Research Article

The Status of Water Quality in Various Fish and Shrimp Farms of Sindh Province, Pakistan: Abundance of Planktonic Biomass in Relation to Physicochemical Properties of Pond Water

Rahat Rukhsana[1], Shahnaz Rashid[2], Asma Fatima[2], Owais Iqbal Khan[3], Syed Babar Hussain Shah[4], Mumtaz Ali[4] and Ghulam Abbas[2]*

[1]Directorate General of Marine and Coastal Fisheries Development Karachi, Government of Sindh, Pakistan; [2]Centre of Excellence in Marine Biology, University of Karachi, Pakistan; [3]Institute of Environmental Studies, University of Karachi, Pakistan; [4]College of Fisheries, Ocean University of China, Qingdao, 266003, China.

Abstract | This research aims to study the water quality of 10 fish farms located in different regions of Sindh and to suggest a guideline for favorable physicochemical parameters for fish and shrimp farming. Water samples (n = 3 each) were collected from these farms and analyzed for contents of ammonia, alkalinity, temperature, nitrate, salinity, nitrite, pH, total hardness, dissolved oxygen (DO), chlorophyll-a and phytoplankton-density during the period from March, 2015 to June, 2016. The chlorophyll-a concentration was determined by using the acetone extraction technique. Ponds water sample (50 liters) was filtered through plankton net of 20 µm pore size and preserved in 4% formaldehyde for the analysis of phytoplankton. Subsequently, the phytoplankton were counted under microscope. Result showed that water quality parameters of all fish farms were suitable for farming purpose excluding Shamimul Hassan Farm, Fish Farm Green Co. and Ghulam Ali Nizamani Farm, where high level of total hardness was recorded as 1000±2.65 mg l^{-1}, 700±4.80 mg l^{-1}, and 975±4.73 mg l^{-1}, respectively. The minimum chlorophyll-a (1.4-2.1 mg l^{-1}) was found in the ponds water of Shamimul Hassan Farm, Fish Farm Green Co., and Ghulam Ali Nizamani Fish Farm, although the remaining farms showed maximum values 5.8-7.5 mg l^{-1}. Similar trend for the minimum (2.3 ×10^5 cells 1^{-1}) and maximum (13.2 ×10^5 cells 1^{-1}) concentration of phytoplankton cell density was also found in all the ponds, representing a strong correlation (P>0.05) between chlorophyll-a and phytoplankton cell density. Significant correlation (P>0.05) was also found among temperature, pH, salinity, nitrite, nitrate, ammonia, alkalinity, total hardness, chlorophyll-a and phytoplankton-density. Eigenvalues of the first two principal components represented 99.97 % of the total variability in water quality of fish and shrimp ponds at different farms. Positive loadings indicated high contribution of water quality variables throughout the study period.

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***Correspondence** | Ghulam Abbas, Centre of Excellence in Marine Biology, University of Karachi, Karachi-75270, Pakistan; **Email:** ghulamabbas@uok.edu.pk
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Introduction

Water quality assessment in aquaculture ponds is crucial to identify the variation and optimal range of limnological parameters like pH, temperature, alkalinity, total hardness, potassium, nitrate, phosphate, sulphate, and dissolved oxygen (DO) of water which is necessary for the enhancement of primary productivity of ponds water (Durge *et al*., 2018; Bronmark and Hansson, 2005). Water quality is the key factor for fish health, growth and high production as well (Ramanathan and Amsath, 2018; Kumar *et al*., 2017; Kiran, 2010; Sikoki and Veen, 2004). It is reported that pond water quality can be worsened by providing extreme feed and fertilizers, which is liable for low DO concentrations, as well as high NH_3, NO_2 and phosphorus concentration (Bauer *et al*., 2017; Tamizhazhagan and Pugazhendy, 2016; Herbeck *et al*., 2013; Naylor *et al*., 1998). Whereas, too much nutrients are gathered and responsible to cause polluted and anoxic condition by phytoplankton blooms in aquaculture ponds (Boyd, 2015; Wu *et al*., 2014; Munni *et al*., 2013; Jackson *et al*., 2004; Alonsorodrígues and Osuna, 2003; Burford and Williams, 2001; Desai, 1995). There are a number of key factors which determine water quality in which some are the basic constituent of water like pH, salinity, alkalinity and hardness, whereas, some constituents of water are produced by the result of metabolic break down of organic substances like ammonia, nitrate and nitrite (Kumar *et al*., 2017; Vijayalakshmi *et al*., 2013; Sahu *et al*., 2012; Rao *et al*., 2010; Sikoki and Veen, 2004; Wurts and Durbow. 1992). Furthermore, William and Robert (1992) described that most variables of water quality are not continuous and vary day-to-day such as pH values, while pond water alkalinity and hardness values are relatively constant nonetheless can alter over time. Water quality parameters interact with each other and influence primary productivity of the ponds. If the conditions are particularly unfavorable, and harmful substances such as ammonia and nitrite may be present in lethal concentrations, resulting pH and DO concentration may fluctuate dangerously.

Therefore, it is necessary to maintain water quality and to manage the aquatic environment of fish and shrimp farms at optimum level. It is worthy to note that the range of water quality parameters varies from species to species and even between different development stages of the same species. This study aims to assess water quality of fish and shrimp farms located in different regions of Sindh for favorable physicochemical parameters which are responsible for good growth of primary production.

Materials and Methods

In this study, 10 fish farms were selected from different regions of Sindh province such as Gulshan-e-maymar, Thatta, Garho, Ghotki, Tando Ghulam Ali, Talhar Badin, Sujawal, Mirpur Khas, Ehsanabad Karachi and Dhabiji Mirpur Sakro for the evaluation of water quality and production. Water samples (n= 3) were collected from each farm in pre washed polyethylene bottles (100 liter each) and brought into the laboratory of Seed Production Unit Hawksbay during the period from March, 2015 to June, 2016. These water samples were analyzed on the same day for temperature °C with the help of digital thermometer, pH (Bench top PH meter PHSJ-2F), salinity (%) by Atago hand refractometer, DO (mg l^{-1}) by portable test kit (Merck KGaA, 64271, Germany), ammonia (mg l^{-1}) by Indophenol derivative photometric method NOVA 400, nitrate (mg l^{-1}) (2, 6-dimethylphenol photometric method by NOVA 400), nitrite (mg l^{-1}) by Griess's reaction, a photometric method by NOVA 400, alkalinity (mg l^{-1}) by methyl orange titration method and total hardness (mg l^{-1}) by EDTA titration method. The chlorophyll-a concentration was determined by using the acetone extraction technique (Rai and Rajashekhar, 2014). Pond water sample (50 liters) was filtered through plankton net of 20 µm pore size and preserved in 4% formaldehyde for the analysis of phytoplankton. Subsequently, the phytoplankton were counted under microscope (Rai and Rajashekhar, 2014). Deionized water was used throughout the study period. All the chemicals and reagents of analytical grade were supplied by Merck. Data was statistically analyzed through principal component analysis (PCA), simple correlation and regression by using SPSS 21 software.

