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Appraisal of Fish Health Assessment Index in Three Major Reservoirs in Ekiti State, Southwest Nigeria

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Increased anthropogenic activities and chemical contaminants in Ekiti State reservoirs have substantial effects on the reservoirs' fish, which are valuable indicators of the health of the aquatic environments. The aim of the study was comparatively assessing the probable environmental deterioration in Egbe, Ero and Ureje reservoirs using the fish Health Assessment Index (HAI). Blood component analysis, necropsy data, and parasite index were used to compute HAI. Haematocrit values were not within the normal range in 78.85% (Ureje reservoir), 73.47% (Egbe reservoir), 57.38% (Ero reservoir), and endoparasite were present in 32.69%, 26.53% and 44.26% of fish examined from Ureje, Egbe, Ero reservoirs. Abnormalities of eyes, fins, skin, and liver were observed in a small proportion in the fish from the reservoirs. HAI of *Oreochromis niloticus* in the reservoirs was in order of Ureje reservoir (31.15 ± 2.81) > Egbe reservoir (29.39 ± 2.57) > Ero reservoir (25.00 ± 2.43). Condition factor of fish was in order of Ero (2.07 ± 0.03) > Egbe (1.98 ± 0.01) > Ureje (1.97 ± 0.01). In comparison to control site, reservoirs' fish were in deplorable conditions as evidenced by HAI. Therefore, HAI is useful as an early indicator of the well-being of the aquatic ecosystems, in order to enhance the sustainability of the aquatic resources and also to compare the health status of fish from different aquatic environments.

Keywords: Necropsy; haematocrit; parasite index; aquatic ecosystems; abnormalities

I. INTRODUCTION

Anthropogenic impacts such as habitat changes and climate alteration due to increased nutrients as well as chemical contaminants can have substantial effects on the inherent aquatic populations. The biotic populations provide adequate information on the general environmental conditions, the well-being of the ecosystem and biological evaluations are fast and are very cheap in comparison to chemical investigation (Van der Oost *et al*., 2003). Fish reside in different water bodies, which human population uses for recreation and drinking purposes are important indicators of the health of water environment. In the natural environment, fish that thrive and breed in a given territory are susceptible during their lifetime to different stressors in the habitat such as diseases, depraved water quality, parasites, and chemical pollutants. The monitoring of inimical effects by employing biological markers beginning from organismal to the molecular level is useful in the assessment of the cumulative effects on fishes and other organisms. One of the biological methods engaged in field assessment of the effect of stress on fish population's health in past years was the quantitative post-mortem based indices of organs and tissues (Adams *et al*., 1993). Post-mortem based evaluations involve the quantification of situation indices by external and internal examinations of fish. Necropsy-based technique was evolved by Goede and Barton (1990) for assessing the health of individual fish so that records can be

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established for the purpose of observing and identifying fish reactions to stressors in the surroundings while Adams *et al.* (1993) intended to reduce the deficiencies of the necropsy-based method, evolved the "quantitative Health Assessment Index" (HAI) by adjusting and improving the autopsy-based method. HAI, built on proportions and ranks of abnormalities in experimental fish tissues and organs due to stressors in the environment, offers fish health profiles and also gives room for numerical appraisals of data among fish populations. HAI had been used widely in different regions. In North America, it was used to assess the consequences of pollution on the surroundings (Chaiyapechara *et al.*, 2003). It was used in Hartwell Reservoir, South Carolina, which was polluted with biphenyls and River Pigeon which collected discharges from a blanched craft mill in North Carolina (Adams *et al.*, 1993). It was verified and modified for their indigenous environments via various studies in South Africa. In the Olifants River System, Avenant-Oldewage *et al.* (1995), Robinson (1996), Luus-Powell (1997) and Watson (2001) used it. HAI was used by Jooste *et al.* (2005) on the Ga-Selati River by using many fish species as pointer organisms. In the Vaal River System, Crafford (2000); Groenewald (2000) and Crafford and Avenant-Oldewage (2009) employed it, and Sara *et al.* (2014) engaged it on Hout River Dam, Limpopo province. In addition, health HAI has been used in provincial site comparisons (Schleiger, 2004). In Nigeria, Olarinmoye *et al.* (2008) used health assessment index in the health evaluation of *Chrysichthys nigrodigitatus* populations in Lagos lagoon. Their reports revealed that the HAI of the fish varied from site to site with the fish from the healthiest environment (Lagos lagoon) having the least HAI value and the highest HAI value obtained in fish from the poorest environment (Badagry lagoon). However, there is no any documented record of employment of this index in fish health evaluation in Nigeria except in Lagos State. The purpose of this study was to ascertain whether or not fish Health Assessment Index (HAI) is helpful in differentiating across locations and to evaluate and compare potential environmental degradation by looking at the health of *Oreochromis niloticus* in the Egbe, Ero, and Ureje reservoirs, in Ekiti State using HAI. The choice of *Oreochromis niloticus* for this study is because it is the only species that occurs in the three reservoirs throughout the year and people's choice as their primary source of protein, especially in low-income households as a result of its palatable taste and undeniable market demand (Olagbemide & Owolabi, 2023). Besides, Tilapia has been successfully used for HAI in other places (Watson *et al.*, 2012; Madanire-Moyo, 2011; Taylor, 2019).

