



Fish Diversity and Abundance Using Statistical Modelling in Hadejia-Nguru Wetlands (HNWs), Nigeria: An Adaptive Environmental Assessment

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Authors' contributions

This work was carried out in collaboration among all authors. Authors JG and NMA carried out the field and performed the statistical analyses. Authors YAY and AA designed the first draft of the manuscript. Author JG create study area map and supervised the entire work. All authors read and approved the final manuscript.

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ABSTRACT

Fisheries and aquaculture plays a significant role in the Nigerian economy by providing employment, diversifying livelihoods, providing animal nutrition, and earning returns on foreign exchange. Fish is an important economic factor for many nations, as serves as a staple diet in many countries. As evident, in many developed nations, fishing is a crucial source of livelihood, particularly for low-income families in rural areas, where it offer local jobs in many communities and is a key source of food for millions. Over the past few decades, fish populations have deteriorated dramatically, and species at risk have experienced growing environmental challenges. Dams, overfishing, pollution, erosion, soil loss and other human activities are main threats to fisheries ecology. The presents study aimed to analyze the decline in diversity of the fish, adaptive management of artisanal fishermen in the wetlands of Hadejia-Nguru, Guri local government area

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of Jigawa State and to explore the correlation of environmental factors for the decline in fish diversity. In this study the data were collected through questionnaire interview (QI), focus group conversation (FGD), and field data collection (FDC), and the test objectives were accomplished via the analysis workflow. Geostatistical software was used to analyze the information obtained from QI, FGD and other sources while other auxiliary data and field data were collected using GPS receiver. The research findings can be considered as a tools for decision-making, policy-making, management plan development, fish conservation strategies plan and ultimately help to achieve the UN's Sustainable Development Goals (SDGs) 1, 2, 8, 14 and 15 of the 2030 agenda.

Keywords: Fish; biodiversity; decline; adaptive management; wetlands.

1. INTRODUCTION

Wetlands have an enormous significance for both human and animal life; such as for scientific operations, water management, resource-rich, nitrogen depletion and others. Anthropogenic behavior and effects on climate change have gradually disrupted the natural cycle [1]. Worldwide, about 1,280 million hectares are covered by wetlands. Sadly about 50 percent of the world's wetlands are destroyed due to human activity and climate change. Additionally, wetlands provide humans with good and valuable resources, including fish, wildlife, mining, electricity and recreation [2]. Wetlands play an instrumental role by serving as a transition zone with varying water regimes and acting as natural filters which can improve water quality by reducing water aquifer nutrient loads, often referred to as 'catchment kidneys' due to their rich food webs and biodiversity [3], [4]. On the other hand, wetlands provide multiple multi-dimensional services within their environment, such as water purification, supporting natural resources that provide essential human and animal resources. Wetlands also offer multi-functions such as flood control, and water pollution, waste water treatment, farming activities and providing fishing ground sites with opportunities for fishing and sailing events [1], [5]. Wetlands offer people residing inside and around the buffer zone a chance to improve their livelihood [6].

Nigeria's natural resources are exceptional in providing freshwater and marine coastal wetlands. The freshwater wetlands are the Imo River, Lake Chad, Ogun-Osun River, Niger Delta River, Niger River, and Benue River, while the Cross River Estuary, Imo River, Qua Iboec River Estuary, and Niger River Estuary are the coastal saline wetlands [7], [8]. Such aquatic ecosystems which carry vast amounts of water have been transformed into a residence for various fishery-related activities [9]. This opportunistic behavior of fishermen is also relevant provided the

capacity of fishermen to adapt and monitor their susceptibility to fishing displacement [10]. It is common for fishermen to adapt by adjusting the relevant social ecological systems to take advantage of new emerge technological approaches or mitigate these vulnerabilities [11]. In developed countries a significant amount of these approaches will be applied at local, since livelihoods are the decisions and behavior that people take to cope up with insecurity and adapt to new opportunities [10,12][13]. Fishing is an important source of livelihood for the local communities living in and around the wetlands in particular. Co-management approaches have proliferated across the world to improve the fisheries' condition and maximize their contribution to human wellbeing [8,14]. Ninety per cent of the world's fishermen are specifically involved in small-scale farming, i.e. around 34 million people, and another 100 million are interested in similar activities [15]. Nevertheless, the fishery faces growing threats such as overfishing, commercial vessel competition, water pollution, extinction of fish stocks, and increasing human development and land demand in coastal areas [16]. Increasing fishing pressure results in a reduction in marine biodiversity, which over time will make fisheries less resilient in a changing global climate [17].

On the other side, major threats to the initial fish ecosystems are linked to the development of the hydroelectric power plant in most of the downstream and upstream regions, such as river sand mining, land use change and cage aquaculture activity, which may affect the depth of river water , food source and spawning sites [18,19].

2. MATERIALS AND METHODS

2.1 Study Area

The study area is Guri Local Government Area of Jigawa State, Nigeria. It is geographically located within latitude 12° 45'30" North of the equator

and longitude 10°38'00" East of the green winch meridian. Guri local government is at the middle of Hadejia Nguru wetland. Its relative location from Dutse the Jigawa State capital is northeast of about 162 km by road. It is therefore bordered to the North and East by Yobe State and South by Bauchi State, and west by Birniwa and Kiri-Kasamma. It has an area of 1,060 km² and a population of 115,018 at the 2006 census. Fig. 1 show the study area map.

