Fish growth, diversity and water quality metrics at Chashma Barrage, Pakistan

Aziz Fatima[1], Sehar Khalid[1], Iqra Jabeen[1], Zubaida Bibi[1], Khurram Shahzad Munawar* [2,3], Zahida Nasreen[1]

[1]Department of Zoology, University of Mianwali, 42200, Pakistan.
[2] Department of Chemistry, University of Mianwali, 42200, Pakistan.
[3] Institute of Chemistry, University of Sargodha, 40100, Pakistan.

***Corresponding author's email:** khurramchemist@gmail.com

Abstract

Freshwater quality is crucial for fish growth and diversity. It is determined through biological, chemical and physical factors. This study investigates the role of freshwaterfactors in fish growth and diversity at Chashma Barrage. Data is collected weekly from September 2022 to March 2023. Approved Standard Procedures of Analysis of the Association of the Chemists (AOAC) determined different freshwater factors, includingtemperature, PH, conductivity, salinity, chloride, dissolved oxygen, light penetration, hardness, nitrite, nitrate, TDS, and plankton for 18 fish species. Mean and standard deviation are used to describe the data. Shannon, Simpson, Evenness, and Richness indices are used forfish diversity. Almost all water factors confirm the standard values for fish growth and diversity. It was observed that the cyprinidae family with nine species is dominant. Species from Poeciliidae, Channidae, Siluridae, Mastacembelidae, Schilbeidae, Cichlidae, Bagridae, and Clariidae families were also captured. The Chashma Barrage environment supportsaquatic life. Although lake conditions are optimal for fish, fish cannot grow to acceptable levels due to the lack of interest and awareness. The species number in Barrage confirms water quality for fish growth and diversity. By producing fish in large quantities, exports will increase, which will strengthen the economy. Fish quality will improve human health by increasing the per capita consumption rate. Freshwater parameters are adversely affected by anthropogenic activities. The present study suggests that improving fish growth and diversity can attract fish farming and enhance the state of the economy.

Keywords: Freshwater, Fish growth, Fish diversity, Shanon analysis, Simpson analysis.

Article History: **Received:** 12th June 2024, **Revised:** 25th June 2024, **Accepted**: 10th July 2024, **Published:** 8th August 2024.

Introduction

The study of the water quality factors provides valuable information about its biotic components. Fish is an important freshwater biota as it is an inexpensive and Excellent food source, providing all the essential amino acids, fatty acids, vitamins and minerals. Water quality variables play a significant role in governing fish growth and diversity. Water quality factorsinclude chemical, physical and biological properties. The most common factors monitored for water quality are

temperature, pH, hardness, alkalinity, salinity, plankton, TDS, and conductivity are interconnected and must be sustainable for maximum fish production [1]. Ammonia is easily soluble in water, and a large amount of use can cause fish poisoning. Plankton is swimming and microscopic plants and animals, and feed for fish and other aquatic animals. Nitrate and nitrite are the sources of nitrogen for fish. Fish use nitrogen to synthesize biomolecules like amino acids and nucleotides.

Fish satisfies the human demand for protein and provides other essential nutrients such as omega-3 fatty acids, iodine, vitamin D, and calcium. Fishcontain biological molecules that increase physical and mental performance. Water is the nutrient medium for fish growth and survival [2]. Water quality variables directly affect fish growth because fish get nutrients from the water. To observe the diversity of fish in certain areas, it is important to understand the significance of water's physical and chemical factors.Each fish has a unique set of water variables to ensure proper growth and reproduction. Each species has its best range for its best performance within allowable limits. All water variables arenot fixed but change and cause water quality degradation [2]. The study of parameter undulation provides knowledge about water quality and its impact on fish diversity [3].

