHYSICO-CHEMISTRY OF PONDS STOCKED WITH Zn+Pb+Mn MIXTURE STRESSED FISH

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ABSTRACT

A group of fish species viz. *Cirrhina mrigala*, *Labeo rohita*, *Catla catla*, *Hypophthalmichthys molitrix* and *Ctenopharyngodon idella* were exposed to the sub-lethal Zn+Pb+Mn mixture concentrations in glass aquaria, for a period of 90 days. The other group of fish species was not given any stress. After metals mixture exposure, stressed and control groups were stocked in out-door earthen ponds, separately. Both the groups were reared for fourteen fortnights under semi-intensive pond culture system. Correlation and regression analyses on increase in fish biomass, dry weights of planktonic biomass and physico-chemical variables of pond's water were performed, on fortnightly data. In stressed fish pond, light penetration and chloride contents had exerted significantly direct while total ammonia, temperature and dissolved oxygen showed significant but inverse influence on increase in fish biomass. However, in control, only variable light penetration exhibited direct relationship with increase in fish biomass. Temperature and chloride contents exhibited direct impacts on planktonic productivity of metals mixture stressed fish. However, in control, temperature, total ammonia and phosphates showed direct relationship with pond productivity. It was also found that dependence of increase in fish biomass on dry weights of planktonic biomass was higher in control than stressed pond.

Keywords: Metals, regression, fish yield, planktonic biomass, physico-chemical parameters.

INTRODUCTION

Fish yield is susceptible to environmental factors and depends highly on the physico-chemical characteristics of water. Production of fish in inland waters of Pakistan has been declined due to reduction in their growth capability, susceptible to water contamination with heavy metals as a consequence of both natural and anthropogenic activities (Hayat and Javed, 2008). The heavy metals are found in mixture form in the aquatic bodies and alter physico-chemical characteristics such as pH, temperature, carbon dioxide, dissolved oxygen, total hardness, calcium, magnesium, total ammonia, total alkalinity, carbonates, bicarbonates, nitrates, phosphates, sodium and potassium contents of water. In this way, metallic ions pollution deteriorates the water quality, exerting stressful conditions on the fish (Linbo *et al*., 2009). At low pH, these metals would become mobilised and released into the water column hence, become harmful to aquatic organisms (Eisler, 1998). An organisms ability to maintain its internal environment such as, metabolism and reproduction, became reduced as a result of environmental stress i.e. high temperature, low dissolved oxygen and high ammonia (Ezra and Nwankwo, 2001). Ultimately, the survival and growth of fish in polluted water bodies decline, leading towards high mortality as well as reduced fish yields that would not cope up with the increasing demands of protein source for human beings consumption.

Most of the freshwater fish species rely on plankton during their developmental stages primarily during fry and fingerling stage (Wetzel, 2001). In addition, plankton also serve as an ample food for various fish species and leads to enhanced fish yield in water bodies (Dhawan and Kaur, 2002). The plankton community is comprised of phytoplankton or primary producers and zooplankton or secondary producers (Battish, 1992). The productivity in terms of planktonic biomass is also regulated by various physico-chemical factors such as, pH, temperature, electrical conductivity, transparency, total hardness, nitrates and phosphates (Mahboob and Sheri, 2001). The physico-chemical characteristics affect the biotic components of an aquatic environment in various ways. The change in these characteristics of water leads to variation in the dry weights of planktonic biomass that would ultimately affect increase in fish yield of the aquatic body (Ugwumba and Ugwumba, 1993).

In order to check the possible effects of physico-chemical parameters on increase in biomass of metals mixture stressed fish in the natural water bodies, the research work was conducted to evaluate relationships among increase in biomass, planktonic productivity and physico-chemistry of ponds, stocked with Zn+Pb+Mn mixture stressed fish.

