ECOLOGICAL IMPLICATIONS OF FISH AND GEAR DIVERSITY IN SHIRORO DAM RESERVOIR, NIGER STATE, NIGERIA

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ABSTRACT
The natural biodiversity of the aquatic ecosystems in Nigeria has encountered changes in stock diversity and trophic composition due to fragmentation and overexploitation. These changes have resulted in the disappearance and dominance of species. This study was designed to assess the fish and gear diversity of the Shiroro Dam Reservoir (SDR) and provide empirical data for the management and sustainability of the natural fish resources. A structured questionnaire was used to obtain data on fishes and gears from selected/respondent fishers at the landing site monthly. Gillnets (Gn), Malian traps (Mt), and Cast nets (Cn) were the main gears identified in SDR. Each of Gn and Mt had a 33 % user preference against the 27 % for Cn. A higher percentage (60 %) of the fishers used gears following the state's allowable mesh size (5.0 - 9.99 cm) regulations. Collected fish samples comprised 20 species in 16 genera, 13 families, and 7- orders. Species diversity was generally low; 1-D: 0.11- 0.56. The guild composition: 27.20 % Herbivores, 21.59 % carnivores, and 51.20 % omnivores indicate trophic imbalance (low F/C ratio). Hence, the need to control the carnivore's population and introduce a Community-Based Fisheries Management Approach with cross-scale linkages.

Keywords: functional trophic diversity, ichthyofauna diversity, trophic guild, Diversity index, fish community structure, relative abundance

INTRODUCTION

The freshwater ecosystem represents the most significant repository of biological diversity on the planet (Schmidt-Kloiber *et al*., 2019; Manel *et al*., 2020). It provides enormous supports for a wide variety of fishes (Schmidt-Kloiber *et al*., 2019). As constituted by genetic, species, and ecosystem diversities, biodiversity is most abundant in the tropics. A functioning ecosystem with the right blend of biodiversity will provide such valuable services as regulative, supportive, and cultural services (Rawat and Agarwal, 2015).

Fragmentation by damming and fishing poses some existential threats to the fish community and their diversity in rivers today (Lestari *et al*., 2018; Jézéquel *et al*., 2020). Fishing activities are also responsible for changes in trophic guild (herbivore, carnivore, and omnivore) composition of the fish community. An exemplar occurrence was the Bureng River scenario, where a ratio: 1:55 of *Clarias batrachus* and *Poecilia reticulata* (predator to prey) was reported to have caused imbalances in both population sizes and fish trophic structure. Another was in Penjalin Reservoir, Central Java, with 87% composition of predators, leading to an imbalance in the fish community. These are proof that a disproportionately higher carnivorous fish population could ruin the food chain and drive to unstable ecosystems (Bumbeer *et al*., 2018; Lestari *et al*., 2018).

Unfortunately, most biodiversity studies are allegedly centred on taxonomic diversity instead of the more reliable ecosystem functioning predictors in functional diversity (Van der Plas, 2019). Therefore, the current study is necessary to assess fish gears, species, and guilds diversity and abundances in SDR. This work attempts to verify and /or update existing information on the socio-ecological status of the fishery and present useful metrics for sustainable exploitation and management of SDR.