Pakistan has an area of 780000 hectares, of which wetlands cover 9.7%. Twenty-three thousand nine hundred seventy-seven fish species exist worldwide, and Pakistan is blessed with 171 freshwater fish species [4]. The Indus is the largest river in Pakistan, totaling 3200 kilometers [5]. Its drainage area reaches one million square kilometers. It is important to Pakistan's economy because it supports irrigation and fish production. The Chashma Barrage was built with the support of the Indus Valley Settlement Plan. It covers an area of 34099 hectares and has an altitude of 225 m [6]. There are 160-193 species of freshwater fish in Pakistan and more than 80 species of fish in the Chashma Barrage. Cyprinidae is the main family of the Chashma Barrage. Its physical and chemical conditions are suitable for the growth and diversity of fish. Its pH value is 6.5 to 7.2, which is valuable for normal fish growth. The average temperature in summer is 41 ^{o}C and the average in winter is 4.5 ^{o}C [6].

The major water fauna consists of cold-blooded organisms, so their biological reactions depend on water temperature [7]. Among all the physical parameters of water, the temperature is the most significant factor for fish. It regulates the physiological process and antioxidant system of fish. Variations in antioxidants result in lipid peroxidation that structurally and functionally disrupts cell membranes [8].

In 1993, the contribution of Pakistani fish to animal protein was 3.8 %, but in 2013, it dropped to 2.2%. It is found that a decrease in annual per capita fish consumption from 2.8 kg to 1.9 kg. The world's per capita fish consumption is 19.9 kg, South Asia is 7.3 kg, and Pakistan is only 1.9 kg (Pakistan Aquaculture Growth Potential Report 2019). Chashma Barrage has water parameters that are conducive to fish growth. If natural conditions are maintained and anthropological influence is prevented, it can become a better source of fish production in Pakistan to increase per capita consumption.

Literature Review

The physiological effects of water pollution on fish by measuring the levels of serum glucose, aspartate aminotransferase activity (AST) and alanine aminotransferase (ALT) were studied [9]. Enzyme colorimetry infers that

these are physiological indicators of water pollution. Sedgwick-Rafter counting chamber average variation was used to study the relationship between physicochemical variables and plankton composition and Heterobranchus longitillis and Hoteroclania spy [10]. The results show that no single variable is sufficient to promote fish growth. This study found the distribution of fish in the Chenab River by applying the statistical data of Simpson, Shannon Diversity, Evenness, Margaleftaf and Dominance, as well as the large number of fishes observed at the Qadirabad head of the Chenab River (Pakistan) due to the existence of natural and artificial ponds [4]. The analysis of variance, correlation and multiple regression analysis was used to study the impact of water physical and chemical factors on tilapia and observed that all variables except pH and electrical conductivity were inappropriate amountsof the pond [11]. Detrending correspondence analysis (DCA) was used to explore the influence of physical andchemical variables on fish diversity and concluded that temperature is an importantparameter for fish growth [12]. The influence of biotic and abiotic factors was tested on fish using the mean and standard deviation [13]. He concluded that all water parameters are beneficial to the growth of fish. Simpson, Shanon, species uniformity, and richness indices were used to study thebasic effects of physical and chemical variables on fish diversity [14]. The resultsof these indices indicate that Chasma Barrage has the most fish species. The effects of heavy metal toxicity on fish in the Ravi River (Pakistan) was investigated through analysis of variance, regression analysis and correlation analysis and foundthat the liver, kidney and gills of fish are more likely to accumulate metals [15]. Systematic and identification keys were used to observe freshwater fish diversity atthe Tanda Dam in Kohat (Pakistan). He concluded that the decrease in fish populations was due to pollution, illegal hunting, trade, and games [16]. The biodiversity of fish in freshwater bodies of the Suleiman Range (Pakistan) was studied through relative abundance and explained that the relative abundance ranges from 2.9 to 41.52, while the snow carp is a sign of more diversity [17]. The factors on which the growth and diversity of the fish depend are shown in Figure 1.