The HAI employed in this work is in accordance with the methodologies established by Adams *et al.* (1993), with the accompanying statistical analysis to identify the variables most suggestive of the health of the fish; to evaluate the effect of infections of different endo- and ectoparasites on fish condition. Since haematocrits are thought to be reliable markers of how fish will react to environmental stressors, they are included in the overall HAI evaluation. For each reservoir and season independently, the condition factor for the fish species was computed to relate it to the HAI in the reservoirs.

II. MATERIALS AND METHOD

A. Area of Study

Ekiti State, situated at the eastern part of the Greenwich Meridian at the north of Equator between longitudes of 4° 45' and 5° 45' east and latitudes of 7° 15' and 8° 5'. It shares border with Kwara, Kogi and Osun States in the north, east and south respectively. Ekiti State reservoirs are in the collection of metamorphic and igneous rocks situated underneath stratified rocks in southwestern Nigeria. This investigation was carried out in Egbe, Ero and Ureje reservoirs, which are the three major reservoirs in the state. The locations of the reservoirs in Ekiti State map are shown in Figure 1. Fishing, recreational, agricultural and domestic activities and disposal of sewage are all common occurrences, particularly in human communities around the reservoirs. Insecticides and agricultural-based chemicals are regularly used in the reservoirs' catchment areas for various agricultural and domestic operations to improve production and fight insect pests respectively. There is dumping of household solid as well as liquid wastes into the reservoirs directly without treatment by the communities and families around the reservoirs. In addition, runoffs from farms are conveyed directly into the reservoirs. Afe Babalola University fish farm in Ado-Ekiti was considered the control site. To the best of our knowledge, this fish farm is devoid of any industrial effluent and/or other facilities that may cause pollution and thus cause adverse effects on aquatic ecosystem.

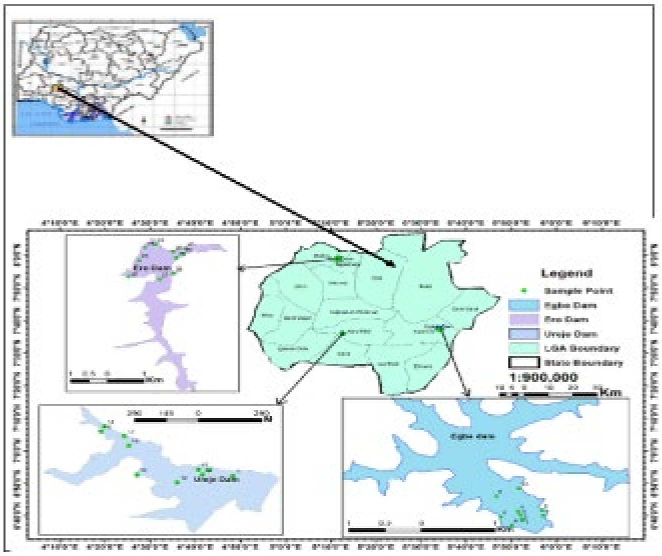

Figure 1. Map of Ekiti State showing the locations of Egbe, Ero, and Ureje dams, southwest Nigeria

B. Ethical Approval

Permissions were acquired from the Ekiti State Water Corporation and the University of Ilorin's ethical committees, and the research was conducted in accordance with ethical norms.

