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Relationship Between Physico-Chemical Parameters and Reproductive Indices of *Parachanna obscura* (Gunther 1861) in Eleyele Reservoir, Ibadan, Nigeria

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Abstract

Propagation in fishes depends on the level of gonad maturation which could be influenced by environmental conditions. However, declining water quality due to environmental degradation has been identified as a hindrance to such ecosystem services in aquatic ecosystems. Therefore, size distribution and stages of gonad development of *P. obscura* in relation to physic-chemical parameters of Eleyele reservoir were studied. Samples of water and Parachanna obscura were collected monthly from five stratified sampling points and fishers catch, respectively for 24 months. Fish were grouped according to sizes (10-15.9, 16.0-19.9 and ≥ 20 cm), and gonads assessed for maturation. Relationship between reproductive indices and physic-chemical parameters were determined using Principal Component Analysis. The size-groups distributions were 10-15.9 cm (28.6%), 16.0-19.9 cm (38.7%) and ≥ 20 cm (32.7%). All the five maturation stages (I-V) were discerned in the female while only stages II-IV were observed in male samples. All the size groups showed strong associations with pH (β=0.346), ammonia (β=0.303) and temperature (β=0.161). Ovary development was significantly influenced by DO (β=0.827), TDS (β=0.777) and TS (β=0.813), while testes maturation was more influenced by temperature (β=0.626). This information will serve as guides for effective ecosystem management through the control of anthropogenic activities on this reservoir and similar water bodies to enhance resource conservation and/or sustainable management.

Keywords: Pesticides; Ecosystem; Ovary; Testis

Introduction

Lakes and reservoirs constitute very important nursery and breeding grounds for a large variety of fish species, making it crucial to feeding millions of people around the globe. However in recent time, resources from these ecosystems are not only being over-exploited but the environment also ecologically degraded [1,2]. The major causes of species decline in these ecosystems as reported by Ajani and Omitoyin are anthropogenic activities such as chemical and pesticides released by agricultural activities, effluents discharged from aquaculture, solid wastes dumped from residential areas and harvesting of juvenile fishes by artisanal fishermen. According to Kirsten, environmental conditions influence fish distributions, communities and seasonal movements [3,4]. Concern over loss of biological diversity and ecosystem function, therefore, informed research into the environmental status of fishing grounds [5,6].

Fish population structures in freshwater bodies are known to be influenced by biotic and abiotic factors. Abiotic factor associated with fish population structure and gonad maturation include dissolved oxygen, pH and turbidity [7,8]. In most teleost, successful reproduction depends on gonadal development which is invariably stimulated by favorable environmental conditions. However, declining water quality due to environmental disconcertion threatens the stability of the biotic integrity and therefore hampers the ecosystem services and functions of the aquatic ecosystems [9].

Although there is considerable information on ecology and reproductive biology of *P. obscura* in most Nigerian lakes, little is however known about the relationship between various physicochemical parameters and gonad development in *P. obscura* [10,11].

Materials and Methods

Eleyele reservoir, located in Ibadan North-West area of Ibadan metropolis, Nigeria lie at Latitude 7˚25'0''–7˚26'15'' N and Longitude 3˚50'45''–3052'15'' E. The reservoir was spatially stratified into five zones as S1–S5 based on hydrological features, for water sampling following Kareem and APHA [12,13]. Samples of *P. obscura* were bimonthly collected from fishers catch. Water variables measured includes dissolved oxygen (mg/L), water temperature (°C), pH, chemical oxygen demand (mg/L), total solid (mg/L), total dissolved solid (mg/L), conductivity (µS cm^{-1}), nitrate (mg/L), nitrite (mg/L), ammonia (mg/L), calcium (mg/L), magnesium (mg/L), sulphate (mg/L), phosphate (mg/L), mean depth (m). Fish were grouped according to sizes following the method of Ayinla [14]. The stages of sexual maturity were determined based on visual and histological characteristics as modified by Nunez and Duponchelle [15] and Marcano; i.e. immature, developing, mature, ripe and spent. The data collected were analyzed using descriptive statistics, Spearman rank correlation and Principal Components Analysis (PCA) using PAST programme [16-18].