2.2 Methodology

Questionnaire was used in collection of data from the artisanal fishermen in the selected villages. The questionnaire was done at homestead, during fishing in the river and market places depending on the presence of the fishermen and who cooperated and responded to the questions

being asked. Thus, in-depth interviews were used to produce data that complements the survey and is more useful in addressing some of the goals. Accordingly, based on this report, fifty (50) artisanal fishermen were selected and interviewed from selected villages with fishing grounds sites using purposive sampling techniques. Data obtained from all questionnaires, in-depth interviews and field studies were compiled, coded and processed for descriptive analysis using Microsoft Office Excel and the Statistical Package for Social Scientists (SPSS) in order to provide an overview of the frequency of cases contained in the different categories of variables. Details on the various categories was provided in the form of table and bar charts. Although qualitative data obtained from in-depth interviews have been compiled using a thematic framework analysis approach.

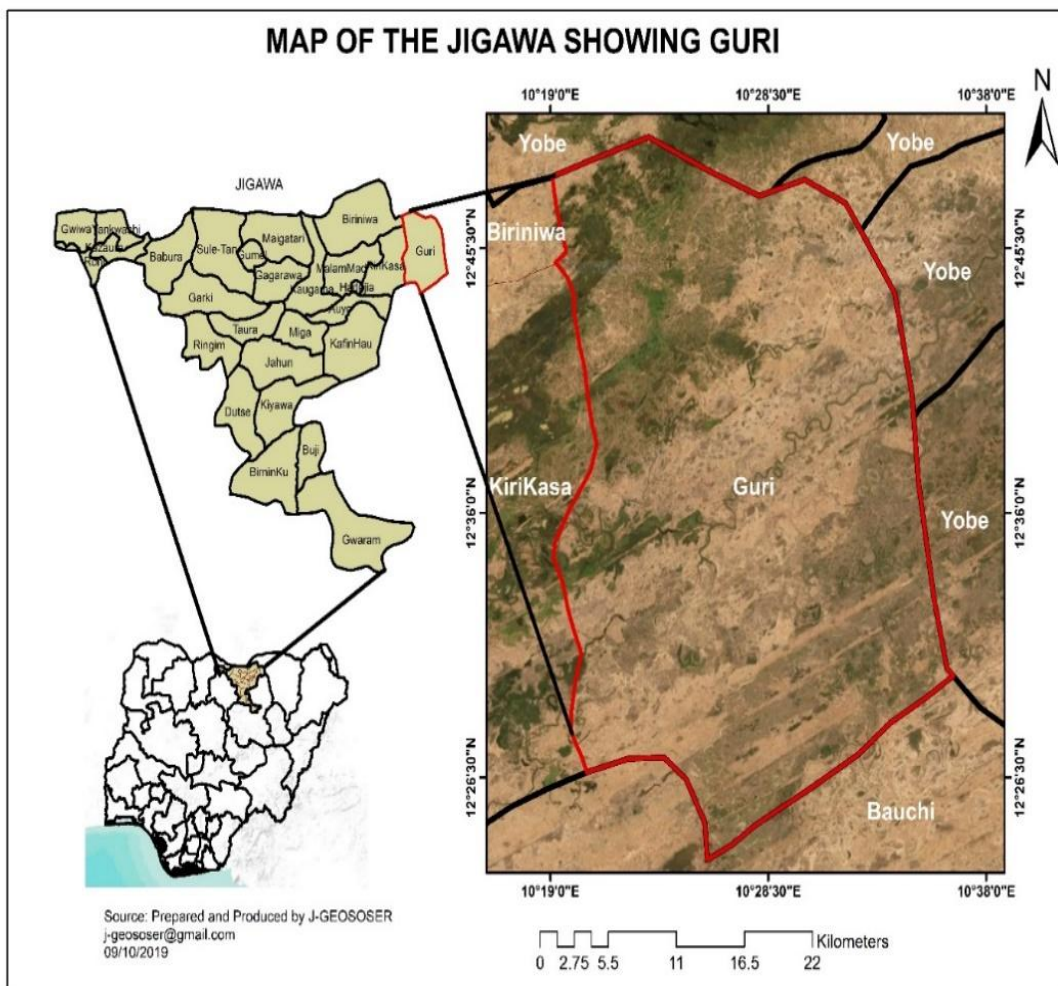


Fig. 1. Study area map

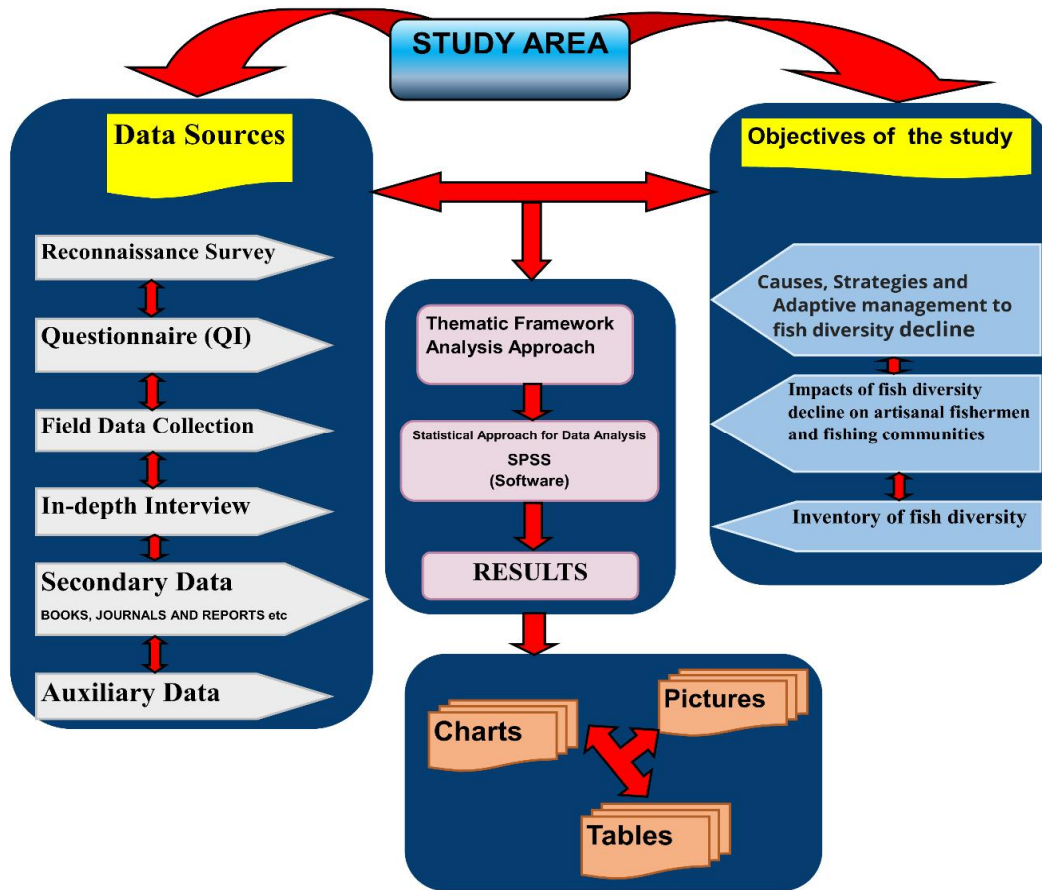


Fig. 2. Study workflow

3. RESULTS AND DISCUSSION

3.1 Results

The result from the Fig. 3a, indicates that, the category (M) consist of the fish species such as; *Alestes leuciscus*, *Brycinusleuciscus*, *Petrocephalus bovei*, where about 69.8% of fishermen stated as the kind of fish species that are rare to catch frequently, whenever fished at respective fishing grounds. While the category (N) consists of the fish species such as; *Mormyrus tapirus*, *Mormyrus rume*., Therefore, from the finding of this research, the reason for availability of such fish species in the study area, is because they are the dominant fish species due their nature of growing rapidly. In Fig. 3: C, indicated category O; aquatic vegetation, overfishing, use of bad fishing methods, use of bad fishing gears, water level fluctuation and water depth reduction are main reasons for fish decline. Whereas the category P means; night

fishing and sand mining as indicated in figure below.

