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ARTICLE

Fillet Quality and Gut Content Analysis of *Parachanna obscura* and *Clarias agboyiensis*

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ABSTRACT

Nigeria waters are rich with a variety of fish species but only very few are cultured and available for consumption. This study was conducted to know the fillet quality, gut content and condition of *Parachanna obscura* and *Clarias agboyiensis* in Nigeria using Igbokoda river as a reference because it is a the major fishing site in the nation. Studies were conducted on the viscera somatic index based on the organ weight and the body weight of the fish and the food item consumed by *Parachanna obscura* and *Clarias agboyiensis* between May to October, 2019 to infer on the fillet quality and gut content of *P. obscura* and *C. agboyiensis* in the water body respectively. A summary of food items that constituted the diet of *Clarias agboyiensis* are *Baccillariophyta,* fish, fat droplets, *dinoflagellate*, insect and *Chlorophyta* which constituted the most important food items both occurring in all stomachs containing food. The fishes has more muscle than the viscera organs which indicate that the weight of the fish before dressing out is higher than the weight of the fish after dressing out. This is suggestive of a good quality of food fish. There was a significant correlation between body weight and total length of specimens found in this study. Increases in total length resulted in corresponding increases in body weight. The result for the condition factor showed was below the expected or standard value (K = 1) which shows this species was not in favorable environmental condition. It is therefore necessary to allow phytoplanktons grow well in water body to increase availability of food items to *Parachanna obscura* and *Clarias agboyiensis*. *P. obscura* and *C. agboyiensis* are also good food fishes of a high fillet quality. They are omnivorous feeders therefore having potentials for aquaculture.

1. Introduction

Fish is a vital source of high-quality protein, providing approximately 16% of animal protein consumed by the world's population and human demand of fish consumption has increased all over the world [1]. Fish is a resource mostly exploited by man and is basically linked to the tropic chain in the entire environment where they are

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commonly found [2].

Nigeria is highly blessed and endowed with vast expense of inland freshwater and brackish ecosystems with abundant fish species and these water bodies play an important role in the provision of protein to Nigerians [3]. Nigeria fresh water bodies are the richest in West Africa in terms of fish abundance [4]. Many depend heavily on the resources of such water bodies for their main source of animal protein and family income [5]. *Parachanna obscura* is a widely distributed fresh water fish endemic to Africa. It is called snake head fish and it is a hardy species that can survive stressful condition with rapid growth performance and high nutritional value and economic potential. *Parachanna obscura* is commonly found in intertropical convergent zone where water temperature is 26-28 degree centigrade. They are both bottom dwellers and a fresh water migratory species.

The desirability and suitability of *Clarias agboyiensis*, a Clariid species as a pond-raised fish is one of the small clariid catfishes of southwestern Nigeria (West Africa). Large numbers of this species are caught with various fishing gear throughout the year in freshwater swamps and rivers of the region. Despite their small size, they are exploited as food fish and command fairly high market prices, especially when smoked. Because of its economic importance and easy maintenance in captivity an evaluation proved it desirable for cultivation in ponds [6]. Information on length-weight relationship is one of the crucial requirements for fisheries management purposes. It is also important to study how their food intake helps their increase in length and weight and also the relationship between them. The condition which leads to survival of this fish in that environment could also be examined

The nature of food depends to a great extent upon the nature of environment as well as ecological point of view [7]. Stomach content analysis provides important insight into fish feeding pattern and quantitative assessment of food habits as an important aspect of fisheries management. The food habit of *Parachanna obscura* and *Clarias agboyiensis* gives more insight on what they feed on and how it can be improvised for a successful culture to ensure survival and optimum growth. It also determines the rate of growth of fish species. Gut content analysis also gives information on seasonal and life history changes of fish because the types and magnitude of food available as well as the season it occurs play an important role in the history of fish [8]. Viscero somatic index is used to evaluate the dress out percentage of a fish after processing which is an indicator of fish quality. It helps to determine how much food fish is left for consumption after the visceral mass has been removed. Viscera mean the visceral organs in the fish like the intestine. Viscero somatic index is basically used to investigate how much materials is deposited in the visceral rather than in the muscle (the edible part of the fish) that is the ratio of the viscera mass to the body mass of the fish. The structure, length and conformation of the intestine are closely related to the diet of the fish [9]. Therefore, understanding this relationship is important to predict the diet of fishes, how fishes feed and the mechanism of feeding[10]. Therefore, this study is also aimed at examining the stomach contents of *Parachanna obscura* and *Clarias agboyiensis* in Igbokoda River highlighting the viscero somatic index, condition factor and gut content of the species in the natural habitat for optimal utilization by local fisheries and processing factories.