MATERIALS AND METHODS

The research work was conducted at Fisheries Research Farms, Department of Zoology, Wildlife and Fisheries, University of Agriculture, Faisalabad. The fingerlings (90-day age) of five fish species viz. *Cirrhina mrigala*, *Labeo rohita*, *Catla catla*, *Hypophthalmichthys molitrix* and *Ctenopharyngodon idella* were brought to the laboratory and acclimatized for 10 days in cemented tanks. Stock of each fish species having similar wet weights, fork and total lengths were divided into two groups viz. stressed and control, and kept separately in glass aquaria. Chemically pure chloride compounds of zinc, lead and manganese were dissolved in deionized water and stock solutions prepared. These metals stock solutions were mixed on ionic basis to prepare mixture of Zn+Pb+Mn. The stressed group of fish viz. *Cirrhina mrigala*, *Labeo rohita*, *Catla catla*, *Hypophthalmichthys molitrix* and *Ctenopharyngodon idella* was exposed to 1/3rd of LC_{50} (sub-lethal) concentrations of Zn+Pb+Mn mixture i.e., 17.85, 18.84, 18.21, 21.03 and 18.59mgL^{-1}, respectively (Javed and Yaqoob, 2011). However, the control group of fish was kept un-stressed in metal free water. All the fish were exposed to sub-lethal concentrations, separately, for 90 days at constant water temperature (28^{o}C), pH (7.50) and total hardness (225mgL^{-1}). Constant aeration was supplied to all the test media (water) with an air pump fixed with capillary system. The fish were fed, to-satiation, with the feed (32% digestible protein and 3.00Kcalg^{-1} of energy) twice a day.

After sub-lethal exposure, mixture (Zn+Pb+Mn) stressed and control fish were stocked in out-door earthen ponds (0.012 ha), separately, at the rate of 65 fish per pond with the stocking density of 20, 40, 15, 10 and 15 percent for *Cirrhina mrigala*, *Labeo rohita*, *Catla catla*, *Hypophthalmichthys molitrix* and *Ctenopharyngodon idella*, respectively. Both ponds were fertilized with broiler droppings at the rate of 0.17g nitrogen per 100g fish weight daily, in order to promote the pond biota for fish consumption. The fish were also provided supplementary feed, at the rate of three percent of their wet body weight initially and then decreased gradually with decline in water temperature. However, no feed was offered to the fish at water temperature below 25^{o}C. The fish were grown in earthen ponds for fourteen fortnights. From each pond, random sampling (n = 7) of each fish species was done by using drag net and total fish biomass (g) was recorded, on fortnightly basis. After data collection, fish were released back into their respective ponds.

Physico-chemical Analyses of Pond's Water: The limnological parameters viz. water temperature, dissolved oxygen, pH, electrical conductivity, sodium, potassium, light penetration, total ammonia, total alkalinity, total hardness, phosphates, nitrates, chlorides and dry weights of planktonic biomass of both ponds were monitored, fortnightly. Water temperature and dissolved oxygen were determined by the meter HANNA HI-9146 while pH and electrical conductivity by the digital meters viz. HI-8520 and HI-9146, respectively. Sodium and potassium were determined with the help of Flame Photometer (PFPI) through the method Nos.10a and 11a of "Hand Book-60", respectively (Richards, 1954). Light penetration was determined with the help of Secchi's disc while total ammonia was measured through APHA (1998) by using spectrophotometer at 420nm absorbance and 1cm path length. For estimation of total alkalinity, methyl orange indicator method (APHA, 1998) was used, whereas total hardness was measured by titration of water sample with EDTA using Erichrom Black T (EBT), as indicator. Phosphates and nitrates were also determined with the help of Bausch and Lomb spectronic-21 at 430nm and 400nm, respectively (APHA, 1998). The chlorides in the water samples were estimated by Argentometric methods (APHA, 1971). Productivity of water is measured by estimating the dry weights of planktonic biomass. The planktonic biomass was determined indirectly, from the total solids and total dissolved solids (Hayat, 2009).

Statistical Analysis: The data obtained from this experiment were analyzed statistically by using MICROSTATC and MSTATC packages of the computer by following (Steel *et al*., 1996). The correlation and regression analyses were performed to find-out relationships among various parameters described for the study.

RESULTS

The increase in biomass of ponds stocked with control and stressed fish, at final harvest, are shown in Table 1.

1) Relationship between Increase in Fish Biomass and Physico-chemical Variables of Pond's Water: The dependence of increase in fish biomass of stressed and control ponds on the physico-chemical variables of water were analyzed by using step-wise regression models and their equations are presented in Table 2.