Category Q means; fish species as *Parailia pellucide*, *Pollimyrus isidori*, *Distichodus rostratus*, *Bagrus bajad*. While Category R means; fish species as *Hydrocynus vittatus lineatus*, *Brycinusleuciscus*. The category (R) consists of the fish species such as; *Hydrocynus vittatus lineatus*, *Brycinusleuciscus*, where about 31.3% of fishermen revealed as the kind of fish species that are moderately available whenever fished at various fishing grounds Therefore, from the result it indicates that, the categories (Q and R) are fish species that are rarely available in this study area.

In Fig. 5: shown different fishermen adopted alternative livelihood as one of the adaptive management to fish diversity decline. Therefore, finding of this research shows that, to prevent the declining trend of fish biodiversity in the study

area, the fishermen adopt to develop alternative livelihood such as downstream activities (farming) and other allied activities (artisanal skill) in order to substitute the fishing activities that are negatively impacting fish biodiversity resources in the study area. However, some alternative livelihood adopted by fishermen as adaptive management to fishing diversity decline in the study area. In Fig. 4: Category S means; clearance of aquatic vegetation, alternative livelihood, restriction on night fishing and use of best fishing gears. While Category T means; use of best fishing methods. In Category I means; limit on the number of nets, days and areas of fishing, ban of destructive fishing gears, and restriction on night fishing and reduction on exploitation rate. While Category J means; seizure of bad fishing gears, reduction on sand mining and fishing of immature fish.

The mean differences of all correlated analysis indicated the significant relationship based on statistical modelling.

3.2 Discussion

3.2.1 Fisheries management and participatory; A community-based

The participatory model of management requires relationships between the resource providers and consumers. Building such partnerships has never been easy, however, it requires fishermen who are well-organized enough to carry out such a partnership, it requires appropriate community-based institutions. It also requires the government to have an appropriate policy environment and willingness to engage in participatory management. It also requires appropriate government institutions to interact

