

Anthropogenic Impacts on Fish Diversity in Lake Alau: Assessing Distribution, Composition, and Abundance

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Abstract

A study was undertaken from January 2019 to June 2020 to examine the impact of human activities on the variety of fish in Lake Alau. Despite initially selecting five sampling points, only three (Stations 1, 2, and 3) were utilized due to security concerns. The assessment of the fish population involved the use of different fishing equipment, such as hooks and lines, gillnets, cast nets, and traps. Standard procedures were employed to estimate species diversity indices. The findings indicated a total of 3399 fish samples, encompassing 10 families and 22 species. The Cichlidae family was the most abundant, with 1276 samples from 4 species, predominantly *Sarotherodon galilaeus*, while the Cyprinidae family was the least abundant, with just 88 fish specimens represented by *Labeo senegalensis*. The Shannon Weiner and Simpson's Diversity index suggested a stable and mature fish community in the lake, with minor variations attributed to agricultural activities and the discharge of wastewater, among other factors. The comprehensive results emphasize the significance of monitoring and managing water quality in Lake Alau to uphold its diverse fish species. Future research is recommended to focus on prolonged monitoring and strategies for minimizing negative environmental impacts to preserve and improve the ecological wellbeing of the lake ecosystem.

Introduction

The growth in human population and the requirement for products and services have caused a range of negative consequences for freshwater ecosystems (Ganassin et al., 2019). As a result of extensive human activities and involvement, most

freshwater ecosystems have experienced deterioration and the loss of habitats, thus endangering the survival of many fish species (Negi and Mamgain, 2013). It's important to note that aquatic environments are strongly influenced by a variety of conditions, including salinity, water flow, substrate type, aquatic plant life, exposure to sunlight, water turbidity, and temperature. These factors have a significant impact on the diversity of fish species present in these environments (Dudgeon et al., 2006; Isroni et al., 2023). Fish diversity encompasses species richness, species abundance, and phylogenetic diversity. It's worth mentioning that fish constitute the largest and most diverse class of vertebrates, with many species holding considerable ecological and economic significance (Nelson et al., 2016). Aquatic organisms known as fish are among the most well-known species, and they are extensively harvested from natural populations as a significant food source. Moreover, fish occupy the top or near-top levels of the food chain, making them a reliable indicator of a well-balanced aquatic ecosystem. Additionally, fish play a crucial role in ensuring food security for millions of people (Sala et al., 2021).

It's interesting to note that fisheries catching a wide range of species can provide nutrients to our society and are essential for food security, especially in less developed regions. According to Mcclanahan et al. (2015), fish offer approximately 20% of animal protein for 3.3 billion people (Bartley, 2022).

Monitoring fish communities accurately is crucial for understanding species composition, abundance, and population structure, which are essential for conserving fish resources and diversity. Climate change, habitat loss, overfishing, environmental pollution, and invasive species pose significant threats to global fish diversity, highlighting the importance of addressing these challenges for the sustainable management and conservation of fish populations. (Rees *et al.*, 2014).

The activities of humans have caused permanent changes in the structure of the landscape, which have had significant effects on freshwater ecosystems. Lake Alau has been impacted by human activities such as inputs from the main feeders and runoff from catchments. Local communities have also contributed to the disturbance by engaging in dredging for commercial sand and gravel. Additionally, unregulated or poorly regulated commercial fishing has led to a decrease in the populations of many common fish species in the lake (Ohaturuonye et al., 2018). The study aimed to evaluate how these human activities have influenced the distribution, composition, and abundance of fish species in Lake Alau.

Materials and Method

Study Area

Lake Alau, located in Borno State, Nigeria, is the second-largest lake in the area. Its formation dates back to 1985 when the Ngadda River was dammed, sourcing water from the Mandara Plateau. The lake spans an area between Latitude 12°N and 13°N, and Longitudes 11°E and 13°E, covering a total of 56 square kilometers. Originally, it was intended to supply water to Maiduguri Metropolis and irrigate over 8,000 hectares of farmland, and its creation was overseen by the Chad Basin Development Authority. The area experiences a Sahelian climate, with three distinct seasons: a rainy season from June to September, a harmattan season from October to February, and a dry, hot season from March to May. The months of March and April see the lowest water levels, resulting in exposed lakebeds of sand and rocks. The dam, standing at a height of 9 meters

and with a reservoir area of 50 square kilometers, can store up to 112 million cubic meters of water.