Stressed Fish Pond: The regression co-efficient for increase in total fish biomass on light penetration of water was found positive and highly significant (Step 1). This relationship explains 67.30% variations in increase in biomass due to light penetration of water. The variable viz. total ammonia exerted negative but highly significant regression on the increase in fish biomass. This equation explains 73.60% dependence of increase in fish biomass on light penetration and total ammonia. At step 3, temperature was included in the regression model along with light penetration and total ammonia which exhibited negative but highly significant regression on increase in biomass. This relationship explains 79.30% variations in the increase in fish biomass. Dissolved oxygen along with light penetration, total ammonia and temperature showed negatively highly significant ($P<0.01$) regression on increase in fish biomass (Step 4). This model predicts 85.60% contribution of these variables towards increase in fish biomass of stressed pond. The introduction of chloride in the regression model increased the R^2 value upto 0.892 (Step 5). This variable along with light penetration, total ammonia, temperature and dissolved oxygen exhibited highly positive and significant regression on increase in fish biomass. The partial regression co-efficients for all these variables were negative except for light penetration and chlorides.

Control Fish Pond: Sodium gives negative but highly significant regression on the increase in fish biomass, at step 1. This relationship explains 82.10% variations in the increase in fish biomass due to sodium contents of the control pond. The planktonic biomass along with sodium exhibited negative and highly significant regression on the increase in fish biomass. This model explains 87.10% contribution of these two variables towards increase in biomass. At step 3, potassium was included in the regression model along with sodium and planktonic biomass that resulted into negative but highly significant regression on increase in fish biomass. This relationship predicts 90.60% variations in increase in fish biomass due to these variables. At step 4, light penetration was included in the regression model which exhibited positive and highly significant regression on increase in fish biomass along with sodium contents, planktonic biomass and potassium content. This model explains 92.90% variations in increase in biomass due to these variables. Total ammonia was included at step 5, along with sodium, planktonic biomass, potassium content and light penetration which revealed negative but highly significant regression on an increase in fish biomass. This regression model explains 95.10% contribution of these variables towards increase in fish biomass of control pond. Temperature along with sodium, planktonic biomass, potassium, light penetration and total ammonia exhibited negative but highly significant partial regression on increase in fish biomass. The contribution of all these variables towards increase in fish biomass was 96.20%. At step 7, total alkalinity was included along with already described variables, which resulted in negative but highly significant regression on increase in fish biomass. The introduction of this variable in the regression model resulted in the increase of R^2 value upto 0.973. At step 8, dissolved oxygen was included along with sodium, planktonic biomass, potassium, light penetration, total ammonia, temperature and total alkalinity. However, the partial regression co-efficient for this variable was negatively significant with R^2 value of 0.977. Control fish pond showed higher increase in fish biomass than the stressed pond at final harvest.

2) Relationship between Planktonic Productivity and Physico-chemical Variables of Pond's Water: Table 3 shows the regression of planktonic biomass of stressed and control ponds on the physico-chemical variables of water.

Stressed Fish Pond: First regression equation gives the regression of planktonic biomass on temperature of water. This relationship explains 74.30% variations in planktonic biomass due to water temperature. The regression co-efficient for this variable was positive and highly significant. The introduction of chloride in the regression model, along with the temperature, resulted into the increase of R^2 value upto 0.781. This regression model explains 78.10% contribution of these variables towards planktonic productivity of the stressed pond. The partial regression co-efficients for both temperature and chlorides were significantly positive.

Control Fish Pond: Step 1 gives the regression of planktonic biomass on water temperature for which the regression co-efficient was positive and highly significant. This relationship explains 85.40% variations in planktonic biomass due to temperature of water. The variable, total ammonia, was included at step 2, along with temperature, which had positive and highly significant regression on planktonic productivity of the control pond. At step 3, total hardness was included in the regression model, which exhibited positive and highly significant regression on planktonic biomass. The R^2 value for this equation was computed as 0.904. The variable, chloride, was included along with temperature, total ammonia and total hardness of water at step 4 which revealed negative but highly significant regression on planktonic biomass. The relationship explains 92.60% dependence of planktonic productivity on these variables. At step 5, the introduction of a variable i.e., "phosphate" in the regression model resulted into highly significant increase in value of R^2. Nitrates along with temperature, total ammonia, total hardness, chlorides and phosphates exhibited negative but highly significant regression on planktonic biomass. This relationship explains 95.60% variations in planktonic productivity of the control pond due to all these variables with statistically significant regression co-efficients, except for total hardness and nitrates.

3) Relationship between Increase in Fish Biomass and Planktonic Productivity of Pond's Water: Table 4 shows regression of increase in fish biomass on the planktonic productivity of ponds. The regression coefficients of variable in the regression model computed for both ponds were statistically highly significant and positive. The increase in fish biomass of stressed and control ponds showed 17.80 and 20.80% dependence on the planktonic productivity, respectively.