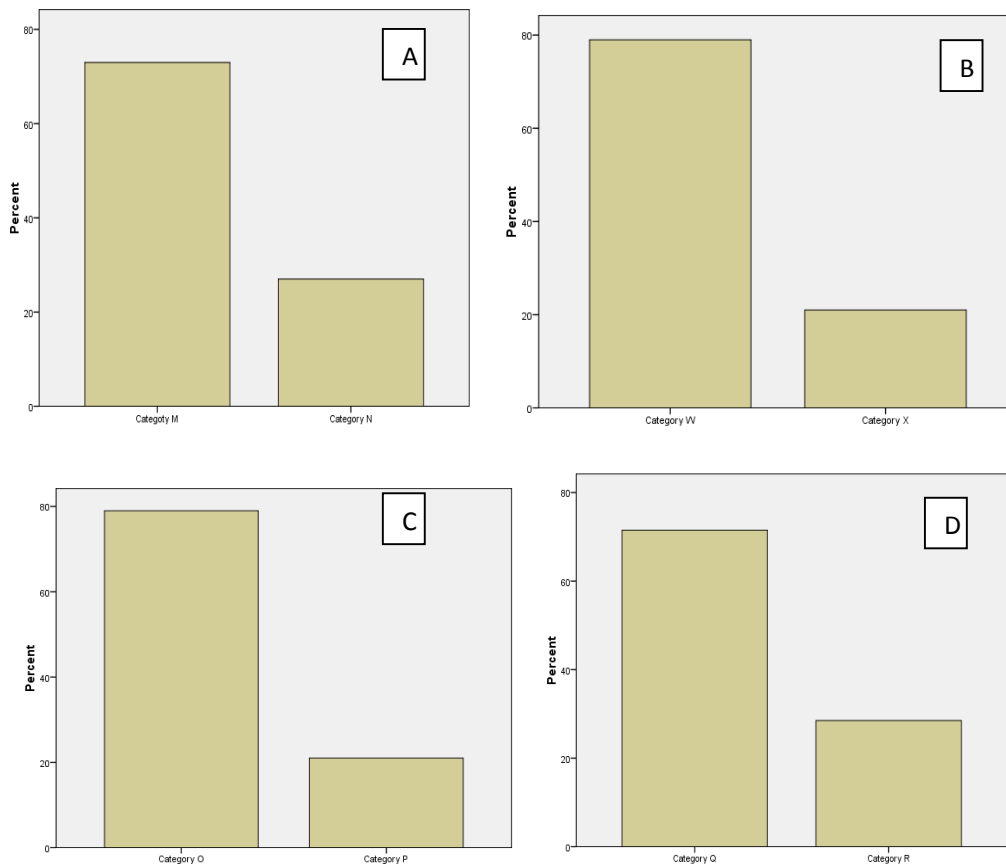


Fig. 3. Note; A: Common fish species do catch frequently. B: The impacts of fish diversity decline to artisanal fishermen and fishing communities (Multiple Answers). C: Fish species are more decrease in population. D: Fish species are more increase in population (multiple answers)

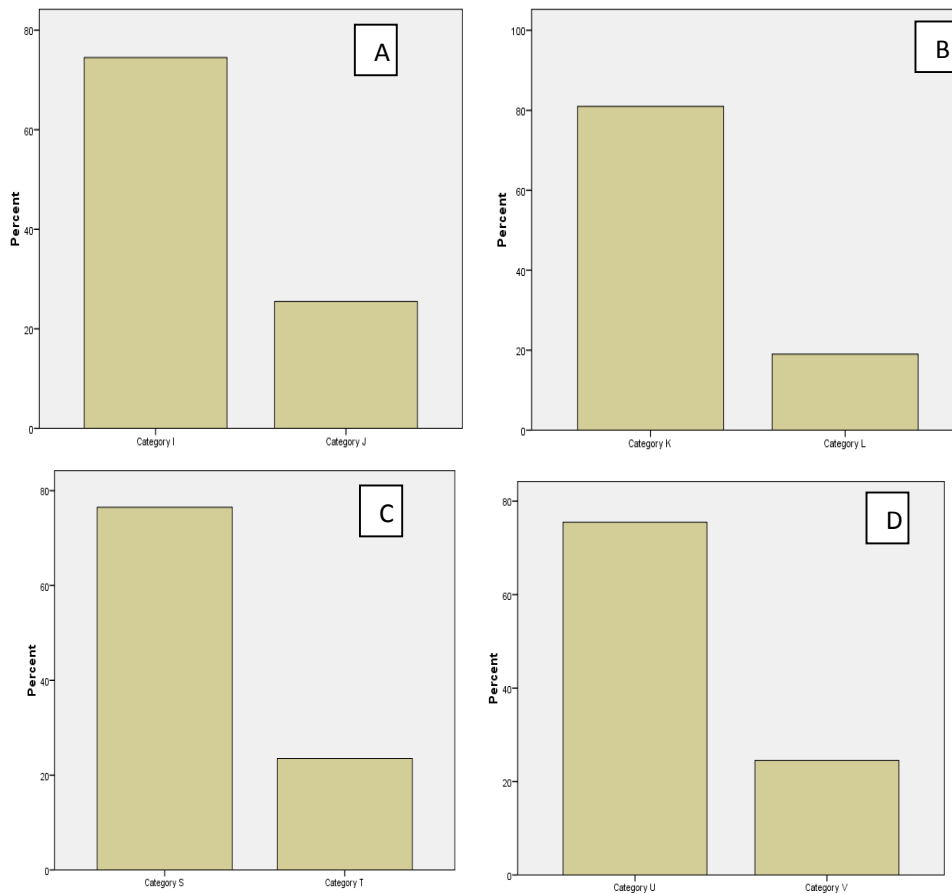


Fig. 4. Note: A; the main fishing gears use in fishing. B; Fishing gears when use affect fish diversity. C; Adaptive management to fish diversity decline that can be established in fishing communities (Multiple Answers). D; Adaptive strategies of fishermen to fish diversity decline (multiple answers)

with fisheries organizations [20]. Fisheries co-management through the collaboration of government agencies and community-based institutions would not even have been the subject of discussion until the 1980s. The prevailing thinking in management was that fishermen were unable to self-regulate. Nevertheless, it was generally assumed that the best way to prevent a catastrophe was for policy control authorities to impose numerous restrictions on fishers [21].