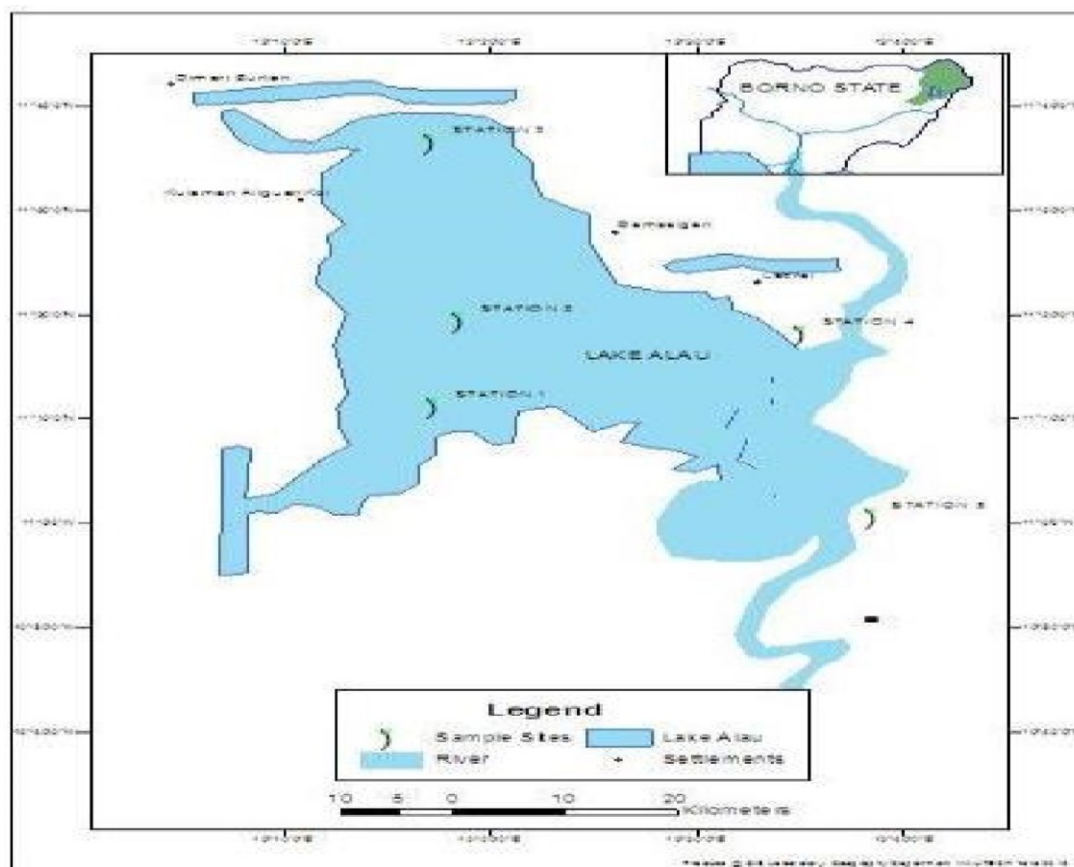


Figure 1: Map of Lake Alau showing the Sampling Station

Sampling of Fish Species

A survey called the Catch Assessment Survey was utilized to gather data, where species were identified and recorded from the catch of fishermen at various landing sites. These sites were visited monthly for a period of eighteen months, from January 2019 to June 2020, to collect data. The different types of fish species found at the landing site were identified and grouped into families using a fish manual by Idodo (2003). The fishing equipment used for sampling included hooks and lines of different sizes and grades, gillnets, cast nets, and traps. The SPSS software package was utilized for conducting data analyses. Diversity indices were calculated for the collected data on fish composition and diversity. The diversity indices were determined based on the approaches outlined by Dodge (2008) and Levine (2014).

$$\text{Simpson's Index } (D) = \sum (n/N)^2$$

Where n = the total number of organisms of a particular species
 N = the total number of organisms of all species.