C. Collection of Fish Specimens

A total 438 *Oreochromis niloticus* were collected from the reservoirs and the control site. Forty-eight and fifty fish samples were collected from Egbe reservoir during dry and rainy seasons, respectively; forty-eight and sixty-four fish samples were from Ero reservoir during dry and rainy seasons, respectively; forty-eight and fifty-six fish samples were from Ureje reservoir during dry and rainy seasons, respectively while fifty-six and sixty-eight fish samples were from the control site during dry and rainy seasons, respectively. Sampling was carried out monthly with the number of fish per sample being 7, 8, 9 or 10 fish depending of the size of fish caught per month. The fish specimens were collected from each of the reservoirs (Egbe, Ero and Ureje) with the assistance of fishermen operating in the reservoirs with the aid of gill nets. The gill nets were left overnight with surface marker buoys for their easy relocation.

D. Haematological Analysis

In situ, collection of blood samples was from puncturing of the cardiac region (Bojarski *et al.*, 2018) into ethylene diamine tetra-acetic acid (EDTA) bottles with the aid of 5 ml syringe and needle that were heparinised. The blood samples after collection were kept on ice and transported to the laboratory. Haemocytometer was used for the assessment of erythrocytes and leucocytes according to the technique of Bomski (1995). Microhematocrit method was used in the estimation of haematocrit (Goldenfarb *et al.*, 1971). Fish were assigned numbers, labelled, and conveyed to the laboratory in ice packed container where additional investigations were immediately conducted on them.

E. Parasite Counts

Using a hand lens, fish samples' fins, opercula, mouths, and skin were examined for external parasites. The fish samples were put in a tray and grossly examined for the presence of parasites. The regions between the fins, under the pelvic fin, and on the pectoral fin were looked at. Mucus scrapings from various body parts were placed on a petri dish, to which a small amount of saline solution was added and were then examined under a light microscope to look for parasites. By placing each organ separately in a petri dish filled with saline solution, the various organs including the skin, gills, opercula, eyes, muscles, liver, kidney, spleen, swim bladder, and digestive tract—were examined for endoparasites. The intestinal tracts were slowly opened, divided into parts, and then washed and cleaned in Petri bowls containing 0.1% solutions of sodium chloride and 0.1 % sodium bicarbonate, respectively. Giemsa stain was applied, and the sample was examined under 40x and 100x magnification to check for endo-parasites. The muscles were also thoroughly examined for encysted parasites. The dissected gills were put in petri dishes with saline solution. On a microscope slide, drops of the saline solution were applied, and parasites in the gills were examined at 40x and 100x amplification. Examination and identification of the fish parasites were according to Paperna (1996) and Bruno *et al.* (2006).

F. Necropsy

Following the procedure outlined by Adam *et al.* (1993), a necropsy was carried out by looking at the fish's fin, skin, eye, opercula, gills, and internal organs (liver, spleen, hindgut, and kidney). In order to prevent biased colour assessments from being made during evaluations of the liver, bile colour, and spleen, Watson's (2001) colour chart was used. External and internal tissues and organs of fish were examined for lesions. On the basis of the extent of abnormalities caused by stressors in the environment, an arithmetic worth was given.

G. Condition Factor

The fish condition factor (K) of the fish species (Pauly, 1983) was computed separately for each sample site and season. Data on body weight and length were used to evaluate the fish condition factor.

$$K = 100\ w/L^b$$

where;

W = Weight of the fish in grams

L = The total length of the fish in centimetres

^{b} = The value obtained from the length-eight equation formula

Fish total length (cm) was measured using measuring board to nearest 0.1 cm as described by Lagler (1978), while body weight (g) was measured using a digital top loading weighing scale, Ohaus CS 5000 model to nearest 0.01 gram.

H. Health Assessment Index Calculation

The calculation of HAI involves the use of blood constituent analysis, necropsy data and parasite index. In the employment of HAI in the evaluation of fish health, haematocrit percentage of greater than 45%, between 30% and 45%, between 19% and 29% and less than 18% were considered to be mild abnormal, normal, moderate abnormal and severely abnormal respectively (Watson *et al.*, 2012). The presence of parasites and haematocrit values were considered as other variables. The various factors used in the assessment of HAI were denoted by arithmetic worth ranging from 0 – 30, with normal condition being assigned 0. All "normal" conditions was represented by 0 and subject to the severe level of the conditions, abnormal conditions take values of 10, 20 or 30. The arithmetic worth of the different factors were added up to compute an index value of each fish in a sample. HAI of a model populace was computed by adding together the fish health index of all the individual fish and divided by the total sum of fish investigated. An increase in the value of HAI value correlate with deteriorated water quality and therefore, intensified stress.