The shared property management literature has demonstrated that consumer groups do not need laws from central policy to render and implement easy and functional management-use schemes. Some of the main conditions for community-based management are fairly well known, key findings from commons research suggest that resource managers can deal with users as part of the solution, rather than as part of the problem

[19]. It does not mean that the role of managers is over, but does mean that the position of managers has shifted its essence. The fishery managers need to know something about participatory processes and local institutions, institution-building is central to fishery management as part of the larger capacity-building issue. The role of fishermen and fishery communities in the management process relies on the existence of self-organizing ability to establish and enforce local rules. Not all fishing societies have the capacity to control themselves, others have patterns of collective organization and decision taking over autonomous resource management. We will have their own fields of resource management and a code of behavior scheme. Collective self-organization does not come easily for certain circumstances, though, and efforts are required to unite and establish organizations [19].

Capacity building in the Society is widely recognized as one of the main components of resource management in small-scale fisheries. This aligns with the belief in a free society that no longer regards the people as objects. It is part of a trend that emphasizes horizontal processes in all areas of resource management and applied ecology, from fishing to forests and protected areas, such as cooperation, partnership and community empowerment [20].

According to [1], in protection the interest of the community, the main objective of Community-Based Fisheries Management Systems are:

- i. Individuals within the community have access to the resource but cannot sell or dispose part or whole of the fishing ground temporarily or permanently.
- ii. The village head and council of elders make decisions on behalf of the group and such decisions are communicated to the people.
- iii. The system is effective where population density is low and there is little internal and

- iv. external pressure on the resource.
- iv. Access to resources, harvesting and consumption of fish are subject to socially determined regulations and form part of resource management and allocation.
- v. Traditional authorities control entrance into the fishing grounds, e.g. during fishing festivals. Seasonal closures, acceptable gear and other regulations are set by traditional authority based on experience.
- vi. Traditional authorities have no licensing systems but fisheries management regulations are rooted in the social concept of resource-sharing, allowing every member to benefit from available resources.
- vii. Sanctions include fines, seizure of gears and social sanctions.
- viii. Supernatural' beings are often believed to set rules for resource utilization and enforce rules.

Causes of Declining Fish Stocks

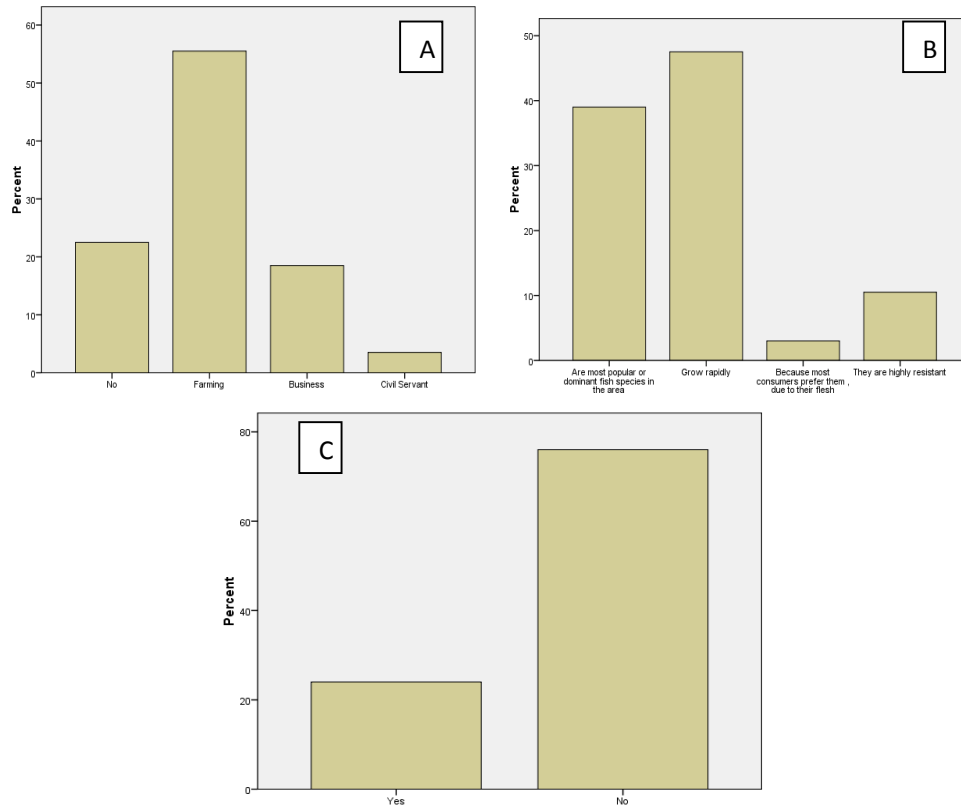


Fig. 5. A; other job available apart from fishing. B; Reasons for catching such type of fish species. C; Decline in fish diversity create misunderstanding among the fishermen

Table 1. Link between seldom exploited fish species and artisanal fishermen's tactics for a reduction in fish diversity

One-Sample Test				
	t	df	Sig. (2-tailed)	Mean Difference
Any other job apart from fishing	38.645	199	.000	2.030
What are the main fishing gears use in fishing	40.618	199	.000	1.255
Which forms of Adaptive management to fish diversity decline that can be established in fishing communities (Multiple Answers)	41.089	199	.000	1.235
What are the adaptive strategies of fishermen to fish diversity decline (Multiple Answers)	40.836	199	.000	1.245

Table 2. Correlation between Adaptive management to fish diversity decline that can be established in fishing communities and other job apart from fishing