2. Materials and Methods

2.1 Description of Study Area

Igbokoda River in Ilaje local government area is a stream and is located in Ondo State, Nigeria. It is located at an elevation of 39 meters above sea level and its population amounts to 71,027. It coordinates are 6º19’0” N and 4º49’0” E in DMS (Degree Minutes Seconds) or 6.31667 and 4.81667 (in decimal degrees). The vast expanse of the water makes for an exciting fishing expedition. This site is located about 142 km from Akure. It is the longest territorial water in Nigeria and has fishing terminal [11]. It is reported that 80% of the population of the study area engages in fishing and that the area always records the bulk produced in Ondo State. The Ilajes who are the major fish producers in Ondo State, with over 80 fishing communities along the coastline [12].

2.2 Fish Sample Collection and Identification

Parachanna obscura and *Clarias agboyiensis* were captured with the assistance of fishermen fishing in Igbokoda River using cast net, long lines and traps. A total of eighty (80) specimens each of *P. obscura* and *C. agboyiensis* were obtained. The species was collected on a monthly basis from May to October and transported live in a plastic container with ice pack to the laboratory for fresh examination. The fish samples were identified using the appropriate field guide. Personal communication with experienced fisher folks on the local name of the fishes was done. The fishes used for the research were further processed after the gut contents were removed for the experiment. The fillet quality was investigated.

2.3 Fish Measurement

Specimen was examined fresh. Morphometric parameters were measured on each sample with the aid of measuring board, measuring rule, weighing balance (JA-5000), pair of scissor and forceps. Morphometric parameters measured were total length (TL), standard length (SL) and head length (HL) which was made to the nearest 0.1 cm using a fish measuring board. A longitudinal incision was made with the aid of stainless steel scissors and forceps along the mid-ventral line from the mouth to the anus to expose the visceral organs and the gut was carefully removed with a pair of throngs. The total weight of the fish was recorded before dissecting. The total weight of viscera was recorded and the total weight of the remaining flesh was recorded.

2.4 Length-Weight Relationship

Length-weight relationship was determined using the formula $\mathbf{W=aL^b}$ according to Nwani *et al*. (2006). The parameters a and b in the formula was estimated through logarithmic transformation form for the purpose of data analysis; thus:

$$\mathbf{Log\ W = Log\ a + b\ Log\ L}$$

where W = weight of the fish in gram, L = total length of fish in centimeter, a = proportionality constant,b = allometric growth coefficient. Equation expressing the length-weight relationship of *Parachanna obscura* and *Clarias agboyiensis* was calculated in relation to possible significance ($p<0.05$), hence the need to transform into logarithm.

2.5 Condition Factor (K)

The condition factor was calculated from length-weight relationship using the following equation.

$$K = \frac{100 \times W}{L^3}$$

where, K = condition factor, W = total weight (g), L = total length (cm) and b = the value obtained from length-weight equation formula.

2.6 Viscero Somatic Index

VSI is basically used to investigate the quality of the fillet and how much material is deposited in the viscera rather than in the flesh. It is calculated as:

$$VSI = \frac{Total\ weight\ of\ all\ visceral}{\text{Total body weight of the fish prior to removal of viscera}} \times 100$$

2.7 Stomach Fullness Classification

Stomach contents classification of the fish species based on degree of fullness was determined. The condition of the stomach was determined visually and categorized as follows: 0/4 = empty stomach, 1/4 = one quarter full stomach, 1/2 = half full stomach, 3/4 = three quarter full stomach, 4/4 = full stomach.

2.8 Gut Contents Analysis

Specimen was dissected from the lower jaw region to the anal region and gut was taken out. The stomach contents were dissected and weighed with and without food materials contained in them. Gut was opened surgically and emptied into petri dish to which 10% saline was added to disperse the contents. The food items were sorted into categories, viewed under photomicrograph at different magnification to aid visibility and identification of food item to species level where possible using key guides by Pennak [13]. Food items in those guts that could not be examined immediately were preserved in refrigerator. Large food items easily recognized with the naked eyes were counted, while microscopic ones were teased to disperse their aggregates in accounting chamber. Food item was counted under objective lens of x10 magnification power of an electrical binocular microscope.