Table 1. Increase in biomass of ponds stocked with stressed and control fish.

	Stressed		Control	
	Total fish biomass (g)	Increase in biomass (g)	Total fish biomass (g)	Increase in biomass (g)
Initial	1612.95	-	1743.53	-
Final harvest (14th fortnight)	25549.93	23936.98	39316.94	37573.41

Table 2.Dependance of increase in fish biomass of stressed and control ponds on the physico-chemistry of water.

Step #			Regression Equation (y = a + bx)	r	R^2
Stressed					
1	Inc. in Biomass	=	- 622.09 + 150.87(L.P.)	0.820	0.673
	S.E.	=	$(16.04)^{p<0.01}$		
2	Inc. in Biomass	=	- 428.26 + 158.00(L.P.) - 305.71(NH_3)	0.858	0.736
	S.E.	=	$(14.74)^{p<0.01}$ $(96.28)^{p<0.01}$		
3	Inc. in Biomass	=	463.38 + 199.02(L.P.) - 410.99(NH_3) - 46.97(Temp)	0.891	0.793
	S.E.	=	$(17.98)^{p<0.01}$ $(91.78)^{p<0.01}$ $(13.97)^{p<0.01}$		
4	Inc. in Biomass	=	6211.26 + 166.31(L.P.) - 390.20(NH_3) - 137.81(Temp) - 395.11(DO)	0.925	0.856
	S.E.	=	$(17.12)^{p<0.01}$ $(77.80)^{p<0.01}$ $(24.83)^{p<0.01}$ $(94.98)^{p<0.01}$		
5	Inc. in Biomass	=	4417.02 + 167.09(L.P.) - 429.54(NH_3) - 137.99(Temp) - 405.52(DO) + 3.39(Cl)	0.945	0.892
	S.E.	=	$(14.99)^{p<0.01}$ $(68.95)^{p<0.01}$ $(21.73)^{p<0.01}$ $(83.18)^{p<0.01}$ $(0.93)^{p<0.01}$		
Control					
1	Inc. in Biomass	=	15603.06 - 21.63(Na)	0.906	0.821
	S.E.	=	$(1.54)^{p<0.01}$		
2	Inc. in Biomass	=	20010.05 - 27.13(Na) - 5.08(P.B.)	0.936	0.871
	S.E.	=	$(1.81)^{p<0.01}$ $(1.17)^{p<0.01}$		
3	Inc. in Biomass	=	21764.18 - 24.37(Na) - 9.34(P.B.) - 177.04(K)	0.955	0.906
	S.E.	=	$(1.69)^{p<0.01}$ $(1.45)^{p<0.01}$ $(43.56)^{p<0.01}$		
4	Inc. in Biomass	=	14742.84 - 12.73(Na) - 11.32(P.B.) - 271.28(K) + 120.11(L.P.)	0.967	0.929
	S.E.	=	$(3.40)^{p<0.01}$ $(1.36)^{p<0.01}$ $(45.22)^{p<0.01}$ $(31.63)^{p<0.01}$		
5	Inc. in Biomass	=	13208.99 - 10.54(Na) - 10.06(P.B.) - 260.32(K) + 130.16(L.P.) - 294.19(NH_3)	0.978	0.951
	S.E.	=	$(2.87)^{p<0.01}$ $(1.17)^{p<0.01}$ $(37.69)^{p<0.01}$ $(26.41)^{p<0.01}$ $(67.77)^{p<0.01}$		
6	Inc. in Biomass	=	16142.48 - 12.78(Na) - 6.51(P.B.) - 275.31(K) + 123.42(L.P.) - 346.78(NH_3) - 67.14(Temp)	0.983	0.962
	S.E.	=	$(2.62)^{p<0.01}$ $(1.46)^{p<0.01}$ $(33.59)^{p<0.01}$ $(23.42)^{p<0.01}$ $(61.80)^{p<0.01}$ $(19.44)^{p<0.01}$		
7	Inc. in Biomass	=	17890.84 - 14.98(Na) - 5.62(P.B.) - 249.71(K) + 100.41(L.P.) - 337.36(NH_3) - 70.91(Temp) - 1.04(Alk)	0.986	0.973
	S.E.	=	$(2.51)^{p<0.01}$ $(1.37)^{p<0.01}$ $(31.96)^{p<0.01}$ $(22.83)^{p<0.01}$ $(56.60)^{p<0.01}$ $(17.82)^{p<0.01}$ $(0.36)^{p<0.01}$		
8	Inc. in Biomass	=	16749.77 - 11.53(Na) - 5.12(P.B.) - 194.47(K) + 105.22(L.P.) - 362.48(NH_3) - 87.06(Temp) - 1.13(Alk) - 206.36(DO)	0.988	0.977
	S.E.	=	$(2.71)^{p<0.01}$ $(1.29)^{p<0.01}$ $(37.01)^{p<0.01}$ $(21.42)^{p<0.01}$ $(53.82)^{p<0.01}$ $(17.84)^{p<0.01}$ $(0.34)^{p<0.01}$ $(81.70)^{p<0.05}$		