Results and Discussion

Water quality profile of fish and shrimp farms located in various districts of Sindh is given in Table 1. The pH values of all fish farms ranged from 6.5-8.6 which is found to be the optimal range for most of the species. An ideal pH is considered to be 6.5-9.0 for most fresh water species (Boyd, 1990; Delince, 1992). The optimal pH range for fish is considered to be from 6.5 to 8.5 especially for brown and rainbow trout (Table 2). It is noted that water pH is considered as a sign between the acidity or alkalinity level and is one of the most important factor regarding survival and growth of fish and shrimp species in aquaculture as well (Kumar *et al*., 2017; Delince, 1992). A desirable pH range for pond water should be 7 to 8 (WHO, 2009; Boyd, 1979; Michael, 1969). Fish may become stressed and die if

Table 1: *Water quality profile of fish and shrimp farms located in various districts of Sindh, Pakistan.*

No	Fish/ Shrimp Farm	Location	pH	DO (mg l^{-1})	Temp. (°C)	Salinity (%)	Ammonia (mg l^{-1})	Nitrite (mg l^{-1})	Nitrate (mg l^{-1})	Alkalinity (mg l^{-1})	Hardness (mg l^{-1})	Chlorophyll-a (mg l^{-1})	Phyto density (x 10^5cells 1^{-1})
1	Shamimul Hassan Farm	Gulshane Maymar	8.1± 0.14	5.5± 0.24	31± 0.16	0.0± 0.0	0.0± 0.0	0.0± 0.0	20± 2.09	156± 2.63	1000± 2.65	1.44± 0.23	2.31± 0.15
2	Memon Fish Farm	Garho	8.6± 0.17	5.6± 0.41	33.2± 0.15	1.4± 0.27	0.0± 0.0	0.0± 0.0	30± 2.25	258± 2.09	230± 3.84	5.81± 0.19	28± 3.84
3	Fish Farm Green Co.	Ghotki	6.8± 0.22	5.9± 1.2	32.2± 0.20	3± 0.16	0.0± 0.0	0.01± 0.00	35± 1.78	324± 2.13	700± 4.80	2.13± 0.11	2.45± 0.13
4	Mir Babu Fish Farm	Tando Ghulam Ali	6.8± 0.23	6.2± 0.6	31.1± 0.3	0.0± 0.0	0.05± 0.02	0.01± 0.00	35± 4.63	192± 2.52	180± 4.36	6.18± 0.51	8.94± 1.36
5	Ghulam Ali Nizamani Farm	Talhar Badin	7.8± 0.22	3.8± 1.4	34.1± 0.17	10± 0.36	0.02± 0.00	0.0± 0.0	30± 3.60	367± 2.48	975± 4.73	1.68± 0.42	2.31± 0.15
6	Abro Fish Farm	Mirpur Bhatoro Sujawal	7.5± 0.23	4.7± 0.21	32.8± 0.22	0.0± 0.0	0.01± 0.00	0.01± 0.0	14± 1.89	450± 1.47	190± 2.42	5.89± 0.36	9.68± 1.22
7	Khipro Fish Farm	Mirpur Khas	8.3± 0.17	6.1± 0.19	31.7± 0.4	0.0± 0.0	0.02± 0.01	0.0± 0.0	12± 1.41	145± 2.31	79± 2.22	6.53± 0.34	10.47± 1.20
8	Tehsar Farm	Ehsan Abad	7.3± 0.21	6.4± 0.32	28.3± 1.4	05± 0.09	0.01± 0.00	0.0± 0.0	15± 1.78	162± 2.75	340± 3.03	6.29± 1.15	11.10± 1.43
9	Baba Hyder Fish Farm	Thatta	6.5± 0.3	4.2± 0.16	33.9± 0.25	05± 0.4	0.0± 0.0	0.01± 0.00	20± 1.78	210± 1.60	156± 2.44	7.48± 1.20	12.31± 2.00
10	Arjeena Salt Work	Dhabiji	6.7± 0.21	5.9± 1.22	29.4± 0.5	06± 1.72	0.01± 0.00	0.0± 0.0	24± 1.78	240± 3.31	190± 1.67	7.53± 0.39	13.17± 1.55

Value of each parameter is the mean of 72 samples (±SD) collected from each farm during 12 months.