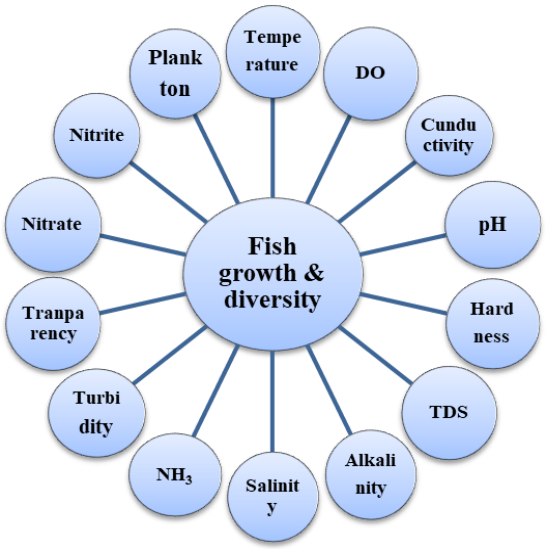

Figure 1**:** Factors affecting the growth and diversity of fish

Methods and Materials

All the chemicals and reagents used in the current work were of analytical grade and used as received from renowned chemical suppliers like Sigma Aldrich.

Sampling area

This study is conducted to find fish growth and diversity at the Chashma Barrage, constructed in 1971 at the Indus River. It is located in the Indus River Basin, 32° 25` N, 71° 22` E and 25km southwest of Mianwali along the Dera Ismail Khan Highway in Punjab. It is used for various purposes like flood control, electricity generation, fish production, and crop irrigation. It is a wetland with a 225 m altitude. Its climate is dry and subtropical, with an annual rainfall of 300-500 mm. It supports dense vegetation and many faunas, including

waterfowl and Indus dolphin. 200000 birds were recorded in 1991. The current study selects Chashma Lake for sampling. It is located at a distance of 13 km from Kundian. It covers an area of 370 km^2 with a longitude of 71.44, a latitude of 32.45 and an elevation of 193 m/633 feet.

Sample collection

This study takes Chashma Lake water for analysis and completed the analysis in the standard lab of the Fisheries Department at Chashma Mianwali. This survey was conducted weekly to collect fish and water samples from Chashma Lake. Sampling was done for 28 weeks from September 2022 to March 2023. Further, the data collection period is winter at Chasma Barrage and the temperature is less than 25 ^oC. Further environmental conditions are discussed in Table 2. The water samplewas taken in a plastic bottle washed with ethanol for decontamination. Data is collected with the collaboration of the Department of Fisheries, Chasma Barrage and water quality indicators analysed on every weekend Fish farming HACH test kit with model FF-1A, Cat NO. 2430-02 (Figure 2) was used to test ammonia, alkalinity, hardness, chloride, dissolved oxygen, carbon dioxide, nitrite, and nitrate.pH was measured through a pH strip.

Figure 2: The digital conductivity meter (left) and fish farming HACH test kit (right) for the measurement of various factors.

To observe the value of salinity, TDS, conductivity, and temperature a digital conductivity meter (company YSI) with Model EC 300, serial No. JC 01764, LOT code 09L1 was used. Light penetration value measured by Sechi disk and Plankton diversity was calculated by using Sedgwick rafting chamber.

Eighteen fish species were sampled with the aid of local fishermen by boating. Different baits and nets were used to capture fish.

Statistical analysis

To analyze the fish diversity and variables, descriptive statistics were applied. Mean and standard deviation were subjected to identify a suitable number of physicochemical parameters of water. Different indices (richness, evenness, Shannon, and Simpson) were applied to calculate the fish diversity and Growth. Microsoft Excel 2010 was used as a standard statistical software to evaluate data statistically.

The Simpson Diversity Index was calculated by using Equation 1:

$$D = N (N – 1) / \Sigma n (n-1) \quad (1)$$

The Shannon Diversity Index is calculated by Equation 2:

$$H = \Sigma pi . lnpi \quad (2)$$

Species Evenness was calculated with the help of Equation 3:

$$H/Ln(Hmax) \quad (3)$$

Results and Conclusion

The descriptive statistics for fish diversity are summarized in Table 1. The results indicate high diversity at Chashma Lake. It was observed that the Cyprinidae family is dominant in the lake. This survey collected 9 species of this family.