Correlations			
		Which forms of Adaptive management to fish diversity decline that can be established in fishing communities (Multiple Answers)	Any other job apart from fishing
Which forms of Adaptive management to fish diversity decline that can be established in fishing communities (Multiple Answers)	Pearson Correlation	1	.041
	Sig. (2-tailed)		.562
	N	200	200
Any other job apart from fishing	Pearson Correlation	.041	1
	Sig. (2-tailed)	.562	
	N	200	200

Table 3. Correlation between the adaptive management to fish diversity decline that can be established in fishing communities and adaptive strategies of fishermen to fish diversity decline

Correlations		Which forms of Adaptive management to fish diversity decline that can be established in fishing communities (Multiple Answers)	What are the adaptive strategies of fishermen to fish diversity decline (Multiple Answers)
Which forms of Adaptive management to fish diversity decline that can be established in fishing communities (Multiple Answers)	Pearson Correlation	1	.781**
	Sig. (2-tailed)		.000
	N	200	200
What are the adaptive strategies of fishermen to fish diversity decline (Multiple Answers)	Pearson Correlation	.781**	1
	Sig. (2-tailed)	.000	
	N	200	200

One-Sample Test				
	t	df	Sig. (2-tailed)	Mean Difference
What best describe your understanding of the term fishing diversity decline	43.939	199	.000	1.170
Have you noticed any changes in fish diversity	55.476	199	.000	1.960
How long are the changes in fish diversity	28.303	199	.000	2.580
How would you rate the noticed the changes in fish diversity declined	23.835	199	.000	2.235
What are the causes of fish diversity decline	40.215	199	.000	1.280
Do you feel human actions on the environment fish diversity	40.760	199	.000	2.065
Which are the fishing gears when use affect fish diversity	42.791	199	.000	1.190

Table 4. Correlation between understandings of the term fishing diversity decline and noticed any changes in fish diversity

Correlations		What best describe your understanding of the term fishing diversity decline	Have you noticed any changes in fish diversity
What best describe your understanding of the term fishing diversity decline	Pearson Correlation	1	-.097
	Sig. (2-tailed)		.171
	N	200	200
Have you noticed any changes in fish diversity	Pearson Correlation	-.097	1
	Sig. (2-tailed)	.171	
	N	200	200

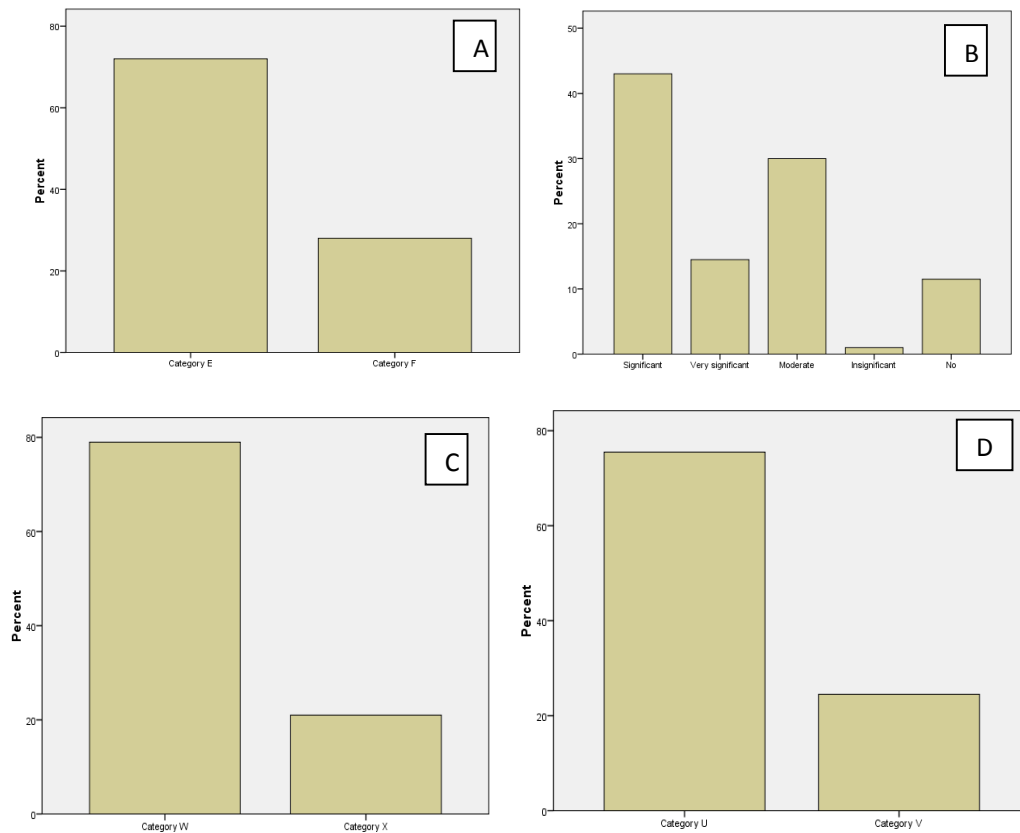


Fig. 6. A; B; C; D; Causes of fish diversity decline

According to, [22,23], the followings are some of the causes of declining fish stocks