Table 2: *Suitability of water quality parameters for fish and shrimp farming.*

No.	Parameters	Minimum	Maximum	Suitability
1	pH	6.5±0.3	8.6±0.17	Optimum pH of 7.4, and range (7-9) is appropriate for all fresh and marine water culture (Kumar *et al.*, 2017; Munni *et al.*, 2013; Boyd, 1990; Michael, 1969).
2	Salinity (%)	0.0±0.0	10±0.36 %	0-0.5 favorable for brown and rainbow trout (Lawson, 1995). 0-3.0 for channel catfish (Boyd, 1990) 0-10 for *Tilapia aurora, T. nilotica* (Stickney, 1986), Red *tilapia,* Grass carp
3	Ammonia (mg l^{-1})	0.0±0.0	0.05±0.02	Admissible limit for most fresh water fish and brackish water shrimp e.g *P. monodon* (Lawson, 1995). <0.01 for marine culture (Huguenin and Colt, 1989)
4	Nitrite (mg l^{-1})	0.0±0.0	0.01±0.00	Safe level for most fresh water fish e.g Rainbow trout, Milk fish (Swann,1993) and brackish water shrimp e.g *P. monodon* (Boyd, 1990)
5	Nitrate (mg l^{-1})	12±1.41	35±4.63	Permissible for aquaculture 20-100 (WHO, 2009; Pillay, 1992) <20 for Rainbow trout and <80 Carp (Suobodova *et al.*, 1993)
6	Alkalinity (mg l^{-1})	145±2.31	450±1.47	Sufficient for most aquaculture purposes 20- 400 mg/l (WHO, 2009; Meade,1989; Munni *et al.*, 2013)>20 for Catfish and >80 for Hybrid striped bass (Lawson, 1995)
7	Total hardness (mg l^{-1})	79±2.22	1000±2.65	20-300 mg/l optimum level for most aquaculture activities (Kumar *et al.*, 2017; Vijayalakshmi *et al.*, 2013; Bhatnagar and Devi 2013; Munni *et al.*, 2013; Rao *et al.*, 2010; WHO, 2009; Bhatnagar *et al.*, 2004; Lawson, 1995; Wurts and Robert, 1992; Boyd, 1990). >300 mg/l considered as lethal (Bhatnagar *et al.*, 2004). >20 for Channel catfish and Rainbow trout. 300-500 for Silver carp.
8	Dissolved oxygen (mg l^{-1})	3.8±1.4	6.4±0.32	3.70-8.38 mg/l optimum level for aquaculture ponds (Solis, 1998; Emerson and Abell, 2001; Thirupathaiah *et al.*, 2012; Munni *et al.*, 2013; Akter *et al.*, 2015; Hossain *et al.*, 2007; WHO, 2009; Shoaib *et al.*, 2017; Kumar *et al.*, 2017; Abbasi *et al.*, 2016; Ali *et al.*, 2007; Michael, 1969).
9	Temperature (°C)	28.3±1.4	34.1±0.17	20–32 °C optimum water temperature level for fish in ponds (Jonassen, 1999; WHO, 2009; Munni *et al.*, 2013; Kumar *et al.*, 2017)
10	Chlorophyll a (mg l^{-1})	1.4±0.23	7.5±0.12	Chlorophyll-a (6.5-14.5 mg/m^3); Rai and Rajashekar (2014); Sahu *et al.* (2012).
11	Phytoplankton density (x10^5cells 1^{-1})	2.3±0.15	13.17±1.55	Phytoplankton density (2.5-14.0 x10^5cells 1^{-1}); Sahu *et al.* (2012); Rai and Rajashekar (2014).

pH drops below 5 or rises above 10 (William and Robert6, 1992). Whereas, pH values above 10.8 and below 5 may be rapidly fatal for most species especially for carp (Lawson, 1995).

The total amount of oxygen in a solution is known as dissolved oxygen (DO). This vital parameter reflects the biological processes like growth, physiology, survival and behavior of aquatic organisms (Tara *et al*., 2011). Emerson and Abell (2001) reported optimal DO level as >4mg l^{-1} which is suitable for fish in ponds. Some other researchers, for instance, Kumar *et al*. (2017); Solis (1998); Thirupathaiah *et al*. (2012) suggested an ideal DO range from 6.5 to 7.9 mg l^{-1} in fresh water fish ponds. In addition, similar range of DO was reported by Hossain *et al*. (2007) and Akter *et al*. (2015) as 3.7 to 5.0 mg l^{-1} in their fresh water fish ponds as compared to our results (3.8 to 6.4 mgl^{-1}) as shown in Table 1. Furthermore, the appropriate range of DO for fish production was recommended as 0.08- 6.18 mgl^{-1}by Shoaib *et al*. (2017), 7.5- 8.38 mgl^{-1} by Ali *et al*. (2007), 6.5-7.9 mgl^{-1} by Kumar *et al*. (2017) and 3.96-6.31 mgl^{-1} by Abbasi *et al*. (2016) and also stated that salinity and temperature could directly affect the dissolved oxygen level in the water.

Temperature is an essential biological factor for maintaining metabolic activities in the organisms. As we know that, fish is a cold blooded vertebrate and their body temperature is dependent on the environment and also fluctuated with water temperature, that may affect fish metabolism and physiological performance. The optimum temperature of pond water has been reported between 20°C to 30°C for fish survival (Jonassen *et al*., 1999). However, Kumar *et al*. (2017) found 27.8°C to 31.90°C in their fresh water fish ponds and our results (28.3±1.4°C to 34.1±0.17°C) are within this range (Tables 1 and 2). According to Ntenegwe *et al*. (2008), Desai (1995), Prameena and Sheeja (2016), the temperature of water be influenced by the seasonal changes, geographical location and sampling period.

Salinity is a dynamic factor that directly affects the growth and density of culture organisms and help to maintain osmoregulations in the body (Shibu, 1991). It is reported that, fresh and brackish water fish species generally expressed low tolerance against higher salinity (Kumar *et al*., 2017), while it can be different from species to species. Although, salinity values recorded in our study varies from 0 % to 10 % (Tables 1 and 2), which is a desirable range for many fresh water fish species especially *Tilapia aurora* and *Tilapia nilotica* (Stickney, 1986). Salinity range from 0 % to 0.5 % is found to be favorable for most fresh water fish (Lawson, 1995). Boyd (1990) suggested an optimal salinity range for channel catfish (0.5% to 3.0 %). A level less than 20 % is considered favorable for rainbow trout. Whereas such salinity limits do not favour marine culture activity mentioned by Huang *et al*. (2020) and Khan *et al*. (2018).

Generally, ammonia toxicity depends upon pH of water. At higher PH, a smaller amount of total ammonia nitrogen causes toxic effects on water quality of fish and shrimp ponds (Boyd, 1990). The observed value of ammonia in this study ranged from 0-0.05 mg l^{-1} (Tables 1 and 2). A tolerance range of ammonia for fresh water fish is reported as 0-0.05 mg l^{-1} (Lawson, 1995). It is noted that, the utmost level of ammonia was found in Mir Babu fish farm as compared to others which may be lethal for aquaculture species. Whereas, Huguenin and Colt (1989) suggested that ammonia concentrations should be less than 0.01 mg $l^{-1}$for marine aquaculture activities. Nitrite is formed as an intermediary product during the conversion of ammonia contents to nitrates. In our study, nitrite concentration was found between 0-0.01 mg l^{-1} (Tables 1 and 2) which is reported to be safe for most fresh water species e.g. rainbow trout, milk fish (Swann, 1993) and for brackish water shrimp e.g. *Penaeus monodon* (Boyd, 1990). Nitrate is the culmination product of the nitrification process and is the smallest toxic of the major inorganic nitrogenous compounds in water (Kumar *et al*., 2017; Sajitha and Vijayamma, 2016). In the present study, nitrates ranged from 12 mg l^{-1} to 35 mg l^{-1} (Tables 1 and 2). These results are comparable to some extent of 45 mg l^{-1} as mentioned by Bhatnagar and Devi (2013) and WHO (2009). Syobodova *et al*. (1993) reported a maximum admissible limit of nitrate i.e., 20 mg l^{-1} for rainbow trout and 80 mg l^{-1} for carps. Whereas a permissible limit of nitrate for aquaculture is reported to be less than 100 mg l^{-1} (Pillay, 1992).