Table 1**:** Simpson, shanon, ichness, and evenness indices (Fish diversity)

Sr. No.	Total Fish Captured	Simpson Diversity Index (1-D)	Shanon Diversity Index (H)	Richness (s)	Evenness
1	913	0.852	2.316	18	0.801
2	992	0.852	2.311	18	0.799
3	1080	0.853	2.312	18	0.799
4	1141	0.838	2.229	18	0.771
5	1079	0.847	2.279	18	0.788
6	1141	0.838	2.229	18	0.771
7	1212	0.83	2.177	18	0.753
8	1174	0.83	2.178	18	0.753
9	1225	0.839	2.229	18	0.771
10	1177	0.832	2.189	18	0.757
11	1237	0.829	2.162	18	0.748
12	1221	0.833	2.193	18	0.758
13	1233	0.834	2.201	18	0.761
14	1240	0.836	2.214	18	0.766
15	1255	0.839	2.233	18	0.772
16	1243	0.837	2.221	18	0.768
17	1197	0.835	2.21	18	0.764
18	1211	0.836	2.213	18	0.765
19	1216	0.837	2.222	18	0.768
20	1223	0.836	2.216	18	0.766
21	1171	0.842	2.249	18	0.778
22	1184	0.837	2.222	18	0.768
23	1155	0.831	2.185	18	0.756
24	1088	0.833	2.196	18	0.759
25	1132	0.835	2.212	18	0.765
26	1095	0.834	2.205	18	0.762
27	1091	0.829	2.179	18	0.754
28	1063	0.831	2.192	18	0.758

The species from other families were also captured, one from Poeciliidae, one from Channidae, one from Siluridae, one from Mastacembelidae, one from Schilbeidae, one from Cichlidae, two from Bagridae and one from Clariidae. Simson diversity index value ranges from 0-1, where 1 indicates maximum diversity. This studyshows that the value of the Simpson diversity index is almost 0.8 for each survey, which is a good gesture for fish diversity. Evenness indicates the relative number of different species. Its value ranges from 0-1. The statistical analysisresults show a high value of evenness ranging from 0.7-0.8. The data of ranges for standard and current study factors are enlisted in Table 2, while the actualparameter values are given in Table 3. The temperature was given the utmost attention. Studying the diversity of the ichthyofauna is crucial since temperature fluctuation can control a variety of metabolic processes in fish. Table 2 explains that Chashma Barrage temperature is suitable for fish diversityand growth because it meets the optimum or standard value of temperature is 21.84 ^{o}C (standard 22-24 ^{o}C). It is also foundthat in summer parasitic infection causes high water temperature [26]. By chemically shifting fish metabolites towards less hazardous compounds and by altering the shape and activity of the accumulated substances, low water pH may be able to increase fish growth[27,28]. Fish exposed to low environmental pH have been noted to experience several negative outcomes, including decreased growth and feed consumption [29]. The study results depict that Chashma Barrage water pH is 7.17 (standard 6.5-9.5) is optimum for fish production.

Table 2: Standard and current study water factor ranges.

Factors	**Good Range**	**Study Results**	**References**
Temperature	22-24 ^{o}C	21.84	[18]
pH	6.5-9.5	7.17	[19]
Alkalinity	50-250 ppm	132.53	[19]
Hardness	>20 ppm	133.96	[19]
Chlorides	1-100 ppm	92.14	[20]
Ammonia	0 ppm	0	[19]
TDS	<0.4 ppt	0.2	[21]
CO_2	<5 ppm	7.14	[19]
Conductivity	50 to 500 µs/cm	242.21	[22]
Salinity	<0.5 ppt	0.1	[23]
Dissolved oxygen	5-15 ppm	7.89	[19]
Nitrite	0 ppm	0.02	[19]
Nitrate	0-40 ppm	6.08	[24]
Light penetration (cm)	35-40 cm	37.74	[25]

Table 3: Parameter values at Chashma Barrage.