Results

All water parameters (DO, 4.69 ± 0.99 mgL^{-1}; COD, 130.23 ± 53.26 mgL^{-1}; transparency, 0.81 ± 0.35 m; nitrate, 3.84 ± 1.95 mgL^{-1}; ammonia, 2.03 ± 1.15 mgL^{-1}; phosphate, 1.93 ± 0.62 mgL^{-1}; chloride, 10.11 ± 8.96 mgL^{-1}) analysed except BOD (4.29 ± 2.23 mgL^{-1}), temperature (26.64 ± 2.36˚C), pH (7.11 ± 0.53), conductivity (0.270 ± 0.21 µS cm^{-1}), total alkalinity (100.42 ± 14.69 mgL^{-1}), total hardness (69.18 ± 30.94 mgL^{-1}), magnesium (3.51 ± 1.31 mgL^{-1}), sodium (0.36 ± 0.25 mgL^{-1}) and sulphate (14.05 ± 5.54 mgL^{-1}) fell outside the permissible limit [19-25]. The three size-groups observed were 10-15.9 cm (28.6%), 16.0-19.9 cm (38.7%) and ≥ 20 cm (32.7%). Also, five maturation stages were discerned in *P. obscura* is shown in **Figure 1**. However, stage I and V were not encountered in male samples [26-28].

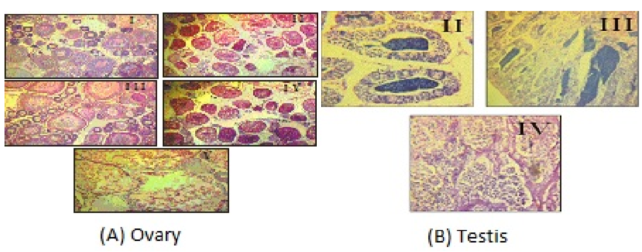

Figure 1: Photomicrograph of Ovary (A) and Testis (B) at different stages of maturation.

Figure 2 and **Table 1** evinced the relationship between water quality parameters and different sizes of Parachanna obscura in Eleyele reservoir. From the result, the varimax factors one (VF1) and two (VF2) accounted respectively for 93.66% and 6.34% of the environmental–fish size categories relationship. VF1 had strong positive loading on large fish size (1.128), and strong negative loadings on small (-0.909) and medium fish sizes (-0.869). VF2 has strong positive loading on small fish size, and strong negative loading on medium fish size [29]. Based on PCA analysis (**Table 1**), pH (0.346), ammonia (0.303), nitrite (0.185), COD (0.178), calcium (0.016) and magnesium (0.214) were positively correlated with the first ordination axis and represent the most important environmental gradients related to the fish population structure. Temperature (0.161), TDS (0.064), phosphate (0.070), nitrate (0.002), electrical conductivity (0.192), calcium (0.125), magnesium (0.065), sulphate (0.009) and TS (0.075) are factors most correlating with the second axis [30].