Inc. in Biomass = Increase in fish biomass (g)	R^2 = Co-efficient of determination	L.P. = Light penetration (cm)	DO = Dissolved oxygen (mg L^{-1})	P.B. = Dry weight of planktonic biomass (mg L^{-1})
S.E. = Standard error	$p<0.01$= Highly significant	NH_3 = Total ammonia (mg L^{-1})	Cl = Chlorides (mg L^{-1})	K = Potassium (mg L^{-1})
r = Multiple regression co-efficient	$p<0.05$= Significant	Temp = Temperature (˚C)	Na = Sodium (mg L^{-1})	Alk = Total alkalinity (mg L^{-1})

Table 3.Dependance of planktonic productivity of both stressed and control fish ponds on the physico-chemical variables.

Step #			Regression Equation (y = a + bx)	r	R^2
Stressed					
1	Plank. Biomass	=	- 151.53 + 12.38(Temp)	0.862	0.743
	S.E.	=	(1.11) $^{p<0.01}$		
2	Plank. Biomass	=	- 353.80 + 12.76 (Temp) + 0.34(Cl)	0.884	0.781
	S.E.	=	(1.05) $^{p<0.01}$ (0.13) $^{p<0.05}$		
Control					
1	Plank. Biomass	=	- 140.84 + 12.11(Temp)	0.924	0.854
	S.E.	=	(0.76) $^{p<0.01}$		
2	Plank. Biomass	=	- 165.09 + 12.17(Temp) + 18.34(NH_3)	0.936	0.876
	S.E.	=	(0.71) $^{p<0.01}$ (6.67) $^{p<0.01}$		
3	Plank. Biomass	=	- 344.86 + 12.89(Temp) + 21.42(NH_3) + 0.57(Hard)	0.951	0.904
	S.E.	=	(0.67) $^{p<0.01}$ (6.02) $^{p<0.01}$ (0.16) $^{p<0.01}$		
4	Plank. Biomass	=	- 298.29 + 13.55(Temp) + 38.86(NH_3) + 0.635(Hard) - 0.196(Cl)	0.963	0.926
	S.E.	=	(0.62) $^{p<0.01}$ (7.31) $^{p<0.01}$ (0.15) $^{p<0.01}$ (0.06) $^{p<0.01}$		
5	Plank. Biomass	=	- 321.92 + 14.60(Temp) + 47.71(NH_3) + 0.531(Hard) - 0.203(Cl) + 78.15(Phos)	0.970	0.941
	S.E.	=	(0.66) $^{p<0.01}$ (7.20) $^{p<0.01}$ (0.14) $^{p<0.01}$ (0.05) $^{p<0.01}$ (25.06) $^{p<0.01}$		
6	Plank. Biomass	=	- 293.68 + 13.32(Temp) + 38.89(NH_3) + 0.755(Hard) - 0.20(Cl) + 84.33(Phos) - 9.64(Ni)	0.978	0.956
	S.E.	=	(0.68) $^{p<0.01}$ (6.80) $^{p<0.01}$ (0.14) $^{p<0.01}$ (0.04) $^{p<0.01}$ (22.08) $^{p<0.01}$ (2.72) $^{p<0.01}$		

Plank. Biomass = Dry weight of planktonic biomass (mg L^{-1}) R^2 = Co-efficient of determination Temp = Temperature (˚C) Hard = Total water hardness (mg L^{-1})
S.E. = Standard error p<0.01= Highly significant Cl = Chlorides (mg L^{-1}) Phos = Phosphates (mg L^{-1})
r = Multiple regression co-efficient p<0.05= Significant NH_3 = Total ammonia (mg L^{-1}) Ni = Nitrates (mg L^{-1})

Table 4. Dependence of increase in fish biomass of stressed and control ponds on planktonic productivity.