- i. Overfishing or overharvesting: The rate of fishing is greater than the ability of the stock to replenish or replace itself.
- ii. Habitat loss or destruction e.g. deforestation, sand filling of wetlands, swamps, mangrove forests for construction purposes and destruction of coral reefs by dynamite fishing.
- iii. Habitat fragmentation: is a form of habitat destruction involving the removal or modification of the original habitat leaving only patches. It causes degeneration of biodiversity, disruption of life cycles, and isolation of some fish species in islands of habitats.
- iv. Introduction of species create major problems such as predation, uncontrolled breeding because of lack of natural checks and balances, disruption of food chains, competition for space, nutrition, mineral resources and changes in ecosystems.
- v. Pollution (oil, industrial, etc.) of coastal areas and wetlands lowers habitat quality. Excessive release of chemicals over extended periods will poison habitats and spread out into food chains, cause loss of the aesthetic values of beaches due to unsightly oil slicks, damage to marine life, ecosystem changes due to species mortality and changes in food chains and decrease in fishery resources.
- vi. Trawling for fish disturbs the benthos.
- vii. Human population pressure.
- viii. Poor agricultural practices, e.g. destruction of watersheds, clearing of river banks and other critical areas cause silting of river beds and loss of water courses, excessive use of agrochemicals cause problems of chemical persistence in the soil.

3.2.2 Causes of fish diversity decline

This section presents the causes of the decline in fish diversity in the study area, and are divided into two factors: natural or ecological factors and

human or anthropogenic factors. Nature causes environmental or biological influences such as: marine plants, water level fluctuation and water depth loss, while human or anthropogenic influences are caused by; overfishing, use of poor farming techniques, use of poor fishing equipment, sand mining and night fishing. Thus, from the Fig. 6., group E stands for; aquatic vegetation, overfishing, use of bad fishing techniques, use of bad fishing equipment, water level fluctuation and water depth reduction, where approximately 69.7 per cent of fishermen reported a decrease in the sample region as the causes of fish abundance. While type F stands for; night fishing and sand extraction, where nearly 30.3 per cent of fishermen reported a reduction in the research field as the causes of fish diversity. Therefore, it has been seen from the result that both categories (E and F) are triggers of declining fish diversity in the study region, which is consistent with findings from [24] on the function of economic activities on declining fish biodiversity in Hakaluki Haor, Bangladesh 's largest inland freshwater ecosystem. The Fig. 6 showed the percentage of fishermen base in the study area on the causes of the decline in fish diversity.

- Marine Plants
- To overfish
- Application of poor farming methods
- Application of weak gears in fishing
- Fluctuations in water temperatures
- Reducing water density
- Fishing by night
- Sand Extraction

3.2.3 The fish diversity impacts decline on artisan fishermen and fishing communities

This section presents the impacts of declining fish diversity on the study area's artisan fishermen and fishing communities as; reduction of livelihood means, increased pressure on land resources, decrease in number of commercially important fish species and mass migration of non-indigenous fishermen to other locations [25]. Thus, from the Fig. 6, division (W) stands for impacts such as; reduction of livelihood implies, increase demand on land stocks and decrease in the amount of economically significant fish species, where approximately 78.3 per cent of fishermen recorded as impacts induced by the decline in the study region of fish diversity. Although category (X) stands for impact as; mass

relocation of non-indigenous fishermen to other areas, where approximately 21.7 per cent of fishermen reported the effect caused by decreasing fish diversity in the study region. Thus, from the result seen in the figure below, all categories (W and X) are impacts of decreasing fish diversity in the study area. The Fig. 6 shows the percentage of fishermen base in the research region on the impacts of the reduction in fish diversity.

3.2.4 Reduction of livelihood means

From the result obtained in the Fig. 6 indicates that, about 78.3 percent of fishermen said that reducing livelihood means is one of the impacts of the decline in the study area of fish diversity. The conclusion of this study is that the subsistence of fishermen and representatives of other groups has been reduced due to a recurrent reduction in the composition of fish species, due to the fact that earnings from fishing operations have been significantly reduced as many fishermen have not been able to satisfy the regular demand for themselves and their families and thus have an effect on fishing communities as a whole. It has also been noted that artisanal fishermen are more likely to be the worst affected as many (if not all) count on this as their livelihood source. This observation is compatible with that of [5], [26].

3.2.5 Pressure increase on land resources

As seen in the Fig. 6, roughly 78.3 per cent of fishermen reported growing strain on land stocks as one of the impacts of decreasing fish abundance in the field of research. Consequently, the finding of this research shows that there has been increased pressure on land resources, particularly farming and potash mining, as most fishermen have changed from fishing to either farming or potash mining due to the frequent decline in rare catches of fish species. Decrease in Number of Commercially Important Fish Species from the result obtained in the Fig. 6 about 78.3 per cent of fishermen reported a decrease in the number of commercially important fish species. Therefore, from the findings of this research, there has been a decrease in the commercially important fish species available, since most fishermen catch fewer fish whenever they engage in fishing which will not be sufficient to sell commercially and make less or no profit. Even most of the fish types that customers favor were very difficult to capture.