S/No	Temp (°C)	pH	Alkalinity (ppm)	Hardness (ppm)	Chlorides (ppm)	Ammonia chlorides (ppm)	TDS (ppt)	CO_2 (ppm)	Conductivity (µS)	Salinity (ppt)	DO (ppm)	Nitrite (ppm)	Nitrite (ppm)	Light penetration (cm)
1	22.3	7.1	119.7	154	90	0.001	0.18	5	235	0.1	7.5	0.02	5.51	35
2	21.25	7.1	119.7	154	60	0.001	0.15	5	233	0.1	7.6	0.02	5.7	35
3	20.2	7.2	136.8	154	90	0.002	0.17	5	230	0.1	7.5	0.01	5.89	36
4	18.85	7.3	119.7	137	90	0.002	0.19	5	227	0.1	7.5	0.01	6.01	37
5	17.5	7.5	136.8	120	60	0.002	0.21	10	224	0.1	7.8	0.02	6.12	38
6	17.4	7.2	119.7	137	120	0.001	0.22	10	227	0.1	7.6	0.01	6.06	38
7	17.3	6.9	119.7	154	90	0.001	0.23	10	230	0.1	8.1	0.02	5.99	38
8	16.4	7	136.8	120	60	0.002	0.2	10	235	0.1	8.3	0.02	6.12	41
9	15.5	7.1	153.9	137	120	0.001	0.17	10	239	0.1	8.5	0.01	6.25	45
10	15.3	7.2	136.8	154	90	0.001	0.19	10	240	0.1	8.3	0.02	6.38	44
11	15.1	7.3	119.7	120	120	0.002	0.21	10	240	0.1	8.5	0.02	6.5	44
12	16.1	7.1	119.7	120	90	0.002	0.23	10	240	0.1	8.2	0.02	6.2	45
13	20.1	6.9	136.8	120	90	0.001	0.21	10	340	0.1	8.1	0.01	5.9	42
14	23.1	7.2	119.7	137	120	0.001	0.22	10	245	0.1	8.1	0.01	6.2	43
15	22.9	7.1	136.8	137	90	0.002	0.19	5	224	0.1	8.3	0.02	5.8	5.6
16	26.5	7.2	153.9	120	60	0.002	0.22	10	231	0.1	8.4	0.02	6.2	42
17	24.1	6.8	153.9	120	90	0.001	0.21	5	235	0.1	8.1	0.01	6.1	36
18	23.2	7.3	119.7	120	60	0.001	0.18	5	240	0.1	7.8	0.02	5.6	36
19	25.5	7.3	136.8	154	120	0.002	0.17	5	248	0.1	7.8	0.02	6.1	36
20	26.7	7.2	136.8	120	120	0.001	0.17	10	247	0.1	8.1	0.01	6.5	36
21	22.4	7.4	119.7	137	90	0.001	0.21	5	260	0.1	7.8	0.01	6.4	37
22	28.3	6.9	136.8	137	60	0.002	0.23	5	226	0.1	7.5	0.02	6.1	38
23	25.1	7.1	153.9	154	90	0.002	0.21	5	234	0.1	7.5	0.02	6.3	37
24	26.6	7.3	136.8	120	120	0.001	0.19	5	260	0.1	7.6	0.01	5.9	37
25	23.2	7.1	119.7	120	90	0.002	0.18	5	240	0.1	7.7	0.02	5.8	38
26	25.9	7.2	136.8	137	120	0.001	0.22	5	245	0.1	7.5	0.01	6.1	39
27	27.1	7.3	119.7	137	90	0.001	0.21	5	246	0.1	7.6	0.01	6.2	39
28	27.5	7.3	153.9	120	90	0.002	0.21	5	261	0.1	7.5	0.01	6.2	39
Mean	21.8	7.2	132.5	133	92	0	0.2	7	242	0.1	7.89	0.02	6.1	37
S.D	4.2	0.1	12.85	14	21	0.005	0.02	2	22	0.04	0.35	0.01	0.25	7

The pH of the water in an aquarium can drastically decrease due to low alkalinity, which can kill or severely stress fish and have a negative impact on biofilter performance. Total alkalinity denotes the amount of base contained in water (bicarbonates, carbonates, phosphates, hydroxides, and so on). Hardness describes the overall concentration of divalent salts [30]. As calcium is a major part ofhardness and is important for the Fish egg, tissues and bones perspective, the optimum level of water hardness is essential for fish growth. The results of thestudy show that Chashma Barrage hardness (133.96 ppm) is very close to softhardness and is near the optimum level of water hardness for fish growth. Further,the study results show that the alkalinity is
132.53 ppm and meets the optimum level because the high level of alkalinity leads to low production of fish. Findings show that the chloride level is 92.14 ppm (optimum level is 1-100 ppm), which supports that fish cells may cause low nutrients due to the high chloride, leading to loss of water.