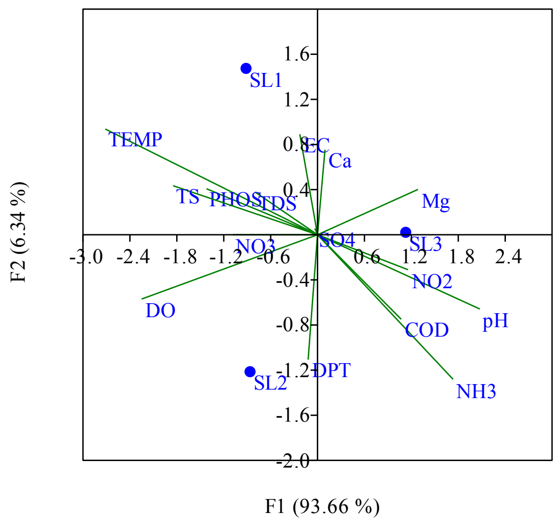

Figure 2: Principal Component Analysis (PCA) bi-plot of environmental variables (arrows) and fish categories (dots) in Eleyele reservoir. SL1–Small sizes; SL2–Medium sizes; SL3–Large sizes; TEMP–Temperature; DO–Dissolved oxygen; COD–Chemical Oxygen Demand; TS–Total Solids; TDS–Total Dissolved Solids; EC–Electrical Conductivity; NO_3–Nitrate; NO_2–Nitrite; NH_3–Ammonia; Ca–Calcium; Mg–Magnesium; SO_4–Sulphate and DPT–Depth. CCA test of axes 1 significant (p<0.01) at 1000 permutations.

Table 1: Eigene values of the principal components of environmental variables and fish size categories in Eleyele reservoir.

Variables	Components	
	F1	F2
SL1	-0.909	1.479
SL2	-0.869	-1.210
SL3	1.128	0.017
DO (mgl^{-1})	-0.375	-0.091
pH	0.346	-0.113
Temperature (˚C)	-0.452	0.161
TDS (mgl^{-1})	-0.133	0.064
Phosphate (mgl^{-1})	-0.237	0.070
Nitrate (mgl^{-1})	-0.181	0.002
Ammonia (mgl^{-1})	0.303	-0.142
Nitrite (mgl^{-1})	0.185	-0.042

Conductivity (μS cm^{-1})	-0.048	0.192
COD (mgl^{-1})	0.178	-0.127
Ca_{2+} (mgl^{-1})	0.016	0.125
Mg_{2+} (mgl^{-1})	0.214	0.065
SO_4 (mgl^{-1})	-0.006	0.009
TS (mgl^{-1})	-0.308	0.075
Depth (m)	-0.020	-0.184
Eigenvalues	0.0037	0.0002
% Variance Explained	94.87	5.13
% Cumulative Variance	94.87	100.00

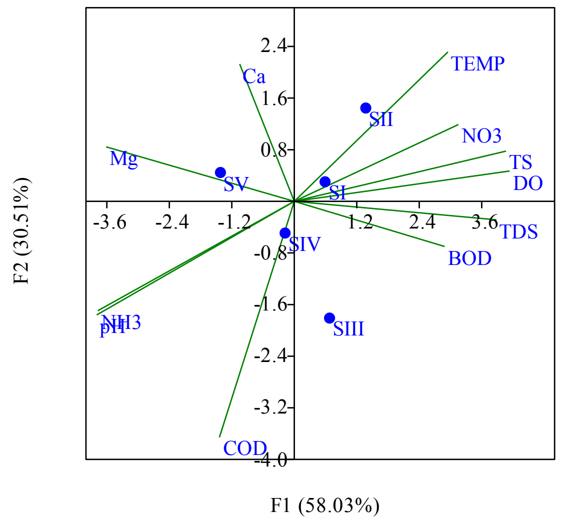

Figure 3: Principal Component Analysis (PCA) bi-plot of environmental variables (arrows) and gonad developmental stages (dots) in female *P. obscura*. SI–Immature; SII–Maturing; SIII–Ripening; SIV–Ripe; SV–Spent; TEMP–Temperature; DO–Dissolved oxygen; COD–Chemical Oxygen Demand; BOD–Biological Oxygen Demand; TS–Total Solids; TDS–Total Dissolved Solids; NO_3–Nitrate; NH_3–Ammonia; Ca–Calcium and Mg–Magnesium. CCA test of axes 1 significant (p<0.01) at 1000 permutations.

The correlation between physic-chemical properties and ovary maturation stages shows that nitrate was an important parameter influencing SI (**Figure 3**). The temperature was the prominent variable affecting SII while BOD slightly affects SIII. Also, SIV and SV showed more remarkable relationship with COD and magnesium, respectively. Moreover, ovary developmental stages in *P. obscura* were more influence by temperature, ammonia, pH and chemical oxygen demand as shown by relative length of vectors. **Table 2** summarizes the PCA: eigene values of each PCs, total variance as well as cumulative variance with strong loading values highlighted [31].