Alkalinity describes the buffering capacity of water solution (Elayaraj *et al*., 2016). Sufficient level of alkalinity for most aquaculture purposes is reported between 25 mg l^{-1} to 100 mg l^{-1} (Bhatnagar and Devi, 2013), while 20 mg l^{-1} to 400 mg $l^{-1}$was reported by Meade (1989). Lawson (1995) recommended alkalinity level for cat fish which is greater than 20 mg $l^{-1}$and for hybrid striped bass it must be greater than 80 mg l^{-1}. In this study, the measured value of alkalinity was observed as 145-450 mg l^{-1} (Tables 1 and 2), which is greater than recommended range and higher in Fish Farm Green Co., Ghulam Ali Nizamani Fish Farm and Abro Fish Farm. Kumar *et al.* (2017), while studying pond water quality in Thanjavur District in Tamilnadu, documented alkalinity values from 68 mg l^{-1} to 95 mg l^{-1}.

Dissolved minerals, primarily calcium and magnesium, describe the total hardness (mg l^{-1}) of water. It is reported that calcium (Ca) and magnesium (Mg) both are vital for bone and scale formation of fish (Kumar *et al.*, 2017; Stevens, 2007). In the present investigation, total hardness (TDS) level was 79-1000 mg l^{-1} (Tables 1 and 2), whereas an optimum range has been reported as 20-300 mg l^{-1} for channel catfish and rainbow trout (Lawson 1995; Boyd, 1990). A favorable range of TDS for Silver carp is considered as 300-500 mg l^{-1}. The total hardness ranging from 25 to 150 mg l^{-1} was found to be suitable for healthy fish culture as described by Singh *et al.* (2010) and William and Robert (1992). However, our results showed high concentration of TDS in Shamimul Hassan farm, Fish Farm Green Co., and Ghulam Ali Nizamani Fish Farm. Furthermore, Bhatnagar *et al.* (2004) mentioned that less than 20 mg l^{-1} value of TDS may cause stress and poor growth in cultured fish species, while the fatal value is higher than 300 mg l^{-1} (William and Robert, 1992). Chlorophyll-a is known as the most significant index of phytoplankton biomass. In the present study, concentration of chlorophyll-a ranged from 1.4 mg l^{-1} to 7.5 mg l^{-1} showing high variation among ponds water. The minimum chlorophyll-a (1.4-2.1 mg l^{-1}) was found in the ponds water of Shamimul Hassan Farm, Fish Farm Green Co., and Ghulam Ali Nizamani Fish Farm. But, the remaining farms showed maximum values (5.8-7.5 mg l^{-1}). Similar trend for the minimum (2.3 ×10^5 cells 1^{-1}) and maximum (13.2 ×10^5 cells 1^{-1}) concentration of phytoplankton cell density was found in all ponds water. These results are advocated by a strong correlation (*P>0.05*) between chlorophyll-a and phytoplankton cell density (Figure 1).

Evidence to support this is available as salinity strongly correlated with chlorophyll-a (Table 3). This shows that salinity concentration in ponds water played significant role in producing phytoplankton biomass abundantly (Rai and Rajashekhar, 2014). It has also been observed direct correlation (P<0.01) of pH with salinity, ammonia, nitrate, alkalinity and total hardness of the ponds water while, DO significantly correlated (P<0.05) with nitrate, alkalinity and temperature (Table 3). Although, a positive correlation was found among physicochemical parameters of ponds water in all farms (Table 4).

The Principal Component Analysis (PCA) of the water quality variables established two principal components (Figure 2). Eigenvalues of the first component (PC-1) and second component (PC-2) represented 99.97 % of the total variability in water quality of fish and shrimp ponds at different farms (Figure 3). PC-1 accounted for 92.57 % of the total variance which was due to the positive loadings of dissolved oxygen, ammonia, nitrite, nitrate, chlorophyll-a and phytoplankton density, and negative loading of hardness, alkalinity, temperature, salinity and pH. PC-2 contributed 7.40 % of the total variability which was found to be positively loaded by salinity, temperature, alkalinity, hardness, nitrite and nitrate, and negatively loaded by pH, ammonia, DO, chlorophyll-a and phytoplankton density.

Table 3: *Simple correlation coefficient of physicochemical parameters of various fish and shrimp farms in Sindh.*

	pH	Salinity	Ammonia	Nitrite	Nitrate	Alkalinity	Hardness	DO	Temp.	Chl-a
Salinity	0.887**									
Ammonia	-0.721**	-0.289								
Nitrite	-0.175	-0.123	-0.350							
Nitrate	-0.761**	-0.277	0.339	-0.357						
Alkalinity	0.689**	0.756**	0.588**	0.393	0.455					
Hardness	0.846**	0.745**	-0.246	0.363	-0.321	0.222				
DO	0.168	0.285	-0.227	0.268	0.45*	0.576*	0.355			
Temperature	0.154	0.273	-0.332	0.286	0.49*	0.587*	0.355	0.581*		
Chlorophyll-a	0.161	0.652**	-0.342	0.386	0.59*	0.587*	0.365	0.581*	0.593*	
Phytoplankton density	0.177	0.673**	-0.312	0.486*	0.79*	0.448*	0.322	0.671**	0.542*	0.561**

*Significance level at *(P < 0.05); ** (P < 0.01); DO represents dissolved oxygen.*

Table 4: *Regression coefficients of physicochemical parameters of various fish and shrimp farms in Sindh.*