Stomach contents were analyzed using two (2) methods, frequency of occurrence and numerical methods as describe by Hyslop [14]. To avoid post mortem digestion, the stomach content was kept in the refrigerator for further analysis.

2.9 Statistical Analysis

All data collected were subjected to statistical analysis using statistical package for social science (SPSS 2007) software. Analysis of variance (ANOVA) was used to test for significant differences at 5% from data of stomach contents, standard and total lengths, weight and condition factors, morphometric parameters and length class interval of the species measured. Length-weight and morphometric were subjected to least square regression and correlation analysis. Student t-test was used to test for significant difference in the fullness index and stomach contents between seasons. Least Significant Difference (LSD) was carried out to rank means where necessary.

3. Results

A total of 80 specimens of *Parachanna obscura* and *Clarias agboyiensis* were obtained. The total length of *Parachanna obscura* ranged from 22.4 cm to 31.1 cm and standard length ranged from 19.2 cm to 28.6 cm, the weight ranged from 77.3 g to 229 g in Table 1, while the total length of *Clarias agboyiensis* ranged from 20.0 cm to 27.7 cm and standard length ranged from 18.1 cm

to 24.8 cm, the weight ranged from 50.42 g to 185.07 g in Table 2. There was a significant correlation between body weight and total length of specimens found in this study. The reported "b" value of this study for *P. obscura* is "b" 1.556, 1.546, 1.599, 1.559, 1.567 and 1.579 (Table 1) for the month July, August, September and October respectively while the reported "b" value of this study for *C. agboyiensis* is "b" 1.423, 1.492, 1.477, 1.406, 1.431 and 1.499 (Table 2) for the month of July, August, September and October respectively.

The ratio of the visceral mass to the body mass of fish for *P. obscura* in the month of July to October were 5.00, 3.97, 4.15 and 4.51 (Table 3) which indicate that the weight of the fish before dressing out is higher than the weight of the fish after dressing out while for *Clarias agboyiensis* for the month of July to October were 3.75, 4.32, 3.27 and 3.00 (Table 3) which indicate that the weight of the fish before dressing out is higher than the weight of the fish after dressing out.

Out of the 80 specimens collected on *P. obscura*, 0% had empty stomachs, 5% had 1/4 full stomachs, 62.5% had 2/4 full stomachs, 17.5% had 3/4 full stomachs and 15% had full stomachs. During the course of this examination, it was observed that the fullness of the stomach was not in relation to length or weight. Table 7 shows the overall number of food items present in *Parachanna obscura* while out of the 40 specimens collected on *C. agboyiensis*, 0% had empty stomachs, 42.5% had 1/4 full stomachs, 25% had 2/4 full stomachs, 22.5% had 3/4 full stomachs and 10% had full stomachs. During the course of this examination, it was observed that the fullness of the stomach was not in relation to length or weight.

Table 5 shows the stomach fullness of *Parachanna obscura* analyzed. 62.5% of the sampled stomachs were 2/4 half full stomach. A summary of food items that constituted the diet of *Clarias agboyiensis* from Igbokoda river is given in Table 6. Baccillariophyta, fish, fat droplets, dinoflagellate, insect, others and chlorophyta constituted the most important food items both occurring in all stomachs containing food (100% in occurrence). The stomach fullness of *Clarias agboyiensis* analyzed. 42.5% of the sampled stomachs were 1/4 full stomach.

Table 1. Length Weight Relationship of *Parachanna obscura* in Igbokoda River

MONTHS	EQUATION	BETA VALUE
MAY	LogW=1.556× - 0.510	1.549
JUNE	LogW=1.546× - 0.632	1.544
JULY	LogW=1.599× - 0.726	1.599
AUGUST	LogW=1.559× - 0.510	1.559
SEPTEMBER	LogW=1.567×- 0.684	1.567
OCTOBER	LogW=1.579× - 0.699	1.579

Table 2. Length Weight Relationship of *Clarias agboyiensis* in Igbokoda River

MONTHS	EQUATION	BETA VALUE
MAY	LogW=1.423× - 0.477	1.448
JUNE	LogW=1.492× - 0.572	1.439
JULY	LogW=1.477× - 0.569	1.477
AUGUST	LogW=1.406× - 0.474	1.406
SEPTEMBER	LogW=1.431× - O.309	1.431
OCTOBER	LogW=1.499× - 0.592	1.499