The process of decaying organic materials and uneaten foods produced Ammonia. The high level of ammonia in water may not enable fish to release ammonia from the body and cause many organs to be damaged. Further fish is a source of protein for humans and high ammonia consumption of food may cause many diseases, which lead to coma and ultimately death of the person [31]. This study found ammonia level is 0.02 ppm, which confirms that this optimum level is essential for fish growth and human health. A low level of TDS (0.02 ppt) confirms that the Chashma Barrage water is beneficial for fish growth because the highrate of TDS may disturb the egg development and fertilization process [32].Conductivity is the capacity of water topass an electric current. It is one of the basic parameters of water, which is used asan indicator to determine the level of ions in water. If the conductivity value becomes high or low immediately causes pollution [33]. The conductivity of Chashma Lake is 242.21 µS, which is suitable for growth.

Nitrite is an intermediate product of the nitrogen cycle. Fish intakes nitrite through gills. Its higher level may disturb various processes of fish like the circulatory system [34]. However, fish survive in less concentration of nitrite. The results of this study show that 0.02 ppm concentration of nitrite ions supports fish growth.

Light is an important factor for the development and growth of fish, but different species and even different developmental stages of the same species have different light requirements [35]. Findings reveal that the light penetration of Chashma Lake is 37.74 cm, which is the most suitable for every stage of fish growth. Salinity is a water quality variable and essential factor in growth regulation, which contains dissolved salt in water and other chemical ingredients. Salinity affects the survival rate of fish, especially at the larval stage. It has been investigated that minimum growth occurs in marine fish at a low level of salinity but in freshwater fish growth occurs at a high level of salinity [46]. Results show that 0.10 ppt of salinity is beneficial for fish development as well as growth. DO has a great influence on nutrient solubility, is necessary for the respiration of fish and plays a significant role in controlling the biological characteristics of water [47]. 7.89 ppm of dissolved oxygen is beneficial for fish survival. Carbon dioxide is an important gas in the respiratory process of fish. In Chashma Lake the presence of 7.14 ppm of carbon dioxide ensures a healthy environment for fish as its increasing level causes toxicity. Nitrate is the last chemical of the nitrogen cycle. The large amount of nitrate affects both food intake and the survival rate of fish. Due to the use of a high quantity of fertilizers, aquatic life isin great danger of nitrate toxicity [38]. If the nitrate concentration becomes high

from the optimal range, it decreases the growth of Fish. This study shows that Chashma Lake has 6.08 ppm nitrate which supports fish health because the high level of nitrate leads to fish stress. Figure 3 shows various types of chemical analysis to determine the water chemistry at Chashma Barrage. Chashma Lake has 6.08 ppm nitrate which supports fish health because the high level of nitrate leads to fish stress. Figure 3 shows various types of chemical analysis to determine the water chemistry at Chashma Barrage.

Figure 3: Chemical analysis to confirm the Chashma Barrage water chemistry.

Future Research

In this study, we observed the optimal parameters for fish growth including different physical and chemical analyses. Future research may be conducted on different cross-countries or environments to support or falsify this research recommendation. Future research may consider these chemical and physical analyses and might be able to create an artificial environment which improves fish growth farming.