	Regression coefficients		Standard deviation (SD)	Student's t-ratio	R^2
	intercept	slope			
pH	26.87	0.16	0.076	-0.93	3.45
DO	18.85	0.12	0.042	1.95*	44.36
Temperature	20.84	0.13	0.036	1.96*	49.28
Salinity	16.48	2.97	0.059	3.55**	84.31
Ammonia	13.25	0.77	0.025	-0.47	2.07
Nitrite	19.47	0.13	0.087	1.48*	48.29
Nitrate	21.76	0.32	0.081	-0.36	2.66
Alkalinity	9.98	2.84	0.056	3.86**	81.51
Hardness	23.53	0.74	0.008	-0.21	2.49
Chlorophyll-a	20.94	0.63	0.050	0.42**	63.11
Phytoplankton density	21.16	0.71	0.066	0.46**	73.54

*Significance level at *(P < 0.05); ** (P < 0.01).*

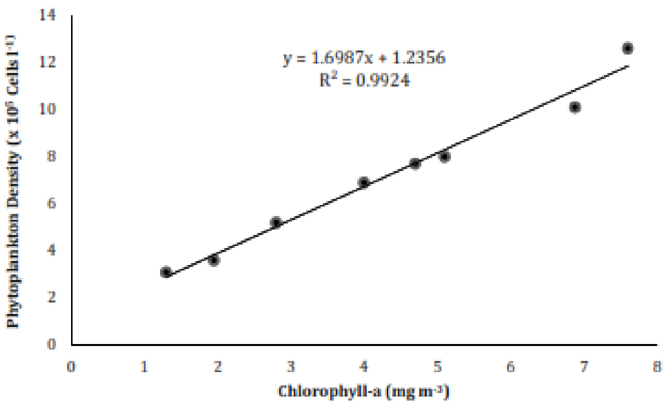

Figure 1: *Relationship between chlorophyll-a concentration and phytoplankton density of different aqua farms located in Sindh province, Pakistan.*

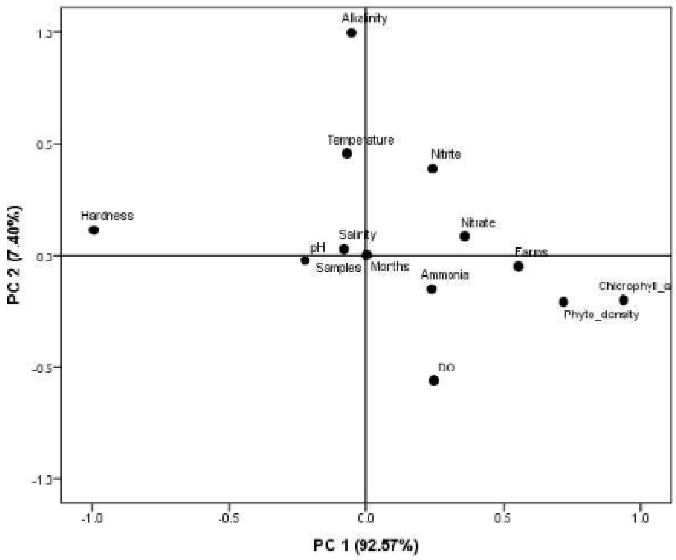

Figure 2: *Principal component plot of water quality variables during the study period.*

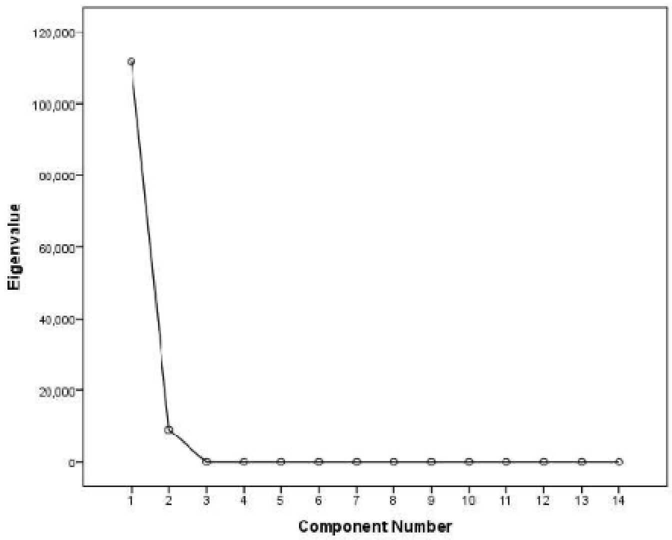

Figure 3: *Scree plot between different principal components and their eigenvalues.*

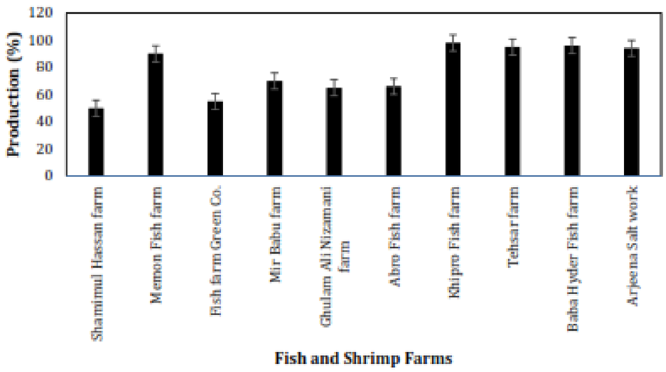

Figure 4: *Fish and shrimp production of different farms located in Sindh province, Pakistan.*

Similar results are found during the research of Rai and Rajashekhar (2014). In the present study, it is evidently noted that water quality was directly associated with the productivity of ponds regarding annual production of fish and shrimp as shown in Figure 4.

Planktonic biomass (phytoplankton, filamentous algae and zooplankton) were recorded from fish and shrimp ponds. Their variety and density are shown in Table 5.

Significant growth rate of planktonic biomass was found in all ponds ranging from 6549-9389 number of individuals in 50 liters water sample, except three farms viz., Shamimul Hassan Farm, Fish Farm Green Co. and Ghulam Ali Nizamani Farm. Majority of the species *Anabaena, Merismopedia, Oscillatoria, Chroococcus limneticus, Brachionus quadridentatus, Chroococcus tenax, Coelosphaerium kuetzingianum Brachionus falcatus, Chroococcus minor, Brachionus* *calyciflorus, Keratella tropica, Filinea Brachionus, Brachionus quadridentatus,. Bosmina longristrous, Bosmina coregoni, Ceripodaphnia reticuleta, Keratella tropica,* and *Cosmarium granatum, Lecane luna Cosmarium formosulum, Daphnia lumholtzi, Cosmarium leave, Westella, and Brachionus falcatus, Lecane luna* and *Filinea longiseta. Bosmina longristrous, Bosmina coregoni, Ceripodaphnia reticuleta* and *Daphnia lumholtzi* were present in the ponds of Khipro Fish Farm, Tehsar Farm, Baba Hyder Fish Farm and Arjeena Salt Work throughout the year. Significantly higher population of *Microcystis* happened in these ponds, which might have been due to the accumulation of organic manure (Mahar *et al*., 2010). According to them, *Microcystis* species are more common in organic rich environment as compared to other plankton species.