4. Discussion

4.1 Length Weight Relationship

Parachanna obscura and *Clarias agboyiensis* growth was negative allometry (Tables 1 and 2). The regression coefficient (b) for isometric growth is '3' and a value lesser than '3' indicates negative allometry growth which shows that fish becomes smaller while a value greater than '3' indicates positive allometry growth which indicates that fish becomes heavier for a particular length as it increases in size [15]. Kunda et al. [16] proposed that fluctuations observed in certain length groups might be due to variation in sample size, sex, gonad condition and amount of gut content. Length weight relationship measurements are important for the estimation of weight where only length data are available, and the condition index of the specimens. The result gotten from this study for the condition factor showed above was below the expected or standard value (K = 1) which shows this species was not in favorable environmental condition. Hence, the analysis of length weight relationship condition and relative condition factors proved to be very helpful tool in the research of fisheries that later could be used in fisheries management and assessment of fish stock [17,18]. The relative condition factor (K) gives an idea about fish physiological status and is also useful to compare feeding, climate and other condition of a fish. The correlation coefficient "r" were negative for *Parachanna obscura* and *Clarias agboyiensis*. This means that there as a negative correlation between length and weight of *P. obscura* and *C. agboyiensis* in Igbokoda River. Undernourished/ thin fish has a condition factor of less than 1. Adequately fed or fat fish has a condition factor greater than 1. The condition factor usually increases when sexual maturation approaches, the fact that sexually immatured fishes were used in this study could have also contributed to the low values recorded in its condition factor. [19] reported that the larger the condition factors the better the well-being of the fish. In this study the result of the condition factor indicated that the environment of fish species was not conducive (K<1) for the whole month in both species.

Table 3. Viscero Somatic Index of *Parachanna obscura* and *Clarias agboyiensis* during the Period of Study

SPECIES	MONTHS						
	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	MEAN(VSI)
Parachanna obscura	4.86	4.27	5.00	3.97	4.15	4.51	4.46
Clarias agboyiensis	4.12	3.97	3.57	4.32	3.27	3.00	3.70

Table 4. Analysis of Stomach Fullness of *Parachanna Obscura* in Igbokoda River

STOMACH FULLNESS (%)	NUMBER OF SAMPLE	PERCENTAGE (%)
0 (empty)	-	0
25	4	5
50	50	62.5
75	14	17.5
100(full)	12	15
TOTAL	80	100

O-/4- Empty stomach, 25-1/4- 25% Full, 50-2/4- half full, 75-3/4- 75% full, 100-4/4- totally full

Table 5. Analysis of Stomach Fullness of *Clarias agboyiensis* in Igbokoda River

STOMACH FULLNESS %	NUMBER OF SAMPLE	PERCENTAGE %
0 (empty)	-	0
25	34	42.5
50	20	25
75	18	22.5
100(full)	8	10
TOTAL	**80**	**100**

O-/4- Empty stomach, 25-1/4- 25% Full, 50-2/4- half full, 75-3/4- 75% full, 100-4/4- totally full

Table 6. Summary of the Stomach Contents Analysis of *Parachanna obscura* in Igbokoda River

	Frequency of occurrence		Numerical method	
Food items	**No**	**%**	**No**	**%**
DINOFLAGELLATE				
Protopteridinium pentagonum	22	55	18	6.45
BACCILLARIOPHYTA				
Thalassiosira anguste-lineata	18	45	13	4.65
Nitzchia closterium	33	82.5	38	13.62
Licmophora sp.	13	32.5	12	4.30
CRUSTACEAN				
Copepods	13	32.5	15	5.38
INSECT				
Insect part	24	60	35	12.54
FISH				
Fish part	37	92.5	37	13.26
Fish egg	28	70	30	10.25
PLANT MATERIAL				
Plant part	4	10	2	0.72
OTHERS				
Sand particles	39	97.5	39	13.98
Unidentified digested food	40	100	40	14.34