For each sample, the standard deviation was thus computed:

$$SD = \sqrt{\frac{\sum_{i=1}^{N}(Vi-X)^2}{N-1}}$$

N = fish quantity in each site

X = Individual fish mean index

V_i = fish 'i' index worth

The relative standard deviation (coefficient of variance, CV) that is useful in the indication of the extent of stress experienced by a fish population is computed as shown below.

$$CV = 100 \times \frac{SD}{X}$$

The means of HAI of *O. niloticus* from the sampling sites and the appraisal of the differences in their values amongst the sampling sites were assessed by descriptive statistics and analysis of variance (ANOVA), respectively. Significance was reckoned for the results of test when the p-values computed were ≤ 0.05.

III. RESULTS

A. Condition Factor (CF)

The seasonal condition factor is shown in Table 1. CF of the fish in the three reservoirs ranged from 1.19 to 2.52 during the dry season and 1.50 to 2.70 during the rainy season with rainy season having higher mean value. In the reservoirs, the condition factors were higher during the rainy season than the dry season and during both seasons, the mean highest condition factor was recorded in Ero reservoir and the lowest condition factor in Ureje reservoir.

Table 1. Mean seasonal condition factor of *O. niloticus* in Egbe, Ero and Ureje reservoirs

	Condition Factor							
	Dry Season				**Rainy Season**			
Reservoirs	**N**	**Min**	**Max**	**Mean**	**N**	**Min**	**Max**	**Mean**
Egbe	48	1.49	2.40	1.94±0.002	50	1.60	2.53	2.01±0.01
Ero	48	1.50	2.52	2.04±0.03	64	1.68	2.58	2.09±0.01
Ureje	48	1.19	2.39	1.93±0.02	56	1.50	2.70	2.00±0.02

B. Health Assessment Index

Table 2 shows the percentage of total number of fish from the reservoirs and the control site during the seasons with parasites and abnormalities in their organs and the average HAI values from the different locations. The average HAI values of the *O. niloticus* data pooled from both dry and rainy seasons survey showed that the HAI for the fish was greatly influenced by parasite associated abnormalities and the value of haematocrit. HAI value was highest in *O. niloticus* from Ureje reservoir (31.15), followed by that of fish from Egbe reservoir with a value of 29.39 and the lowest HAI value was observed in *O. niloticus* from Ero reservoir (25.00). However, among reservoirs the differences were insignificant statistically at ($P<0.05$) except between fish from Ero and Ureje reservoirs during the dry season. Significant differences occurred in the values of HAI in fish from control site when related to the values of HAI of fish from Egbe, Ero and Ureje reservoirs during the dry and rainy seasons (Table 3). The ratio of the standard deviation to the mean in the values of HAI was utmost in the fish collected from Ero reservoir, followed by that of fish samples from Egbe reservoir and the lowest HAI value observed in *O. niloticus* from Ureje reservoir. The values of haematocrit and endoparasite records appeared as the variables of HAI that were largely accountable for most of the anomalies detected in *O. niloticus* from Egbe, Ero and Ureje reservoirs. Abnormalities of eyes, fins, skin, and liver were observed in a small proportion in the fish from the reservoirs that were examined. Most frequent anomalies were pale and frayed gills and inflammation of the skin. Haematocrit values were not within the normal range according to Adam *et al.* (1993) in 78.85% (Ureje reservoir), 73.47% (Egbe reservoir), 57.38% (Ero reservoir) and 37.10% (control site) of fish examined from the sites, while endoparasite were present in 32.69, 26.53, 44.26% and 25.81% of fish examined from Ureje, Egbe, Ero reservoirs and control site respectively (Table 2).

During the dry season, *O. niloticus* collected from Egbe reservoir had the highest HAI value of 28.33 while Ureje and Ero reservoirs had HAI value of 27.08 and 22.16, respectively. Endoparasites were present in 20.83% (Egbe reservoir), 49.95% (Ero reservoir) and 37.50% (Ureje reservoir) of fish obtained from the reservoirs during dry season while abnormal haematocrit values were 70.83% (Egbe reservoir), 54.05% (Ero reservoir) and 75.00% (Ureje reservoir) in fish obtained from the reservoirs. Fish collected from Ureje reservoir during the rainy season had the peak mean value of HAI of 34.64, Egbe reservoir had HAI value of 30.40 and Ero reservoir had the lowest mean HAI value of 29.38 (Table 2). The percentage haematocrit abnormalities of fish samples from the reservoirs during the rainy season were 76.00% (Egbe reservoir), 62.50% (Ero reservoir) and 82.14% (Ureje reservoir) while endoparasites were present in 32.00% (Egbe reservoir), 41.67% (Ero reservoir) and 28.57% (Ureje reservoir) of fish samples from the reservoirs (Table 2).