$$\text{Simpson's Index of Diversity} = (1 - D).$$

$$\text{Simpson's Reciprocal Index} = (1/D).$$

Result and Discussion

Table 1: Spatial Diversity of fish Species composition in Lake Alau

Family	Species	Site 1 (% Org.)	Site 2 (% Org.)	Site 3 (% Org.)	Total (% Org.)
Cichlidae	<i>Coptodon zilli</i>	43 (26.22)	68 (41.46)	53 (32.32)	164 (4.82)
	<i>Oreochromis niloticus</i>	76 (25.17)	152 (50.33)	74 (24.50)	302 (8.88)
	<i>Hemichromis fesaetus</i>	94 (23.74)	160 (40.40)	142 (35.85)	396 (11.65)
	<i>Serothredon galilaeus</i>	111 (26.81)	123 (29.71)	180 (43.48)	414 (12.18)
Clariidae	<i>Clarias gariepinus</i>	71 (26.89)	91 (34.47)	102 (38.64)	264 (7.77)
	<i>Clarias angularis</i>	42 (33.87)	51 (41.13)	31 (25.00)	124 (3.65)
	<i>Hetrobranchus bidorsalis</i>	15 (19.23)	37 (47.44)	26 (33.33)	78 (2.29)
Mormyridae	<i>Hyperopisus bebe</i>	21 (28.38)	25 (32.43)	28 (37.84)	74 (2.18)
	<i>Marcusenius psittacus</i>	12 (17.39)	31 (44.93)	26 (37.68)	69 (2.03)
	<i>Mormyrus rume</i>	17 (22.08)	24 (31.17)	36 (46.75)	77 (2.27)
	<i>Mormyrus delicious</i>	8 (11.27)	21 (29.58)	42 (59.15)	71 (2.09)
Mochonkidae	<i>Synodontis nigrita</i>	21 (24.14)	25 (28.74)	41 (47.13)	87 (2.56)
	<i>Synodontis eupterus</i>	14 (24.14)	21 (36.21)	23 (39.66)	58 (1.71)
	<i>Synodontis filamentus</i>	7 (21.88)	11 (34.38)	14 (43.75)	32 (0.94)
Characidae	<i>Alestes nurse</i>	34 (26.36)	52 (40.31)	43 (33.33)	129 (3.80)
	<i>Alestes dentex</i>	23 (26.74)	38 (44.19)	25 (29.07)	86 (2.53)
Cyprinidae	<i>Labeo senegalensis</i>	27 (30.68)	32 (36.36)	29 (32.95)	88 (2.59)
Oestoglosidae	<i>Hetrosia niloticus</i>	49 (15.41)	98 (30.82)	171 (53.77)	318 (9.36)
Centropomidae	<i>Lates niloticus</i>	30 (23.08)	36 (27.69)	64 (49.23)	130 (3.82)
Bagridae	<i>Bagrus bayad</i>	42 (28.38)	71 (47.97)	35 (20.23)	148 (4.35)
Schilbeidae	<i>S. intermidius</i>	56 (32.37)	35 (20.23)	82 (47.40)	73 (5.09)
	<i>Schilbe mystus</i>	32 (27.35)	38 (32.48)	47 (40.17)	117 (3.44)
Total		845 (24.86)	1240 (36.48)	1314 (38.66)	3399

Cont. of Table: Shannon Weiner and Simpson Diversity Index of Fish Composition in Lake Alau

Shannon-Weiner Index $H = -\sum p_i \ln p_i$	2.85644	2.85249	2.83714
Evenness $E = H'/\ln H_{max}$	0.924102	0.922825	0.917859
Simpson Index $D = 1/(\sum p_i^2)$	0.932373	0.930329	0.927367