Table 7. Summary of the Stomach Contents of *Clarias agboyiensis*

	Frequency of occurrence		Numerical method	
Food items	**No**	**%**	**No**	**%**
CHLOROPHYTA				
Closterium sp	15	37.5	18	5.20
Scenedesmus	21	52.5	28	8.09
BACCILLARIOPHYTA				
Navicula	29	72.5	15	4.34
Nitzchia	31	77.5	12	3.47
Licmophora ehrenbergii	16	40	16	4.62
Thalassionema nitzschiodes	20	50	6	1.73
Synedra	8	20	7	2.02
DINOFLAGELLATE				
Ceratium lineatum	26	65	30	8.67
CRUSTACEAN				
Copepods	6	15	1	0.29
Cladocera	12	30	11	3.18
INSECT				
Insect part	25	62.5	30	8.67
Tunicate larva	5	12.5	2	0.58
FISH				
Fish part	33	82.5	34	9.83
Fish eggs	16	40	17	4.91
Fat droplets	39	97.5	30	8.67
OTHERS				
Sand particles	40	100	40	11.56
Detritus	6	15	12	3.47
Unidentified digested food	40	100	37	10.69

4.2 Viscero Somatic Index (VSI)

The study of viscero somatic index of this study indicated that the fish has more muscle than the viscera organs indicating that it is a good food fish of a high value and has a high fillet quality. Viscero somatic index is the percentage dress out of the fish weight before and after. The ratio of the visceral mass to the body mass of fish for *P. obscura* in the month of July to October indicated that the weight of the fish before dressing out is higher than the weight of the fish after dressing out while for *Clarias agboyiensis* for the month of July to October also follows suit (Table 3). Viscero somatic index has been used to know the gravimetric (weight) and volumetric (volume) analysis. In addition, knowledge of some quantitative aspects in fishes is an important tool for the study of biological fundamentals of viscero somatic indices, because measurement and analysis of these indices are very important. With respect to this study, *C. agboyiensis* and *P. obscura* are good fishes for consumption because of its rich fillet quality.

4.3 Gut Content Analysis of *Parachanna Obscura* and *Clarias Agboyiensis*

The nature of food depends to a great extent upon the nature of environment as well as ecological point of view [20]. Accurate description of fish food and feeding habits provides the basis for undertaking tropic interactions in aquatic food webs. It determines the rate of growth of fish species, as well as revealing the status of the foraging fish species and provides important insight into fish feeding pattern as an important aspect of fisheries management. The objective of gut content analysis is to estimate the total amount of food consumed by a population. During the course of this examination, it was observed that the fullness of the stomach was not in relation to length or weight.

The stomach fullness of *Parachanna obscura* analyzed. 62.5% of the sampled stomachs were 2/4 half full stomach. This may suggest in abundance of food items during the period of July to October. It also reveals digestion of food during the period of transportation from river to laboratory. Fish tends to optimize the energy content of prey ingested by maximizing their size in relation to their mouth gape [21]. A summary of food items that constituted the diet of *Clarias agboyiensis* from Igbokoda river is given in Table 6. Baccillariophyta, fish, fat droplets, dinoflagellate, insect, others and chlorophyta constituted the most important food items both occurring in all stomachs containing food (100% in occurrence). Others were present in 100% of sample collected followed by fat droplets, fish, baccillariophyta, insect and chlorophyta were the most abundant food items by numerical and occurrence methods in the gut of fish

species. Dietary component of *Clarias agboyiensis* proved undoubtedly that the fish obtain its diet consisting mainly of others, fat droplets, fish, baccillariophyta, insect part and chlorophyta. So the fish was found to be omnivore. The stomach fullness of *Clarias agboyiensis* analyzed. 42.5% of the sampled stomachs were 1/4 full stomach. This may suggest in abundance of food items during the period of July to October. It also reveals digestion of food during the period of transportation from river to laboratory.

5. Conclusions

Fillet quality in this study indicated that the fish specie is a good food fish because it has more muscle than the viscera organs indicating that the weight of the fish before dressing out is higher than the weight of the fish after dressing out. *Parachanna obscura* and *Clarias agboyiensis* were found to be omnivorous fish feeding mainly on both plants and animals. The condition factor of the river is not suitable for the growth of the fishes, with a variety of feed items they fed on. There was no seasonality in the composition or abundance of food items consumed generally in both fishes, because the fish specimens grazed on the same food items throughout the sampling period although at varying quantities or degrees. In conclusion, based on the observations from this research, *Parachanna obscura* and *Clarias agboyiensis* in river Igbokoda may be described as an omnivore feeding on both plants and animal thus a good candidate for aquaculture. It is therefore necessary to allow phytoplanktons grow well in water body to increase availability of food items to *Parachanna obscura* and *Clarias agboyiensis.* It is also a highly marketable food fish because of its fillet quality.