Table 2. Percentage of parasitic infection and tissue abnormalities in *O. niloticus* from Egbe, Ero and Ureje reservoirs

Percentage of *O. niloticus* with parasite, organ and haematocrit anomalies																
Location	**Season**	**N**	**Eyes**	**Skin**	**Fins**	**Opercula**	**Gills**	**Liver**	**Spleen**	**Hind gut**	**Kidney**	**Haematocrit**	**Ecto-parasite**	**Endo-parasite**	**Total HAI**	**CV**
Ref. site	Dry	56	0.00	0.00	7.14	0.00	3.57	0.00	0.00	0.00	0.00	28.57	10.71	35.71	9.64 ± 1.41	77.20
	Rainy	68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	44.12	11.76	17.65	8.23 ± 1.07	76.04
	Combined	124	0.00	0.00	3.23	0.00	1.61	0.00	0.00	0.00	0.00	37.10	11.29	25.81	8.88 ± 0.86	76.66
Egbe	Dry	48	0.00	0.00	0.00	0.00	0.00	20.83	0.00	0.00	0.00	70.83	16.67	20.83	28.33 ± 2.93	55.63
	Rainy	50	0.00	0.00	0.00	0.00	4.00	20.00	0.00	0.00	0.00	76.00	12.00	32.00	30.40 ± 4.22	69.44
	Combined	98	0.00	0.00	0.00	0.00	2.04	20.41	0.00	0.00	0.00	73.47	14.29	26.53	29.39 ± 2.57	65.11
Ero	Dry	48	2.70	0.00	5.41	0.00	5.41	8.11	0.00	0.00	0.00	54.05	13.51	49.95	22.16 ± 2.85	78.25
	Rainy	64	4.17	4.17	8.33	0.00	16.67	0.00	0.00	0.00	0.00	62.50	12.50	41.67	29.38 ± 4.26	71.04
	Combined	112	3.38	1.64	6.56	0.00	9.84	4.92	0.00	0.00	0.00	57.38	13.11	44.26	25.00 ± 2.43	75.89
Ureje	Dry	48	0.00	0.00	8.33	0.00	8.33	8.33	0.00	0.00	0.00	75.00	12.50	37.50	27.08 ± 3.32	60.11
	Rainy	56	3.57	0.00	3.57	0.00	21.43	7.14	0.00	0.00	0.00	82.14	14.29	28.57	34.64 ± 4.32	65.96
	Combined	104	1.92	0.00	5.77	0.00	15.38	7.69	0.00	0.00	0.00	78.85	13.46	32.69	31.15 ± 2.81	63.03

HAI = Health Assessment Index, CV = Coefficient of variance, N = Number of fish sampled

Table 3. Health Assessment Index for *O. niloticus* from the Dams

		HAI		
Season	**Dams**	**Value**	**Standard Deviation**	**Coefficient of variation**
Dry	Ref. site	9.64 ± 1.41^{b}	7.44	77.20
	Egbe	28.33 ± 2.93^{a}	14.34	50.63
	Ero	22.16 ± 2.85^{a}	17.34	78.85
	Ureje	27.08 ± 3.32^{a}	16.28	60.11
Rainy	Ref. site	8.23 ± 1.07^{b}	6.26	76.04
	Egbe	30.40 ± 4.22^{a}	21.11	69.44
	Ero	29.38 ± 4.26^{a}	20.87	71.04
	Ureje	34.64 ± 4.32^{a}	22.85	65.96
Combined seasons	Ref. site	8.88 ± 0.86^{b}	6.80	76.66
	Egbe	29.39 ± 2.57^{a}	17.96	61.11
	Ero	25.00 ± 2.43^{a}	18.97	75.89
	Ureje	31.15 ± 2.81^{a}	20.26	65.03

Mean Health Assessment value having superscript that are different along column are significant at $P<0.0$.