Treatments	Regression Equation (y = a + bx)			r	R^2
Stressed	Inc. in Biomass	=	606.90 + 4.70(Plank. Biomass)	0.422	0.178
	S.E.	=	(1.59) $^{p<0.01}$		
Control	Inc. in Biomass	=	849.70 + 8.00(Plank. Biomass)	0.456	0.208
	S.E.	=	(2.47) $^{p<0.01}$		

Inc. in Biomass = Increase in fish biomass (g) S.E. = Standard error R^2 = Co-efficient of determination
Plank. Biomass = Dry weight of planktonic biomass (mg L^{-1}) r = Multiple regression co-efficient p<0.01 = Highly significant

DISCUSSION

The presence of metallic ion pollutants in the freshwater environs has altered physical and chemical characteristics of water leading towards biochemical disturbances in several vital life sustaining functions of aquatic organisms, specifically fish (Kandemir *et al*., 2010; Pala *et al*., 2017). The metallic ions exposure exerts stressful conditions on fish, by altering enzyme activities and affecting lipid peroxidation products in the tissues (Talas *et al*., 2008) hence, the feed intake by fish declines ultimately resulting into their reduced growth rates (Abbas and Javed, 2016a). Alterations in the water quality parameters such as temperature, pH, dissolved oxygen, light penetration, electrical conductivity and total hardness, beyond optimum levels, could result into reduced planktonic productivity and fish biomass in the freshwater ecosystems (Orun *et al*., 2013; Abbas and Javed, 2016b; Dastan *et al*., 2017).

During present investigation, light penetration had exerted direct influence on the increase in fish biomass in both stressed and control fish ponds. These results are in line to the findings of Roy *et al*. (2014) who also reported that light penetration had significantly direct influence on increase in fish biomass. The present results are also supported by Padmavathi and Prasad (2007). They also observed a direct relationship between light penetration and increase in fish biomass. The chloride contents showed direct impacts on the increase in fish biomass in stressed fish ponds while an indirect/inverse relationship between chloride contents and increase in fish biomass was reported by Singh and Bhatnagar (2010). The total ammonia, temperature and dissolved oxygen revealed significant but negative influence on the increase in fish biomass of ponds while Hayat and Javed (2008) observed significantly direct impacts of these water quality variables on the increase in fish yield. In addition to this, Garg and Bhatnagar (1999) suggested that optimum fish yield in pond may coincide with the temperature of water as it maximizes the metabolic efficiency of fish. Chandra *et al*. (2005) observed that variations in fish growth were dependent on total alkalinity of water. The total alkalinity and dry weight of planktonic biomass of the control fish ponds exerted negative effects on the increase in fish biomass, during present experiment while Tave and Anderson (1993) reported significantly direct relationship of increase in fish biomass with total alkalinity of ponds water. However, Javed and Sheri (1998) observed significantly direct dependence of increase in fish biomass towards planktonic biomass of the control pond.

The temperature appeared to be the water quality variable that imparts significant impacts on dry weight of planktonic biomass of both stressed and control fish ponds. Mahboob and Sheri (2001) also reported that temperature significantly affects the light intensity and had a corresponding effect on the planktonic productivity of ponds as it exerted significant influence on the nutrient release to support plankton populations in water. In ponds stocked with control fish, total ammonia, total hardness and phosphates showed direct relationship with pond productivity. However, the total ammonia contents of pond's water revealed significantly negative relationship with planktonic productivity of ponds (Hayat and Javed, 2008). William and Robert (1992) reported that total hardness induced significant and pronounced impacts on planktonic productivity of ponds. Phosphates exerted significantly direct impacts on the planktonic biomass of ponds fertilized with broiler droppings (Ahmed *et al*., 2011). During present investigation, the nitrates exerted an indirect influence on the planktonic productivity of control pond. However, Mahboob and Zahid (2002) reported that the dry weight of planktonic biomass was significantly and positively correlated with nitrate contents of the pond's water.

In both metals mixture stressed and control fish ponds, increase in fish biomass revealed direct dependence on the existing planktonic productivity indices of ponds. Similarly, Sin (1987) reported higher fish yields in correspondence with increased planktonic productivity of water. Ahmed *et al*. (2011) also reported significantly positive correlation between increase in fish biomass and planktonic biomass in manured ponds. Direct and significant dependence of increase in grass carp yield on planktonic productivity of the pond's water was also reported by Javed and Sheri (1998).

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