References

1. Obe BW, Akin-Obasola BJ, Adeosun A. Physico-chemical parameters of fishponds as it affects fish production in Ado-Ekiti, Ekiti State, Nigeria: 28th Annual Conference of the Fisheries Society of Nigeria (FISON). 2013 Nov 25-29; 97-100.
2. Pawar S S. Analysis of some physicochemical parameters and their effect on the productivity of fishes in two different types of aquatic bodies of Unamgaon and Seipargaon of Patharkandi block of Karimganj district Assam India: International J. of Life Sciences.2017; 5(4): 587-592.
3. Mohammed B, Tewabe D, Zelalem W, Melaku A. Physical, Chemical, Biological properties and fish species type of Geray reservoir: W/Gojjam Zone Ethiopia. Int J Aquac Fish Sci. 2016; 2(1): 008-011.
4. Altaf M, Javid A, Khan AM, Hussain A, Umair M, Ali Z. The status of fish diversity of river Chenab, Pakistan:The Journal of Animal & Plant Sciences. 2015; 25(3):564-9.
5. A Abro N, Waryani B, T Narejo N, Ferrando S, A Abro S, R Abbasi A, K Lashari P, Y Laghari M, Q Jamali G, Naz G, Hussain M. Diversity of freshwater fish in the lower reach of Indus River Sindh province section, Pakistan. Egyptian Journal of Aquatic Biology and Fisheries: 2020 Sep 6;24(6):243-65.
6. Ramsar Sites Information Service. [updated 2023 August 08].
7. Jain S, Sharma G, Mathur YP. Effects of temperature variations on fish in lakes: International Journal of Engineering Research & Technology. 2013; 2(10):2516-23.
8. Singh SP, Sharma JG, Ahmad T, Chakrabarti R. Effect of water temperature on the physiological responses of Asian catfish Clarias batrachus (Linnaeus 1758): Asian Fisheries Science. 2013;26(1):26-38
9. Valon M, Valbona A, Fahri G, Qenan M, Dhurat K, Fatmir C. Evaluating Environmental Pollution by Applying Oxidative Stress Biomarkers as Bioindicators of Water Pollution in Fish: 2013 Sep 1; 22(5):1519-23.
10. Adeogun OA, Fafioye OO, Olaleye BA, Ngobili GO. The relationship between some physicochemical

parameters and plankton composition on fish production in ponds: 19th Annual Conference of the Fisheries Society of Nigeria (FISON). 2005Nov-Dec 29-03;874-92.
11. Makori AJ, Abuom PO, Kapiyo R, Anyona DN, Dida GO. Effects of water physico-chemical parameters on tilapia (Oreochromis niloticus) growth in earthen ponds in Teso North Sub-County, Busia County: Fisheries and Aquatic Sciences: 2017; 20(1):1-0.
12. Yağcı A, Apaydın Yağcı M, Bilgin F, Erbatur İ. The effects of physicochemical parameters on fish distribution in Eğirdir Lake, Turkey: Iranian Journal of Fisheries Science. 2016; 15(2): 846-57.
13. Mohammed B, Tewabe D, Zelalem W, Melaku A. Physical, Chemical, Biological properties and fish species type of Geray reservoir: W/Gojjam Zone Ethiopia. Int J Aquac Fish Sci. 2016; 2 (1):008-011.
14. Kalsoom B, Mishaal B, Sardar T, Nasreen Z, Kalsoom S, Sharif A.Water Quality Parameters and Fish Diversity at Chashma Barrage, Mianwali, Punjab, Pakistan: RADS Journal of Biological Research & Applied Sciences. 2021;12(2):135-45.
15. Jabeen G, Javed M, Azmat H. Assessment of heavy metals in the fish collected from the river Ravi, Pakistan: Pakistan Veterinary Journal. 2012 Mar 1;32(1):107-11.
16. Haseeb A, Azeem T, Masood Z, Mengal F, Rehman UH, Fayyaz A. An investigation on freshwater fish fauna of Tanda dam in Kohat district, Khyber Pakhtunkhwa province of Pakistan: Global Veterinaria. 2015;14(4):576-81.
17. Ali M, Hussain S, Mahmood JA, Iqbal R, Farooq A. Fish diversity of freshwater bodies of SulemanMountain range, Dera Ghazi Khan region, Pakistan: Pakistan journal of Zoology. 2010;42(3): 285-89.
18. Kausar R, Sultan M. Effect of water temperature on the growth performance and feed conversion ratio of Labeo rohita: Pakistan Veterinary Journal. 2006;26(3):105-8.
19. Crosby TC, Hill JE, Martinez CV, Watson CA, Yanong RP. On-Farm Transport of ornamental Fish: FA-119/FA119, 11/2006. EDIS. 2006; 2006:33.
20. Strifling DA. Reducing chloride discharges to surface water and groundwater: a menu of options for policymakers: Envtl. L. 2018; 48:167.
21. Munni MA, Fardus Z, Mia MY, Afrin R. Assessment of pond water quality for fish culture: A case study of Santosh region in Tangail, Bangladesh.Journal of Environmental Science and Natural Resources. 2013; 6(2):157-62.
22. Boyd C E. Principles and measurement of an important production parameter: Global Seafood Alliance. 2017 October 1;
23. A Nassar S, GA Hassan A, F Badran M, M Abdel-Rahim M. Effects of salinity level on growth performance, feed utilization, and chromatic deformity of the hybrid red tilapia, Oreochromis niloticus x O. mossambicus: Egyptian Journal of Aquatic Biology and Fisheries. 2021Mar 1;25(2):49-61.
24. Isaza DF, Cramp RL, Franklin CE. Living in polluted waters: A meta-analysis of the effects of nitrate and interactions with other environmental stressors on freshwater taxa: Environmental Pollution. 2020; 261:114091.
25. Bedassa SB. Identification of possible causes of fish death in Lake LakeKabo: International Journal of Fisheries and Aquaculture. 2019; 11(2): 29-36.
26. Ahmad I, Afshan K, Ramzan M, Hayat S, Raza Rizvi SS, Qayyum M. Effect of water quality parameters on isopod parasite Alitropus typus (Aegidae) of ectotherms in Chashma Lake, Pakistan: Pakistan Journal of Zoology. 2016; 48(3):769-79.