Table 2: Diversity of Fish Species about Month in Lake Alau

Family	Cichlidae	Clariidae	Mormyridae	Mochonkidae	Characidae	Cyprinidae	Oestoglocidae	Centropomidae	Bagradae	Schilbiidae	Total
January	92(7.21)	31(6.65)	26(6.93)	11(6.21)	15(6.98)	5(5.68)	16(5.03)	6(4.62)	10(6.76)	16(5.52)	228(6.71)
February	63(4.94)	18(3.86)	17(5.84)	15(8.47)	8(3.72)	3(3.41)	18(5.66)	9(6.92)	2(1.35)	13(4.48)	166(4.88)
March	71(5.56)	32(6.87)	9(3.09)	8(4.52)	12(5.58)	2(2.27)	22(6.92)	7(5.38)	13(8.78)	21(7.24)	197(5.80)
April	84(6.58)	34(7.30)	14(4.81)	12(6.78)	18(8.37)	8(9.09)	19(5.97)	8(6.15)	5(3.38)	14(4.83)	216(6.35)
May	61(4.78)	36(7.73)	21(7.22)	16(9.04)	7(3.26)	4(4.55)	21(6.60)	6(4.62)	9(6.08)	19(6.55)	200(5.88)
June	58(4.55)	21(4.51)	12(4.12)	9(5.08)	14(6.51)	3(3.41)	16(5.03)	9(6.92)	8(5.40)	16(5.52)	165(4.85)
July	62(4.86)	15(3.22)	15(5.15)	13(7.34)	15(6.98)	11(1.14)	20(6.29)	8(6.15)	12(8.11)	23(7.93)	184(5.41)
August	81(6.35)	19(4.08)	17(5.84)	6(3.39)	9(4.19)	6(6.82)	14(4.40)	6(4.62)	8(5.40)	12(4.14)	178(5.24)
September	70(5.49)	32(6.87)	15(5.15)	10(5.65)	7(3.26)	2(2.27)	17(5.35)	9(6.92)	5(3.38)	13(4.48)	180(5.30)
October	53(4.15)	28(6.01)	11(3.78)	13(7.34)	16(7.44)	5(5.68)	18(5.66)	10(7.69)	13(8.78)	14(4.83)	181(5.33)
November	107(8.39)	33(7.08)	14(4.81)	15(8.47)	12(5.58)	3(3.41)	15(4.72)	11(8.46)	15(10.14)	20(6.90)	245(7.21)
December	98(7.68)	35(7.51)	2(0.69)	9(5.08)	14(6.51)	7(7.95)	22(6.92)	7(5.38)	16(10.81)	12(4.14)	241(7.09)
January	56(4.39)	27(5.79)	18(6.19)	7(3.95)	5(2.33)	9(10.23)	17(5.35)	4(3.08)	5(3.58)	14(4.83)	162(4.77)
February	73(5.72)	17(3.65)	16(5.50)	4(2.26)	14(6.51)	6(6.82)	15(4.72)	9(6.92)	7(4.73)	19(5.55)	180(5.30)
March	39(3.06)	28(6.01)	13(4.47)	12(6.78)	13(6.05)	4(4.55)	23(7.23)	4(3.08)	6(4.05)	18(6.21)	160(4.71)
April	60(4.70)	23(4.94)	23(7.90)	6(3.39)	10(4.65)	9(10.23)	18(5.66)	6(4.62)	5(3.38)	25(8.62)	185(4.85)
May	82(6.43)	15(3.22)	14(4.81)	3(1.69)	11(5.12)	5(5.68)	15(4.72)	7(5.38)	3(2.03)	10(3.45)	165(4.85)
June	66(5.17)	22(4.72)	15(5.15)	8(4.52)	15(6.98)	6(6.82)	12(3.77)	4(3.08)	6(4.05)	12(4.14)	166(4.88)
Total	1276(37.54)	466(13.71)	291(8.56)	177(5.21)	215(6.35)	88(2.59)	318(9.36)	130(3.82)	148(4.35)	290(8.53)	3399

Table 3: Fish Species Composition According to Sites by Percentage

Sites	1		2		3	
Species	Comp by number	Comp by percentage (%)	Comp by number	Comp by percentage (%)	Comp by number	Comp by percentage (%)
Coptodon zilli	43	5.09	68	5.48	53	4.03
Oreochromis niloticus	76	8.99	152	12.26	74	5.63
Hemichromis fessatus	94	11.12	160	12.90	142	10.81
Sarotherodon galilaeus	111	13.14	123	9.92	180	13.70
Clarias gariepinus	71	8.40	91	7.34	102	7.76
Clarias angularis	42	4.97	51	4.11	31	2.36
Hetrobranchus bidorsalis	15	1.78	37	2.98	26	1.98
Hyperopisus bebe	21	2.49	25	2.02	28	2.13
Marcusenius psittacus	12	1.42	31	2.50	26	1.98
Mormyrus rume	17	2.01	24	1.94	36	2.74
mormyrus delicious	8	0.95	21	1.69	42	3.20
Synodontis nigrita	21	2.49	25	2.02	41	3.12
Synodontis eupterus	14	1.66	21	1.69	23	1.75
Synodontis filamentus	7	0.83	11	0.89	14	1.07
Alstes nuese	34	4.02	52	4.19	43	3.27
Alestes dentex	23	2.72	38	3.06	25	1.90
Labeo senegalensis	27	3.20	32	2.58	29	2.21