Table 5: *Planktonic biomass (phytoplankton and zooplankton) recorded in fish and shrimp farms of Sindh, Pakistan.*

	Sampling sites (fish and shrimp farms)									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Oscillatoria	++	+++	+	+++	++	++	+++	++	+++	+++
Anabaena	++	+++	++	+++	+	+++	+++	+++	+++	+++
Spirulina	+	++	++	++	+	+++	+++	++	++	++
Coelosphaerium kuetzingianum	++	++	++	+++	++	+++	++	+++	+++	+++
Chroococcus limneticus	+	+	++	+++	+	+	+++	++	+++	+++
Chroococcus tenax	++	+++	+	+	+++	++	+++	+++	+++	++
Merismopedia	+++	++	++	+++	+	+++	+++	+++	++	+++
Chroococcus minor	+	++	+	++	+	++	+++	++	++	+++
Cosmarium formosulum	++	++	++	++	++	+	+++	+++	+++	+++
Microcystis	+	++	+	+++	+	+++	++	++	+++	+++
Westella	++	+++	+	+++	++	+++	+++	+++	++	+++
Lyngbya	++	+++	++	+	++	++	+++	+++	+++	++
Spirogyra	++	++	++	+++	++	++	+	+++	+++	+++
Cosmarium granatum	++	+++	++	+++	+	+++	+++	++	+++	++
Cylindrospermum	+	+	++	++	+	+++	+++	+++	++	+++
Cosmarium leave	++	++	++	++	++	+	+++	+++	+++	+++
Calothrix	++	+++	++	+++	++	+++	-	+++	+++	++
Cosmarium,	++	+++	+	+++	++	+++	+++	+++	++	+++
Rhizoclonium	+	+++	+	-	+	+++	+++	+++	+++	+++
Stigeoclonium tenu	+	++	+	+++	+	+++	++	+++	+++	++
Brachionus quadridentatus	++	++	++	+	++	++	+++	+++	++	+++
Enteromorpha	++	++	++	+++	++	+++	++	+++	+++	++
Charra	++	++	++	++	++	+++	++	++	+++	+++
Cyclops sp.	+	+	++	++	+	++	+++	+++	+++	+++
Brachionus falcatus	++	++	++	+	++	+++	+++	+++	++	+++
Lecane luna	++	+++	+	+++	++	+++	++	+++	+++	+++
Brachionus calyciflorus,	+++	++	+	+++	++	++	+++	+++	+++	+++
Keratella tropica	++	++	++	++	++	+	++	++	+++	+++
Ceripodaphnia reticuleta	+	+++	+	++	+	+++	+++	+++	++	++
Filinea longiseta	+	+	++	+++	+	+++	+	+++	+++	+++
Thermocyclops hylinus	++	++	++	++	++	++	+++	+++	+++	+++
Bosmina coregoni	++	++	+++	+++	+	+++	++	+++	++	++
Bosmina longristrous	++	++	++	+	++	+++	+++	+++	+++	+++
Mesocyclops sp	+	++	+	+++	+	+++	+++	++	++	+++
Microcyclops varicans	+	++	+	+++	++	+++	++	+++	+++	++
Daphnia lumholtzi	+	++	++	+++	+	+++	+++	+++	++	+++
Keratella tropica	++	++	++	+++	++	++	+++	+++	+++	+++

+: Common; ++: Abundant; +++: Most abundant;-: absent; 1: Shamimul Hassan Farm; 2: Memon Fish Farm; 3: Fish farm Green Co.; 4. Mir Babu Fish Farm; 5: Ghulam Ali Nizamani Farm; 6: Abro Fish Farm; 7: Khipro Fish Farm; 8: Tehsar Farm; 9: Baba Hyder Fish Farm; 10: Arjeena Salt Work.

Conclusions and Recommendations

The results revealed that water quality of all studied fish and shrimp farms is suitable for farming and culturing purposes except Shamimul Hassan Farm, Fish Farm Green Co. and Ghulam Ali Nizamani Farm due to high level of total hardness, whereas alkalinity was exceeded in all farm than recommended range but higher in Fish Farm Green Co., Ghulam Ali Nizamani Farm, and Abro fish farm. However, Mir Babu fish farm showed a higher level of ammonia which may be lethal for both fresh water and marine culture activities and all the parameters were directly affected on the productivity of ponds. Present study also delivers the base line data for farm management and the optimum physicochemical range help to maintain water quality during culture of fish and shrimp species.

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Novelty Statement

Findings of this research will be fruitful in the advancement of commercial fish and shrimp farms in Sindh province through the ponds water quality improvements. Such type of improved quality will increase planktonic biomass in ponds.

Author's Contribution

Rahat Rukhsana collected water samples from various farms, analysed them in lab, designed the experiments and supervised this research, Shehnaz Rashid searched relevant literature and helped in manuscript preparation. Asma Fatima searched literature, manuscript reviewed, primary productivity analysed and composed the document with data acquisition. Owais Iqbal Khan helped in experimental studies, literature reviewed and manuscript preparation including editing, Syed Babar Hussain Shah and Mumtaz Ali conducted statistical analysis of the data and reviewed first version of the manuscript. Ghulam Abbas designed this research, idea conceived, data statistically analyzed, edited the text of this manuscript and submitted its final version for publication.

Conflict of interest

The authors have declared no conflict of interest.

References

Abbasi, M.J., Z. Abbasi, F.N. Khokhar, P. Iqbal and P.J.A. Siddiqui. 2016. Distribution and abundance of major groups of zooplankton in relation to the physico-chemical parameters, in the coastal waters of Karachi, north Arabian Sea, Pakistan. Int. J. Fish. Aqua. Stud., 4: 241-249.

Akter, S., M.M. Rahman and M. Akter. 2015. Composition and abundance of phytoplankton population in fish ponds of Noakhali District, Bangladesh. Amer.-Eura. J. Agric. Environ. Sci., 15: 2143-2148.