Author Contributions

The corresponding author has a 100% contribution to the manuscript.

Conflict of Interest

There is no conflict of interest.

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List of Abbreviations

C. agboyiensis - *Clarias agboyiensis*
P. obscura - *Parachanna obscura*

References

[1] FAO, 2012. World production of fish, crustaceans and mollusks by major fishing areas. Fisheries Information Data and Statistic Unit (FIDI), Fisheries Department, F.A.O Rome.

[2] Craig, J.F., Halls, A.S., Barr, J.J.F., et al., 2004. The Bangladesh floodplain Fisheries Research. 66, 271-286.

[3] Komolafe, O.O., Arawomo, G.A.O., 2011. Observations on the Composition, Physiological Condition and Fisheries in Erinle lake, Osun State, Nigeria. West African Journal of Applied Ecology. 18, 71-78.

[4] Meye, J.A., Ikomi, R.B., 2008. A Study on the Fish Fauna of Urie Creek at Igbide, Niger Delta. The Zoologist. 6, 69-80.

[5] Abubakar, K.A., Haruna, A.B., Ladu, B.M.B., 2006. An Assessment of the Physiochemical Parameters and Productivity of lake Geriyo, Yola, Adamawa State, Nigeria. Biological and Environmental Sciences Journal for the Tropics. 3(1), 18-23.

[6] Fagbenro, O.A., Sydenham, D.H.J., 1988. Evaluation of C*larias isheriensis* (Sydenham) under semi-intensive management in ponds. Aquaculture. 74, 287-291.

[7] Fagbenro, O.A., Adedire, C.O., Ayotunde, E.O., et al., 2000. Heamatological Profile, Food Composition and Digestive Enzymes Assay in the Gut of the African Bony-Tongue Fish, *Heterotis niloticus* (Cuvier, 1829). Tropical Zoology. 13, 1-9.

[8] Akinwumi, F.O., 2003. Food and feeding of *Tilapia zilli* (Pisces, Chichildae) in Ondo State University fish farm. In: 16th Annual Conference of the Fisheries Society of Nigeria (FISON). pp. 195-198.

[9] Miller, S.H., Harley, J.P., 2002. Zoology. McGraw Hill Publishing co; Boston. pp. 504.

[10] Malami, G.Z., Ipinjolu, J.K., Hassan, W.A., et al., 2007. Food and Feeding Habits of Fresh Water Mormyrids (Hyperopisus bebe occidentalis Gunther) in River Rimo and Gonroyo Dam, Nigeria. FISON Conference Proceedings. pp. 120-126.

[11] Babatunde, A., 2010. The Impact of Oil Exploitation on the Socioeconomic Life of the Ilaje-Ugbo People of Ondo State, Nigeria. Journal of Sustainable Development Africa. 12(5), 61-84.

[12] Akegbejo-Samsons, Y., 2005. Comparative Ecology of the African Bony Tongue Fish, *Heterotis niloticus* and the Cat fish *Clarias gariepinus* in the Lower Oluwa River and Adjacent Flood Plains. Ife Journal of Science. 7(1), 15-20.

[13] Pennak, R.W., 1953. Fresh water invertebrates of United States, New York. The Ronald Press.

[14] Hyslop, E.J., 1980. Stomach Content Analyses- A Review of Methods and their Application. Journal of Fish Biology. 17, 411-429.

[15] Zafar, M., Mussaddeq, Y., Akhter, S., et al., 2003. Length-Weight Relationship and Condition Factor of Thaila, *Catla Catla* from Rawal Dam Islamabad, Pakistan. Pakistan Journal of Biological Sciences. 6(17), 1532-1534.

[16] Kunda, M., Dewan, S., Uddin, M.J., et al., 2008. Length Weight Relationship, Condition Factor and Relative Condition Factor of *Macrobranchium Rosenbergii* in rice fields. Asian Fishery Science. 21, 451-456.

[17] Froese. R., Pauly, D., 1998. FISH BASE: Concepts, Design and Data Sources. Manila, ICLARM. pp. 293-299.

[18] Zubia, M.R., Muhammad, O., Adeyemi, S., et al., 2014. Length- Weight Relationship, Condition and Relative condition Factor of Four Mormyrus Species (Family Mormyridae). Journal of Natural Sciences. 5(1-2), 38-46.

[19] Nikolsky, G.V., 1993. The Ecology of Fishes. Academic Press: London. pp. 352.