Heterosis niloticus	49	5.80	98	7.90	171	13.01
Lates niloticus	30	3.55	36	2.90	64	4.87
Bagrus bayad	42	4.97	71	5.73	35	2.66
Schilbe intermedius	56	6.63	35	2.82	82	6.24
Schilbe mystus	32	3.79	38	3.06	47	3.58
TOTAL	845		1240		1314	

Species Composition and Diversity of Fish in Lake Alau

The investigation into the species composition and diversity of fish in Lake Alau unequivocally demonstrated the presence of 3,399 fish, classified into 10 families and twenty-two species (Table 1). Notably, Cichlidae emerged as the preeminent family, accounting for 1,276 fish (37.54%), while Cyprinidae exhibited the lowest representation with 88 fish (2.59%).

In Table 2, you can find a detailed breakdown of the species makeup. It includes interesting information such as the high presence of *Serotherodon galilaeus* in the Cichlidae family. It also highlights the prevalence of *Clarias gariepinus* in the Clariidae family and *Mormyrus rume* in the Mormyridae family. The examination of distribution in different locations revealed varying compositions, with Site 3 showing the greatest diversity and richness compared to Sites 1 and 2. The highest number of sampled fish, 245 (7.21%), was recorded in November 2019, while the lowest, 160 fish (4.71%), was observed in March 2020 out of the total of 3,399 sampled during the study period.

The diversity of animals and their dominance, represented by the Shannon-Weiner Index (H), had values of 2.856, 2.852, and 2.837 for Sites 1, 2, and 3, respectively. The evenness of species (E) varied from 0.918 to 0.924, and the Simpson Index (D) varied from 0.927 to 0.932 across the sites. These values point to a well-established and balanced fish community in the lake.

The investigation of the makeup and variety of species is essential for comparing communities impacted by living disturbances and comprehending the development and stability of these communities (Olawusi-Peters and Ajibare, 2014). In Lake Alau, the diversity of species observed is remarkably high, with a total of 3,399 fish identified, representing ten families and twenty-two species. However, this count is lower than the 27 families reported in the Asejire dam study by Ipinmoroti (2013), the 25 families in the Oramiri-Ukwa river study by Adaka (2014), the 12 families in the Gbedikere Lake, Bassa, Kogi state study by Adeyemi et al. (2010), and the 18 families in the Geriyo lake study by Adedeji et al. (2017).

The analysis of the relative abundance revealed that Cichlids, specifically *Serotherodon galilaeus*, are the predominant species in Lake Alau, making up 37.54% of the observed fish. This discovery is consistent with previous research by Abubakar (2006) who noted cichlids (*O. niloticus*) as the most prevalent species in Lake Geriyo, underscoring their ability to adapt to diverse environmental conditions and their high reproductive capacity (Yongo et al., 2018). This adaptability likely contributes to the wide distribution of cichlids across all sampled sites and their abundance in Lake Alau.

The disparities in both the types and quantities of species present at different sites can be attributed to the unique environmental conditions of each location. Among the three sites, Site 3 stands out for its notably high diversity and abundance of species in comparison to Sites 1 and 2. This disparity is believed to be a result of human-induced factors, particularly the discharge

of wastewater, which has the potential to deteriorate the quality of water and consequently exert negative effects on the diversity of fish species (Mwamburi et al., 2020).

The measurement of biodiversity using the Shannon-Weiner diversity index yielded a value of 2.849, indicating a fair level of diversity among fish species in the study areas.

Additionally, the Simpson's index of diversity returned a value of 0.930, signifying a high level of diversity within the studied area. This index typically ranges from 0 to 1, with a higher value indicating a greater diversity of species. Furthermore, the index suggests the likelihood that any two randomly selected individual fish samples from the studied area will belong to different species.

Conclusion and Recommendation

The results highlight the importance of monitoring and managing water quality in Lake Alau to support its diverse fish population. Future research should prioritize long-term monitoring and strategies for reducing harmful impacts to preserve and improve the overall ecological health of the lake ecosystem.

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