MATERIALS AND METHODS

3.1 Study area

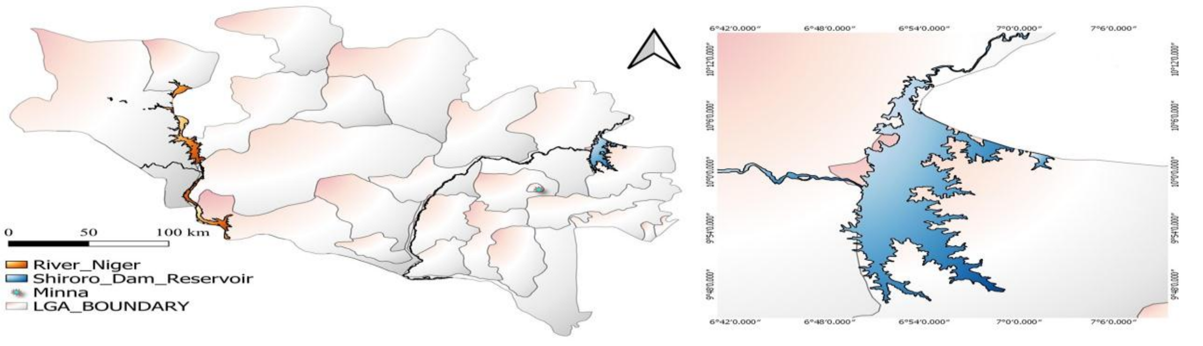

Figure 1: The study area, Shiroro Dam Reservoir inset Niger state

Shiroro reservoir (figure 1) was built in 1984 by damming the Kaduna River at Shiroro village. SDR (UTM: KR69) lies between latitude 9˚46′35″ and 10˚08′36″ North and longitude 6˚50′51″ and 6˚53′14″ East. The reservoir has an approximate surface area of 312km^2 and a mean depth of 22.4 meters. Shiroro Hydro-power reservoir, like many other recently created large artificial lakes in Nigeria and the tropics, was expected to supply special conditions for large scale fishing and fishery development. The dam's vegetation is a rockfill type and stands 115 meters high above the riverbed elevation (Usman and Ifabiy, 2012). The dam was to provide hydroelectric power to the nation. Kwata Zumba landing site located North West of SDR has an open space with scattered grasses where the fisherfolks position their canoes before and after fishing.

Sampling, identification, and classification of fishes

A structured questionnaire was administered to fifteen randomly selected fishers or fishing groups (respondents) from the Kwata Zumba landing site of SDR from June - August 2018. Fishing gears in SDR were identified and their mesh sizes with the aid of a meter ruler. Sampling was undertaken twice in each of the three months of data collection. Catches were sorted according to species, gear, and counted. FishBase and other literary works were used as a reference point for the needed information to identify fish species and their categorization to respective families and trophic guilds (Olaosebikan and Raji, 2013; FishBase, 2020).

Calculation of Biodiversity Indices

The researcher relied on the online biodiversity calculator using the link below to quantify both taxonomic and functional trophic diversity of fishes in SDR.

RESULTS

Gear types and mesh size distribution in SDR

Figure 2 represents the three main fishing gear types (Gn, Cn, and Mt) in SDR. Gn and Mt (33 % each) were the dominant gears relative to Cn (27 %).

The mesh size distribution revealed that 60 % of the SDR gears had mesh sizes ranging from 5.0 - 9.9 cm, while 40 % ranged from 1.0 to 4.9 cm. Mt: 1.0 - 4.9 cm was the most prevalent (33 %) distantly followed by Cn: 1.0 - 4.9 (7 %), whereas Gn: 1.0 - 4.9 cm had no record of existence. In the 5.0 - 9.9 cm category, the order was Gn: 5.0 -9.9 cm (33 %) followed by Cn: 5.0 - 9.9 cm (27 %) while Mt: 5.0 – 9.9 cm has no record.

Fish community structure in SDR

Table 1 presents fish families and their respective species identified in SDR. This study sampled 4,650 fishes belonging to 20 species, 16 genera, 13 families, and seven (7) orders. The family Mormyridae predominated the ichthyofauna with three-species composite. Each of the other families, such as the Alestidae, Cichlidae, Clariidae, Claroteidae, and Mochokidae, had two representative species. In contrast, the rest six families were each represented by one extant taxon.

The relative abundances of fish (families) in figure 3 revealed that the Cichlidae (28 %), Mormyridae (20 %), and Clariidae (18.35 %) were the overarching taxa. The ichthyofauna also included Mochokidae (9 %), Centropomidae (9 %), Alestidae (6 %), and Distichodontidae (0.2 %) families.

Figure 4 characterizes the guild/trophic guild (TG) composition of the fish community in SDR. The three TG identified were omnivores, carnivores, and herbivores. The omnivores (51 %), comprising seven distinct families, are conspicuously the most abundant. The herbivores with a single-family (27 %), and the carnivores, having five families (22 %) were the other cohabiting guilds that constituted the fish community.