Ali, Z., S.S. Ahmad, M. Akhtar, M.A. Khan and M.N. Khan. 2007. Ecology and diversity of planktons in lakes of Uchalli wetlands complex, Pakistan. J. Anim. Plant Sci., 17: 41-42.

Alonso-Rodrígues, R. and F. Páez-Osuna. 2003. Nutrients, phytoplankton and harmful algal blooms in shrimp ponds: A review with special reference to the situation in the Gulf of California. Aquaculture, 219: 317-336. https://doi.org/10.1016/S0044-8486(02)00509-4

Bauer, W., P.C. Abreu and L.H. Poersch. 2017. Plankton and water quality variability in an estuary before and after the shrimp farming effluents: Possible impacts and regeneration. Braz. J. Oceano., 65: 495-508. https://doi.org/10.1590/s1679-87592017143406503

Bhatnagar A., S.N. Jana. S.K. Garg. B.C. Patra. G. Singh. and U.K. Barman. 2004. Water Quality Management in Aquaculture, In: Course Manuel of Summer School on Development of Sustainable Aquaculture Technology in Fresh and Saline Waters. *CS Hargyana Agricult. Hisar* (India). 203-210.

Bhatnagar, A. and P. Devi. 2013. Water quality guidelines for the management of pond fish culture. Int. J. Environ. Sci. 3(6): 1980-2009.

Boyd, C.E., 1979. Water quality in Warm Water Fish Ponds. University Press Alabama, 59. https://doi.org/10.2134/jeq1978.00472425000700010012x

Boyd, C.E., 1990. Water quality in ponds for Aquaculture. Birmingham, Ala.; Auburn

University Press. 482 pp.

Boyd, C.E., 2015. Water Quality: An Introduction. Springer International Publishing.

Bronmark, C. and L.A. Hansson. 2005. The biology of lakes and ponds. Oxford University Press, Oxford, 285.

Burford, M.A., K.C. Williams. 2001. The fate of nitrogenous waste from shrimp feed. Aquaculture. 198 (1-2): 7993. https://doi.org/10.1016/S0044-8486(00)00589-5

Delince, G., 1992. The ecology of the fish pond ecosystem, Kluwer Acadmic. Publisers London, 230. https://doi.org/10.1007/978-94-017-3292-5

Desai, P.V., 1995. Water quality of Dudhsagar river of Dudhsagar (Goa), India. Poll. Res., 14: 377-382.

Durge, L.S., A.M. Chilke and R.N. Chavhan. 2018. Seasonal variations in the physico-chemical parameters of Malgujari pond of Ghugus, district Chandrapur (Maharashtra). Int. J. Sci. Res. Biol. Sci., (5): 5. https://doi.org/10.26438/ijsrbs/v5i5.5257

Elayaraj, B., M. Selvaraju and K.V. Ajayan. 2016. Assay on water quality variations of Pasupatheswarar temple pond, Annamalai Nagar, Tamil Nadu, India. J. Int. Acad. Res. mult., 3: 97-108.

Emerson, S. and J. Abell. 2001. The Biological Pump in the Subtropical North Pacific Ocean, Pretence Inc., Chicago. https://doi.org/10.1029/2000GB001320

Herbeck, L.S., D. Unger, Y. Wu. and T.C. Jennerjahn. 2013. Effluent, nutrient and organic matter export from shrimp and fish ponds causing eutrophication in coastal and back-reef waters of NE Hainan, tropical China. Cont. Shelf Res. 57: 92-104. https://doi.org/10.1016/j.csr.2012.05.006

Hossain, M.Y., S. Jasmine, A.H. Ibrahim, Z.F. Ahmed, J. Ohtomi, B. Fulanda, M. Begum, A. Mamun, M.A., El-Kady and M.A. Wahab. 2007. A preliminary observation on water quality and plankton of an earthen fish pond in Bangladesh: Recommendations for future studies. Pak. J. Biol. Sci., 10: 868-873. https://doi.org/10.3923/pjbs.2007.868.873

Huang, Q., S. Olenin. L. Li. S. Sun. and M. De Troch. 2020. Meiobenthos as food for farmed shrimps in the earthen ponds: Implications for sustainable feeding. Aquaculture. 521: 735094. https://doi.org/10.1016/j.aquaculture.2020.735094

Huguenin, J. E., and J. Colt. 1989. Design and operating Guide for Aquaculture seawater system. Amesterdam: Elsevier.

Jackson, C., N. Preston and P.J. Thompson. 2004. Intake and discharge nutrient loads at three intensive shrimp farms. *Aquac. Res*. 35: 1053-1061. https://doi.org/10.1111/j.1365-2109.2004.01115.x

Jonassen, T.M. A.K. Sland, S.O. Stefansson. 1999. The interaction of temperature and size on growth of juvenile Atlantic Halibut. J. Fish Biol., 54: 556-572. https://doi.org/10.1111/j.1095-8649.1999.tb00635.x

Khan. M.J., A. Malik, M.S. Khattak, Naveedullah, N. Ijaz and I. Ahmad. 2018. Status of water table depths and water quality in district Karak, Khyber pakhtunkhwa province of Pakistan. Sarhad J. Agric., 34: 282-290. https://doi.org/10.17582/journal.sja/2018/34.2.282.290

Kiran, B.R., 2010. Physico-chemical characteristics of fish ponds of Bhadra project at Karnataka. Rasayan J. Chem., 3: 671-676.

Kumar, D., M. Karthik and R. Rajakumar. 2017. Study of seasonal water quality assessment and fish pond conservation in Thanjavur, Tamil Nadu, India. J. Entomol. Zool. Stud., 5: 1232-1238.

Lawson, T.B., 1995. Fundamentals of Aquacultural Engineering. New York: Chapman and Hall. https://doi.org/10.1007/978-1-4613-0479-1

Lloyd, R., 1992. Pollution and Freshwater Fish. West Byfleet: Fishing News Books.

Mahar, M.A., Z.A. Larik, N.T. Nerojo and S.I.H. Jafri. 2010. Limnological study of fishponds and Kalribaghar lower canal at Chilya Fish Hatchery Thatta, Sindh, Pakistan. Pak. J. Zool., 42: 419-430.