The PCA obtained showed four PCs which explained 100% total variance. The first PC explained 54.03% of the total variance and was best represented by SII (1.372), SV (-1.417), DO (0.827), pH (-0.759), TDS (0.777), TS (0.813), Ammonia (-0.755) and Magnesium (-0.723). PC 2 was loaded primarily by SII (1.446), SIII (-1.809) and COD (-0.732), accounted for 30.51% of the total variance [32]. PC 3 explained 12.57% of the total variance and loaded heavily on SI (2.133), SII (-1.068) and Calcium (-0.718). PC 4 was responsible for 2.89% of the total variance and was best represented by SII (-1.073) and SIII (1.728). The bi-plot of the environmental variables and testes development indicates ammonia and chemical oxygen demand to be the most significant environmental factors affecting testes maturation in *P. obscura* (**Figure 4**). Also, SIII stage was more influenced by ammonia and nitrite. There exist weak connection between SIV and alkalinity [33]. The eigene value and the percentage cumulative variability are shown in **Table 3**. Varimax factors one (VF1) had strong positive loading on SIV (1.134), and strong negative loadings on SIII (-1.196) and COD (-0.752). Also, VF2 showed strong positive loading on SIII (-0.726), and strong negative loading on SII (-1.654) (**Table 3**).

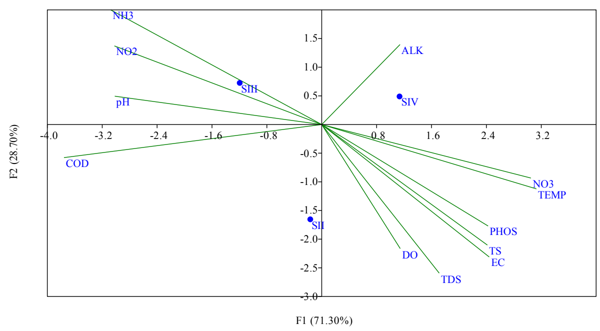

Figure 4: Principal Component Analysis (PCA) bi-plot of environmental variables (arrows) and gonad developmental stages (dots) in male *P. obscura*. SII–Maturing; SIII–Ripening; SIV–Ripe; TEMP–Temperature; DO–Dissolved oxygen; COD–Chemical Oxygen Demand; EC–Electrical Conductivity; TS–Total Solids; TDS–Total Dissolved Solids; NO_3–Nitrate; NO_2–Nitrite; NH_3–Ammonia and PHOS–Phosphate. CCA test of axes 1 significant (p<0.01) at 1000 permutations.

Table 2: Eigene vectors of the principal components between environmental variables and ovary maturity stages.

Variables	Components			
	F1	F2	F3	F4
SI	0.591	0.303	2.133	-0.232
SII	1.372	1.446	-1.068	-0.126
SIII	0.677	-1.809	-0.516	-1.073
SIV	-0.177	-0.492	-0.162	1.728
SV	-1.417	0.446	-0.207	-0.616

DO (mgl^{-1})	0.827	0.0940	-0.282	-0.0478
pH	-0.759	-0.352	-0.033	-0.163
Temperature (°C)	0.590	0.463	-0.178	0.151
TDS (mgl^{-1})	0.777	-0.057	0.060	-0.0746
TS (mgl^{-1})	0.813	0.156	0.152	0.159
BOD (mgl^{-1})	0.578	-0.140	0.394	-0.032
COD (mgl^{-1})	-0.288	-0.732	0.364	-0.036
Nitrate (mgl^{-1})	0.631	0.238	0.028	0.198
Ammonia (mgl^{-1})	-0.755	-0.339	0.159	-0.159
Ca_{2+}(mgl^{-1})	-0.210	0.426	-0.718	-0.042
Mg_{2+} (mgl^{-1})	-0.723	0.169	-0.523	-0.199
Eigenvalues	0.00924	0.00522	0.00215	0.000494
% Variance Explained	54.03	30.51	12.57	2.89
% Cumulative Variance	54.03	84.54	97.11	100.00

Table 3: Eigen vectors of the principal components between environmental variables and gonad developmental stages in male *P. obscura*.