Ichthyofauna diversity in SDR

Generally, Simpson's index of fishes in TDR indicated a strong correlation with the overall pattern of species richness and evenness in figure 5. There was a strong correlational effect of species richness and evenness on species diversity as indicated by the 1-D values of the Mormyridae (1-D = 0.56, S = 0.29 and E = 0.82) and the Claroteidae (1-D = 0.51, S = 0.21 and E = 0.99). In contrast to evenness, species richness was generally low for all fish families. In the current study, the least diversity index was in the Clariidae (1-D = 0.11) and the highest in Mormyridae (1-D = 0.56). The Alestidae (1-D = 0.28), Cichlidae (1-D = 0.39), Mochokidae (1-D = 0.44) and Claroteidae (1-D = 0.51) ranged between the Mormyridae and Cichlidae, respectively.

Shannon index (H = 0.22 - 0.91) including the diversity components: richness (S = 0.14 - 0.29) and Evenness (E = 0.31 - 0.99) showed variability amongst the various groups of fishes. Moreover, the Centropodmidae, Characidae, Schilebeidae, Malapteruridae, Bagridae, Osteoglossidae, and Distichodontidae, representing nearly 54 % of the fish families, were not diverse due to their single-species representation. Conversely, the remaining 46 % represented the diverse groups.

Figure 6 is the functional trophic diversity (FTD) of fishes in SDR. The carnivores (1-D = 0.72) surpassed the omnivores (1-D = 0.68) and herbivores (1-D = 0.39) in diversity. Evenness was not complete, but generally high, with the lowest value E = 0.63 (omnivores). Conversely, richness (S = 0.14) was not as good.

Table 1: Community structure of fishes in SDR

Order (nO)	Family (nF)	Genera	Species	Sample size
Osteoglossiformes (2)	Mormyridae (3)	*Mormyrus*	*deliciosus*	521
		Mormyrus	*macrophthalmus*	80
		Mormyrus	*rume*	374
	Osteoglossidae (1)	*Heterotis*	*niloticus*	14
Cichliformes (1)	Cichlidae (2)	*Oreochromis*	*niloticus*	937
		Tilapia	*zillii*	328
Siluriformes (6)	Clariidae (2)	*Clarias*	*gariepinus*	796
		Heterobranchus	*longifilis*	49
	Claroteidae (2)	*Auchenoglanis*	*occidentalis*	55
		Chrysichthys	*nigrodigitatus*	49
	Mochokidae (2)	*Synodontis*	*budgetti*	281
		Synodontis	*fascipinna*	132
	Bagridae (1)	*Bagrus*	*docmac*	30
	Malapteruridae (1)	*Malapterurus*	*electricus*	61
	Schilbeidae (1)	*Schilbe*	*mystus*	73
Characiformes (3)	Characidae (1)	*Hydrocynus*	*forskahlii*	187
	Distichodontidae (1)	*Distichodus*	*rostratus*	8
	Alestidae (2)	*Alestes*	*nurse*	47
		Alestes	*baremoze*	234
Perciformes (1)	Centropomidae (1)	*Lates*	*niloticus*	394
Total 5	13	16	20	4650