Meade, J.W., 1989. Aquaculture management. New York: Van Nostrand and Reinhold. https://doi.org/10.1007/978-1-4615-6470-6

Michael, R.G., 1969. Seasonal trends in physicochemical factors and plankton of a freshwater fishpond and their role in fish culture. Hydrobiologia, 33: 144-160. https://doi.org/10.1007/BF00181684

Munni, M.A., Z. Fardus, M.Y. Mia and R. Afrin. 2013. Assessment of pond water quality for fish culture: A case study of Santosh region in Tangail, Bangladesh. J. Environ. Sci. Nat.

Res., 6: 157-162. https://doi.org/10.3329/jesnr.v6i2.22112

Naylor, R.L., R.J. Goldburg, H. Mooney, M. Beveridge, J. Clay, C. Folke, N. Kautsky, J. Lubchenco, J. Primavera and M. Williams. 1998. Nature's subsidies to shrimp and salmon farming. Science, 282: 883-884. https://doi.org/10.1126/science.282.5390.883

Ntenegwe, F.N. and M.O. Edema. 2008. Physicochemical and Microbiological Characteristics of water of fish production using small Ponds. Phy. Chem. Earth, 33: 701-707. https://doi.org/10.1016/j.pce.2008.06.032

Pillay, T.V.R., 1992. Aquaculture and the Environment. New York: Halsted Press.

Prameena, J.L. and Sheeja. 2016. Physico-chemical characterization of pond water from Vaduvur, Mannargudi (TK), Thiruvarur District (India). Der Pharma Chemica, 8: 6-11.

Rai, S.V. and M. Rajashekhar. 2014. Seasonal assessment of hydrographic variables and phytoplankton community in the Arabian Sea waters of Kerala, southwest coast of India. Braz. J. Ocean., 62: 279-293. https://doi.org/10.1590/s1679-87592014069906204

Ramanathan, S. and A. Amsath. 2018. Seasonal variations in physico-chemical parameters of Puthukulam pond, Pudukkottai, Tamilnadu. Res. J. Life Sci. Bio. Pharma. Chem. Sci., 4: 656-662.

Rao, C.S., B.S. Rao. Hariharan and M.N. Bharath. 2010. Determination of water quality index of some areas in Guntur District Andhra Pradesh. Inter. J. Appl. Biol. Pharma. Tech., 1: 79-86.

Sahu, G., K.K. Satpathy, A.K. Mohanty and S.K. Sarkar. 2012. Variation in community structure of phytoplankton in relation to physiochemical properties of coastal waters, southeast coast of India. J. Geo-Mar. Sci., 41: 223-241.

Sajitha, V. and S.A. Vijayamma. 2016. Study of physico-chemical parameters and pond water quality assessment by using water quality index at Athiyannoor Panchayath, Kerala, India. Eme. Life Sci. Res., 2: 46-51.

Shibu, S., 1991. Ecology of Paravur Lake. Ph. D. thesis, Univ. of Kerala. Trivandrum.

Shoaib, M., Z. Burhan, S. Shafique, H. Jabeen, and P.J.A. Siddique. 2017. Phytoplankton composition in a mangrove ecosystem at Sandspit, Karachi, Pakistan. Pak. J. Bot., 49: 379-387.

Sikoki, F.D. and F. Veen. 2004. Aspects of water quality and the potential for fish production of Shinro Reservour. Nig. Livest. Syst. Sust. Dev., 2: 1-7.

Singh, M.R., A. Gupta and K.H. Beateswari. 2010. Physicochemical properties of water samples for manipur river system India. J. Appl. Sci. Environ. Manage., 14: 85-89. https://doi.org/10.4314/jasem.v14i4.63263

Solis, N.B., 1998. The biology and culture of *Penaeus monodon*. Department Papers. SEAFDEC Aquac. Dep. Tigbouan, Boilo Philippines. 3-36. 42.

Stevens, C., 2007. Dissolved Oxygen. Sci. Technol., 5: 1-5. Aquaculture Networks. 1:14-16.

Stickney, R.R., 1986. Tilapia tolerance of saline waters: A Review. Prog. Fish Cult., 48: 161-67. https://doi.org/10.1577/1548-8640(1986)48<161:TTOSW>2.0.CO;2

Svobodova, Z., R. L., J. Machova and B. Vykusova. 1993. Water quality and fish health. EIFAC technical paper no. 54. Rome: FAO.

Swann, L., 1993. Water quality water sources used in aquaculture. Water quality fact sheet as-486. Aquaculture Extension. Illinois- Indiana Sea Grant Program. Purdue University, West Lafayette, Ind.

Tamizhazhagan, V. and K. Pugazhendy. 2016. Physico-chemical parameters from the Manappadaiyur and Swamimalai fresh water ponds. Indian Am. J. Pharm. Sci., 3: 444-449.

Tara, J.S., R. Kour and S. Sharma. 2011. Studies on the occurrence and seasonal abundance of aquatic coleopteran in relation to some physicochemical parameters of water of Gharana wetland Wetland reserve Jammu (J and K). Bioscan, 6: 257-261.

Thirupathaiah, M., C.H. Samatha and S. Chintha. 2012. Analysis of water quality using physico-chemical parameters in lower Manair reservoir of Karimnagar district, Andhra Pradesh. Int. J. Environ. Sci., 3: 172-180.

Vijayalakshmi, G., V. Ramadas and H. Nellaiah. 2013. Evaluation of Physico–Chemical Parameters and microbiological populations of Cauvery River water in the Pallipalayam Region of Tamil Nadu, India. Int. J. Res. Eng. Technol., 2: 304- 312.

WHO, 2009. World Health Organization. Guideline for drinking water quality. Geneva.

William A.W. and M.D. Robert. 1992. Interactions of pH, carbon dioxide, alkalinity and hardness in fish ponds. Southern Reginal aquaculture center: SARC Publication NO 464.

Wu, H., R. Peng, Y. Yang, L. He, W. Wang. T. Zheng and G. Lin. 2014. Mariculture pond influence on mangrove areas in South China: Significantly larger nitrogen and phosphorus loadings from sediment wash-out than from tidal water exchange. Aquaculture, 426: 204–212. https://doi.org/10.1016/j.aquaculture.2014.02.009

Wurts, W.A. and R.M. Durbow. 1992. Indications of pH, carbon dioxide, alkalinity and hardness in fish ponds. Southern Reg. Aqua. Centre Fact Sheet, 464: 1-4.