3.2.6 Mass migration of non-indigenous fishermen to other places

From the Fig. 6 over 21.7 percent of fishermen recorded mass relocation of non-indigenous fisheries to other locations as one of the impacts of reduction in fish diversity in the study location. From the findings also, populaces, particularly fishermen, have frequently migrated to other places in order to obtain livelihoods to please themselves and families due to the decrease in species of fish. However, the findings were reported from an interview with a cross section of the fishermen as certain impacts of the reduction of fish abundance in the research region are;

- ✓ At times, fishing ground sites are sometimes quite competitive due to a decline in the biodiversity of fish and often result in confusion among fishermen.
- ✓ Often, owing to the decrease in fish abundance, thieves (poachers) use come in at night in certain fishing grounds and use chemicals like gammalin 20 to capture the trout. The use of additives helps them to capture as many fish as they can in the shortest practicable period. This condition results in substantial losses to the fishing ground holder.
- ✓ Because of the lack of fish species, size-based fishing grounds are typically leased out to artisanal fishermen, which requires a great deal of risk-taking as after the rent is charged, it cannot be reversed if there was enough fish in the fishing grounds to offset the expense or not. Consequently, some sort of arrangement is generally reached between the owners traditionally fishing communities and the person or community of artisanal fishermen who rent it.
- ✓ Often due to a decrease in fish diversity, fishing ground sites, which are very rich in fish supplies, made the owners mostly communities' hire security guards, particularly at night, to protect fishing ground sites from poachers and illegal fishermen from the exploitation of resources.
- ✓ Genetic diversity is reduced as a result of the decline in fish biodiversity, particularly when stock size is significantly reduced from natural level.
- ✓ Due to the decrease in fish abundance in the research region, there is a large concentration of fishermen over a surface area per fishing field.
- ✓ The price of fish in the study area is

increasing due to the decline in the biodiversity of fish, which could be a sign of low harvest resulting from over-exploitation.

- ✓ Due to the decrease in fish abundance in the study region, the struggle for a diminishing resource base caused regular harm or kill of fishing gears. It in effect has led to the civil instability and the fishing community's failure to mobilize for religious, economic or political purposes.

3.2.7 Adaptive management of fisheries

The use of control laws in management strategies helped to determine the standard of fishing operation and the measurement and assessment mechanisms helped guide the setting and development of the goals of the harvest strategy. Management Plan Appraisal is used in the production of harvest approaches to perform assessment of the whole management process [27]. Continuous review of management outputs and outcomes allows for adjustments to new information in response. In addition, cost recovery can allow new research to address emerging issues. The practitioners regarded this method as a means of developing adaptive capability, minimizing risk and growing socio-ecological resistance thus fostering healthy fisheries [28], [29].

3.2.8 The artisanal fishermen strategies to fish diversity decline

This segment presents the approaches taken by artisanal fishermen in the study region to control fish abundance decline; reduce the amount of boats, days and areas of fishing, prohibition of disruptive gears of fishing, reduction of sand mining and fishing of un matured fish, restriction of night fishing and reduction of the rate of harvesting, seizure of bad gears of fishing [20]. Therefore, from the Fig. 6, division (U) stands for techniques such as; decreasing the amount of boats, days and areas of fishing, preventing disruptive fishing gears, restricting night fishing and growing the rate of exploitation, where approximately 70.5 per cent of fishermen reported a reduction in the sample field as the techniques taken to control fish diversity. While category (V) stands for strategies such as: seizure of bad fishing gears, reduction on sand mining and fishing of immature fish, where approximately 29.5 per cent of fishermen revealed a decline in the study area as the strategies taken to manage fish diversity.

Therefore, it has been shown from the result that both categories (U and V) are the strategies to manage the decline in the study area in fish diversity. This is in accordance with [10] on the work of changing fishing practices and their socio-economic implications in South Kenya; The Fig. 6 shows the percentage of fishermen base in the research region on the management approaches taken to minimize fish diversity.

4. CONCLUSION

The study concludes that the artisanal fishermen's production is critically dependent on sustainable management of fisheries resources. This study revealed that, in order to achieve and maintain adequate fish production for present and future consumption, artisanal fishermen and fishing communities must adjust to management that can regulate the recurrent decline in diversity of fish. Therefore such adaptive management may involve monitoring and managing the use of bad fishing equipment, such as small mesh nets that harvest juvenile fish stocks, night fishing, sand mining, unorthodox fishing methods, aquatic vegetation, etc. [30]. By this, artisanal fishermen and coastal groups will be interested in implementing the fisheries law to stop various threats to inland coastal biodiversity [31]. Therefore, the inland fisheries declaration should be revised and well implemented, such a review would facilitate broader consultation with fisheries experts, as well as the mobilization and sensitization of artisanal fishermen for the proper management and protection of fishery biodiversity [23].

5. RECOMMENDATIONS

In order to prevent the decreasing trend of fish diversity in the study region, alternative sources of income need to be created to replace the fishing activities that negatively impact the fish stocks. Fishermen need to be assisted at a subsidized rate in terms of fishing equipment such as big size mesh net. Establishment and enforcement of fisheries laws, edicts, rules and regulations should be done through cooperation and liaison with the artisanal fishermen and local communities in such a way as to facilitate revenue generation and desirable livelihood activities in the region. More efforts are required in clearing aquatic vegetation and thorough work to recognize any beneficial use of invasive typha grass as used elsewhere in the world when making weaving materials such as basketball, mats, and canoe sails and hats [32].

In the study region more Fishery Officers need to be hired and deployed to further develop sustainable fishing practices. The officers may aid in campaigning for public awareness and training of local communities, particularly artisanal fishermen on issues of illegal use of fishing gears and fishing methods [33]. Fishermen need to be organized to unite into cooperative communities that will serve as a forum to raise people about the risks of using bad fishing equipment and methods in fishing activities. All current agencies such as the monitoring and compliance unit of the Federal, State and Local Government Department of Fisheries should be re-equipped to ensure that they have the necessary personnel and equipment to help them to implement and execute policies and regulations for the sector efficiently at all times. Massive public awareness is needed in order to educate local communities and artisanal fishermen to understand the benefits of sustainable exploitation for effective management and conservation of fish resources [34].

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CONSENT

As per international standard or university standard, respondents' written consent has been collected and preserved by the author(s).

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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