nO = number of Order, **nF** = number of Families

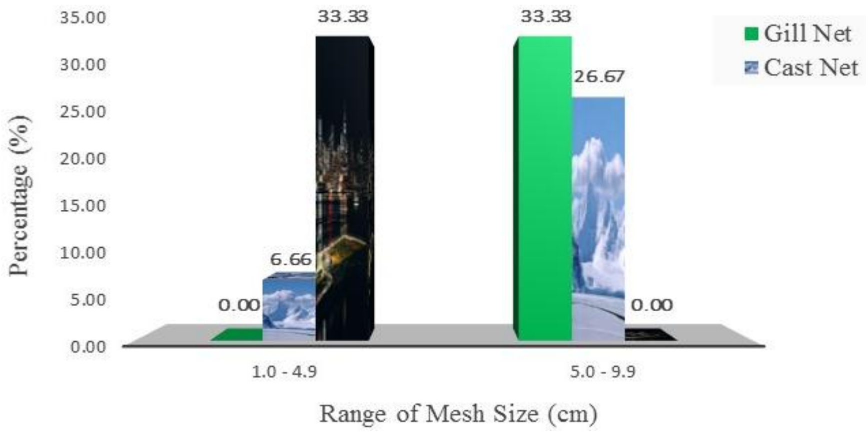

Figure 2: The type and mesh size distribution of fishing gears in SDR

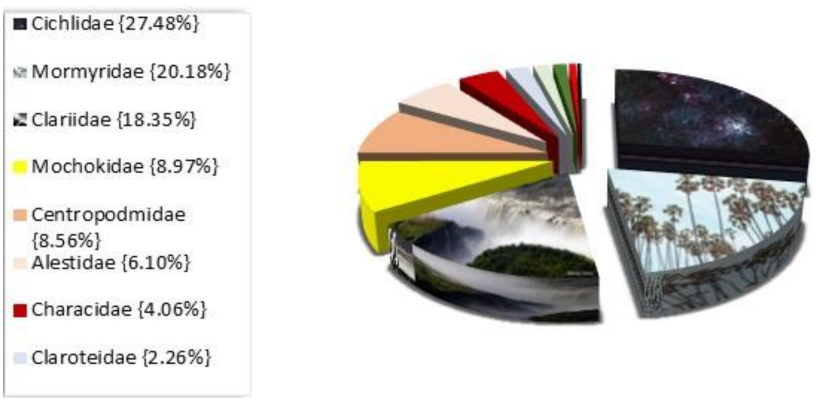

Figure 3: Relative abundance of fishes (family) in SDR

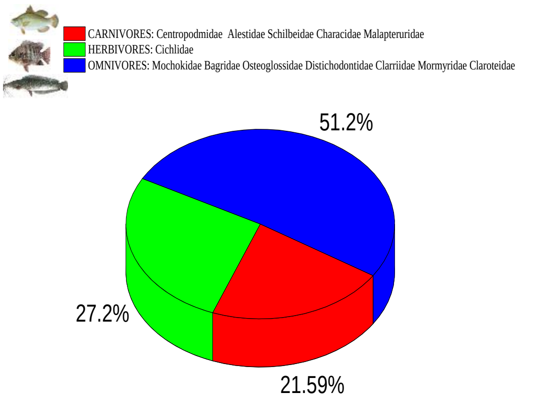

Figure 4: Guild composition of the fish community in SDR

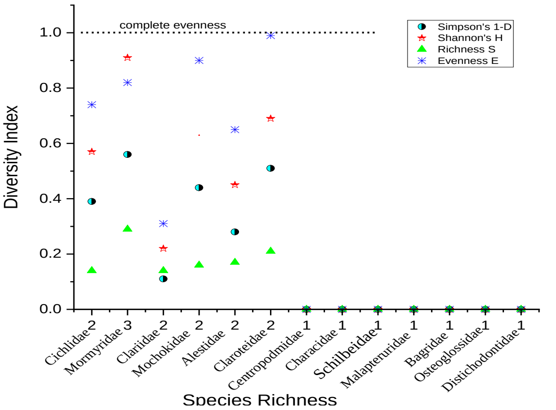

Figure 5: Species diversity of Fishes in SDR

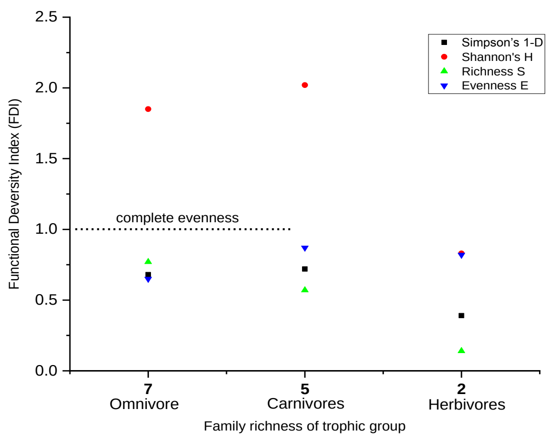

Figure 6: Functional trophic diversity of fishes in SDR

DISCUSSION

Shiroro Dam reservoir is a refuge for nearly 8 % of the 268 freshwater fishes identified in Nigeria (Ejikeme Odo *et al*., 2009). The three fishing gears (Gn, Cn, and Mt) in SDR represent roughly 11 % of gear types in the country's inland fisheries (Ogundiwin, 2014). Gn, Cn, and Mt fisheries went beyond SDR as Bonjoru *et al*. (2019), and many other studies have reported occurrences of these gear types in other inland water bodies around the country.