IV. DISCUSSION

The quantitative evaluation of the health of *Oreochromis niloticus* in the three reservoirs gave a quick, inexpensive, and general overview of the incidence of alteration in the health of the fish in the reservoirs and thus serves as the first useful step in detecting the pollution problem, though, it did not indicate the pollutants that are responsible for such a change. However, comparisons between sites and species, as well as seasonal and chronological alteration in a population, are possible using a standardised methodology. HAI values that were significantly high in the reservoirs than the control site indicated that the fish in the reservoirs were in deprived state when compared with those from the control site, which could be due to high level of parasite load (Olagbemide & Owolabi, 2022), and metals (Olagbemide & Owolabi, 2019) and organochlorine pesticides concentration in the reservoirs. The highest HAI and lowest coefficient of variation observed in Ureje reservoir when related to the values of HAI in Egbe and Ero reservoirs was because fish that inhabit polluted environment are also unprotected from depraved water quality, so, fish taken out of a pollutant exposed populace are likely to have fewer variability in their physiological conditions when compared to fish from unstressed or less stressed environment (Adam *et al.*, 1993). The conclusion regarding the different levels of fish health among the reservoirs was primarily based on high proportions of haematocrit values that are outside the normal range of 30% and 45% (Watson *et al.*, 2012), ectoparasites; endoparasites, abnormalities in the gills, liver, fins, eyes, and inflammations of the skin. But endoparasite and haematocrit values turned out to be HAI variables most responsible for the outcomes of HAI seen in *O. niloticus* removed from the reservoirs.

According to Ujjania *et al.* (2012), who classified a good condition as 1 or a condition factor higher, the mean condition factors in the three reservoirs in this study were greater than 1 and in the standard ranges, indicating a worthy nutritional level during the dry and rainy seasons. Condition factor is a sign of fish general health and can be used to assess environmental contamination (Liebel *et al.*, 2013). It is generally assumed that fish has improved its condition when the condition factor value is higher. However, our observation in this study appears to link rising HAI to an elevated condition factor and illustrate the relative differences in the health status of *O. niloticus* in three reservoirs. Parallel findings were noted by Morado *et al.* (2017) and Nur *et al.* (2020) in their studies that condition factor was inversely connected with quality of water.

Sadauskas-Henrique *et al.* (2010) reported that the condition factor was not directly affected by some contaminants. Generally, contaminants have a detrimental effect on condition factor by making food less accessible and/or increasing the energy required to preserve balance in the body (Bervoets & Blust, 2003); however, untreated domestic wastewater pollution, which is typically associated with high yield (Alberto *et al.*, 2005), may be an exception. According to Jenkins (2004), condition factor varies seasonally in relation to dietary and nutritional availability and places with high levels of human disturbance have more food availability during the rainy season (Teixeira *et al.*, 2005). Since there is more depositional material carried by the heaviest rainfall during the rainy season, there is more food available in areas with heavy human disturbance and hence, higher condition factor during the rainy season.

It is also possible to explain the observed changes in the mean condition factor between the dry and rainy seasons in terms of the dissolved oxygen. The water became well-oxygenated during the rainy season due to increasing levels of dissolved oxygen (Olagbemide & Owolabi, 2019), which allowed the fish's metabolic processes to work more efficiently. The condition factor was also observed to be higher during the rainy season than the dry season by Keyombe *et al.* (2017), and Mohd and Khaironizam (2019). Consequently, predicated on the condition factors recorded from the three reservoirs, *O. niloticus* physiologically acclimated to the reservoirs and thus demonstrates the capacity of the fish to survive a wide range of harsh environmental circumstances.

V. CONCLUSION

Data on parasites and blood parameters were the most accurate predictors of changes in the quality of the water in the reservoirs. Similarly, endoparasite counts and fish blood haematocrit are considered to be the most reliable overall indicators of fish health in reservoirs. For this reason, if variables are being eliminated from the HAI so that the evaluation processes of HAI can be streamlined, the above-mentioned variables should not be discarded. In addition, this biomonitoring technology can be successfully utilised for quick and less expensive water quality check throughout Nigeria, and to detect effects connected with causes of pollutants and to impart the knowledge of the actions required for effective control. However, this study is limited by the inability of fish health assessment to reliably discover impacts that may not be immediately apparent. It is also quite rare to be able to pinpoint the root causes or risk factors for reported anomalies. Furthermore, its foundation is visual evidence, which is less sensitive to sub chronic impacts than tissue and subcellular biomarkers. Lastly, there are no other species present in the reservoirs throughout the year for comparison.

VI. ACKNOWLEDGEMENT

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VII. CONFLICT OF INTEREST

The authors declared that they have no conflicts of interest.

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