Variables	Components	
	F1	F2
SII	-0.167	-1.654
SII	-1.196	0.726
SIV	1.134	0.490
DO (mgl^{-1})	0.229	-0.433
Temperature (°C)	0.626	-0.225
pH	-0.604	0.099
Alkalinity (mgl^{-1})	0.228	0.279
TDS (mgl^{-1})	0.343	-0.519
TS (mgl^{-1})	0.483	-0.421
Conductivity (μS cm^{-1})	0.488	-0.463
COD (mgl^{-1})	-0.752	-0.116
Nitrite (mgl^{-1})	-0.605	0.274
Ammonia (mgl^{-1})	-0.615	0.399
Nitrate (mgl^{-1})	0.610	-0.187
Phosphate (mgl^{-1})	0.485	-0.354
Eigen values	0.0325	0.0131
% Variance Explained	71.30	28.70
% Cumulative Variance	71.30	100

Discussion

Physicochemical parameters of water provide nutritional balance and ultimately govern the biotic relationships of organisms in aquatic ecosystem including ability to withstand pollution load. The analysis of the physicochemical parameters of sampled water reflected the degraded status of the reservoir. Only a few (BOD, temperature, conductivity, total alkalinity, total hardness, and ions) fell within optimum recommended range for growth and survival [34]. The relative importance of environmental factors to fish population structures revealed temperature as the most environmental variable for the population structure, thus, proving to be the best predictor of species ecological categories structure. Similar result was obtained by Arceo-Carranza and Vega-Cendejas. Also, Dirican, Lewis and Rakocinski et al., reported the existence of a good correlation between surface temperature and the fish population structure, suggesting that aquatic organisms depend on certain temperature range for their optimal growth.

The Principal Component Analysis (PCA) of the environmental factors and population structure of *P. obscura* in Eleyele Reservoir revealed considerable positive relationship with pH (β=0.346) and ammonia (β=0.303). In the same way, small (β=1.479) and large (β=1.128) sizes of *P. obscura* showed a significant positive relationship with the measured environmental factors. Similar findings were obtained by Ngodhe et al., Hossain et al. and Kirsten. In agreement with this finding, Lawson considered that young fish and insects are very sensitive to changes in pH. The author cited pH as one of the vital environmental characteristics that decides the survival, metabolism, physiology and growth of aquatic organisms. The relationship between ammonia and fish growth indicated that the fish population structure is largely regulated by the nutrient base and tend to increase with the trophic state of freshwaters. This was also confirmed by Ndungu who demonstrated that the assemblage composition may vary most as a function of environmental and landscape factors [35].

Moreover, correlation of environmental variables with ovary and testes development in this study suggests the influence of certain physic-chemical parameters on gonad maturation. Ovary developmental stages in *P. obscura* were more influenced by temperature, ammonia, pH and chemical oxygen demand as shown by the relative length of vectors. However, dissolved oxygen, total dissolved solid and total solid were the most significant parameters affecting the ovary maturation of *P. obscura* in Eleyele Reservoir [36,37]. In line with this result, Edward, Carini et al. and D'Amours reported strong positive relationships of temperature and dissolved oxygen on the gonad maturation in fish. This observation was also supported by Lawson who stated that the temperature and light play an important role in the gonadal gametogenesis, spawning and initiation of gonadal development. Further, Etim and Obot emphasized that dissolved oxygen affects the solubility and availability of nutrients and hence, it is one of the most significant parameters affecting the productivity of aquatic systems.

Conclusion

The study showed that size composition and gonad maturation in *P. obscura* strongly correlated with environmental parameters. Size distribution related more to pH, ammonia and water temperature, ovary development significantly influenced by DO, TDS and TS while testes maturation was more prompted by temperature. This information will serve as guides for effective ecosystem management.

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