Fishers in SDR are more inclined to fishing with Gn and Mt. Gear preferences are likely due to gear applicability to all depths and water sites. Besides, the suitability of Mt for fishing at the shoreline and rough bottoms is next to none (Ogundiwin, 2014). The passive nature of the Gn and Mt minimizes labour and time. Hence, their suitability for part-time fishing allows fishers' indulgence in other commercial activities.

The current study ranked Gn with Mt on a par. Nonetheless, it validates Ogundiwin (2014) in ranking the gill net as the top fishing gear in Nigerian's artisanal fisheries due to its cost-effectiveness and high fishing power.

Gn and Cn's use in SDR based on data collected for this study conforms with the minimum mesh size (5.0 cm) recommendation of the Niger State (1997) Fishery edicts threshold for netting gears. The edict criminalised the use of mesh sizes below the minimum threshold and considered the act as dangerous to the productivity of artisanal fisheries. The proclamation was intended to minimize juvenile and premature fishes' capture to enhance fish productivity and ensure the sustainability of yields.

SDR exhibited similarity with other African reservoirs/lakes such as Kainji, Tiga, and Bakolori in the preponderance of the Cichlids (Ipinmoroti *et al*., 2017; Abobi and Wolff, 2019). This study gives further credibility to the Cichlids' reported dominance in tropical freshwaters (Balogun, 2005; Mshelia *et al*., 2015). Besides, the Cichlidae taxonomic group is known for reproductive exploits, which ensure their proliferation in most African reservoirs/lakes despite the absence of regulated exploitation (Ogundiwin, 2014).

Species diversity was generally low and widely varied amongst fishes in SDR (1-D and H). Reduced fish diversity may be associated with factors such as overexploitation, effects of richness, relative abundances of species. The current argument derives support from Rodriguez *et al*. (2016), Wang *et al*. (2018), suggesting that species diversity increases with richness and relative abundances of component species in a community.

The functional trophic diversity of fishes in SDR indicated an ecosystem favourably disposed to the predatory species. Ironically, as the most diverse (1-D and H) group in SDR, the carnivores were the least abundant. From an empirical viewpoint, diversity index is partly a function of interacting richness and relative abundances (evenness) of the component fishes (Rodriguez *et al*., 2016; Wang *et al*., 2018).

The dominance of the Cichlidae family in SDR has a potential effect on stabilizing the shorelines ecosystem (Balogun, 2005). The guild composition of 27 % Herbivores, 22 % carnivores, and 51 % omnivores, as well as a forage/carnivores (F/C) ratio of 1265:1004, is considered far too low, considering the proportions reports of previous studies on Kangimi reservoir, Opa reservoir and other freshwater bodies (Balogun, 2005; Taiwo *et al*., 2018; Lestari *et al.*, 2018). The trophic dynamics implication of a disproportionately low F/C ratio is a harbinger of ecosystem instability (Lestari *et al.*, 2018). Thus, a call for adequate management of SDR.

An efficient fisheries conservation and management in SDR must control the predatory species populations to stabilize F/C balance and rebuild the herbivore's species (Lestari *et al.*, 2018). Appropriate monitoring, control, and surveillance (MCS) of fishing related activities are necessary for successful conservation fishery (Cremers *et al*., 2020). For greater efficiency, MCS should take the form of a Community-based Fisheries Management Approach (CBFMA) with cross-scale linkages (Cudney-Bueno and Basurto, 2009). MCS management systems with no cross-scale connections have temporary success. Fishers and fishing communities will maintain their management efforts when rewarded locally with formal cross-scale governance recognition and support. Rule compliance achieved by way of social pressures rather than heavy policing by external officials has better efficiency (Cudney-Bueno and Basurto, 2009).

CONCLUSION

This study reveals that, in SDR, the cichlids and omnivores are the most abundant fish family and trophic group, respectively. Fish diversity was generally low at the species level with the cichlids as the least. The balance of the primary to secondary consumers (F/C ratio) of the fish community was equally low, indicating trophic imbalance instituted by poor management. Hence, the selective control of the carnivore's population and the need for a Community-Based Fisheries Management Approach with cross-scale linkages has become essential.

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