27. Ip YK, Chew SF, Randall DJ.Ammonia toxicity, tolerance, andexcretion: Fish physiology. 2001 Jan 1;20:109-48.
28. Martins CI, Ochola D, Ende SS, Eding EH, Verreth JA. Is growth retardation present in Nile tilapia Oreochromis niloticus cultured in low water exchange recirculating aquaculture systems? Aquaculture. 2009 Dec 16; 298(1-2):43-50.
29. Abbink W, Garcia AB, Roques JA, Partridge GJ, Kloet K, Schneider O.The effect of temperature and pH on the growth and physiological response of juvenile yellowtail kingfish Seriola lalandi in recirculating aquaculture systems: Aquaculture. 2012 Feb 17;330:130-5.
30. Wurts WA, Durborow RM. Interactions of pH, carbon dioxide, alkalinity and hardness in fishponds:1992; 1-3.
31. Kilany M, Fouad MM, Hemdan AM, Hassanien AE. Fish growth performance classification based on ammonia concentrations: In Proceedings of the Third International Afro-European Conference for Industrial Advancement—AECIA 2016. Springer International Publishing. 2018; 330-339.
32. Weber-Scan, Phyllis K, and Lawrence K. Duffy. Effects of total dissolved solids on aquatic organisms. A review of literature and recommendation for salmonid species: American Journal of Environmental Sciences.2007;3(1):1-6.
33. Narejo NT. Effect of physico-chemical parameters on fish growth in Hanna Lake, Balochistan, Pakistan: Pakistan Journal of Analytical & Environmental Chemistry. 2016; 17(2):174-8.
34. Kroupova H, Machova J, Svobodova Z. Nitrite influence on fish: a review. Veterinarni medicina-praha. 2005 Nov 30;50(11):461.
35. Boeuf G, Le Bail PY. Does light have an influence on fish growth? Aquaculture. 1999 Jul 1;177(1-4):129-52.
36. Bœuf G, Payan P. How should salinity influence fish growth? Comparative Biochemistry and Physiology Part C: Toxicology & Pharmacology. 2001Dec 1;130(4):411-23.
37. Elahi N, Ahmed Q, Bat L, Yousuf F. Physicochemical parameters and seasonal variation of coastal waterfrom Balochistan coast, Pakistan:Journal of Coastal Life Medicine. 2015; 3(3):199-203.
38. Schram E, Roques JA, van Kuijk T, Abbink W, van De Heul J, de Vries P, Bierman S, van de Vis H, Flik G. The impact of elevated water ammonia and nitrate concentrations on physiology, growth and feed intake of pikeperch (Sander lucioperca): Aquaculture. 2014; 420:95-104.