[20] Fagbenro, O.A., Adedire, C.O., Ayotunde, E.O., et al., 2000. Heamatological Profile, Food Composition and Digestive Enzymes Assay in the Gut of the African Bony-Tongue Fish, *Heterotis niloticus* (Cuvier, 1829). Tropical Zoology. 13, 1-9.

[21] Igejongbo, T.F., Busari, K., 2015. Food and Feeding Habits of *Clarias Gariepinus* (Burchell, 1822) in River Ogbese, South-Western Nigeria. International Journal of Ecology and Environmental Studies. 8, 224-231.

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ARTICLE

Isolation and Identification of Bacteria Found in the Milt of Cultured *Clarias gariepinus*

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ABSTRACT

This study investigated bacteria that are associated with milt in cultured samples of African catfish - *Clarias gariepinus*. Male broodstocks of *Clarias gariepinus* were collected from private Fish Farm in Ogun State, Nigeria, while the fish's milt was collected and analyzed for microbial load at laboratory of the Department of Microbiology, Federal University of Agriculture, Abeokuta, Ogun State. The molecular characterization of the amplicon was done at International Institute of Tropical Agriculture, Ibadan. Bio-edit was used for importing and mining nucleotide sequences into gene bank. As revealed by the results, bacterial organisms that were present in the milt of *Clarias gariepinus are Aeromonas caviae, Proteus mirabilis, Serratia rubidaea, Pseudomonas mosselii, Acinetobacter soli and Klebsiella variicola*. The Basic Local Alignment Search Tools revealed the percentage similarity ranging from 86%-97.04% and their accession numbers. These bacteria indicated high levels of faecal contamination in the environment. In conclusion, bacteria were found in the milt of cultured catfish and are capable of being pathogenic to humans and may increase the vertical transfer to fry during breeding and rearing stage. Therefore, fish farmers should maintain a hygiene and serene environment during breeding and culturing of catfish.

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1. Introduction

One of the most common Nigerian fresh water fish species is *Clarias gariepinus* of the family *Claridae.* The development of catfish farming in Nigeria was driven by socioeconomic objectives which include generation of additional family income, nutrition improvement of rural community, as well as creation of employment [1]. Although aquaculture production in Nigeria has experienced rapid growth in recent years, the industry is still constrained by some factors such as inadequate cooperative financial intervention on the growth of catfish aquaculture value chain, inadequate feed supply, and issues of fish diseases [2]. Studies have shown that tremendous high mortality rates and economic losses have been reported in catfish aquaculture due to infectious pathogens such as bacteria, viruses, fungi and parasites [3]. In the past, fish farming industry in Nigeria had been more focused towards the quality of eggs and larvae rather than that of sperm. However, in recent time, various authors, in an attempt to produce fingerlings of good quality, gave more attention towards obtaining fish milt with high quality [4]. Ultimately, the quality of milt is a measure of the ability of sperm to successfully fertilize an egg. Through the process of natural selection, the characteristics of sperm will be optimized so as to maximize the fitness of the individual male in relation with the specific reproductive strategy of each species [5]. Some findings have shown that milt of fish could be infected with a wide range of microbes present in the water body [6]. The microbes such as bacteria that are present on the body or internal organs of fish indicate the extent of pollution of the water environment [6]. However information on sperm-related microbiota might divulge the impacts of bacteria in the aggregation of sperm and sperm mortality. Such information might also be useful to identify probiotic bacteria for the improvement of sperm quality. Hence, this research work evaluates bacteria associated with milt in cultured samples of African catfish.

2. Materials and Methods

2.1 Sample Collection and Identification

A total number of eight (8) male broodstock were used. The cultured fish were purchased from the Broodstock Section of a private Fish Farm, Mowe, Ogun State of Nigeria. They were transported live to the laboratory in a large plastic container s filled up to half of its capacity with water and subjected to clinical examinations. Through the features of the redness of the genital papilla, the matured male samples were identified.

2.2 Milt Collection

It is necessary to sacrifice male brood fish or surgically removed part of their testes in order to obtain the fish spermatozoa. Thus, male broodstocks of African Catfish, *Clarias gariepinus* collected for the study were dissected via the abdomen and the gonads were removed using standard laboratory method. However, blood clots and other tissues were rinsed away. The gonads were placed in the buffer solution prior to maceration to maintain its potency. Gonads were macerated in Petri dish and semen was transferred into freshly labeled sample bottles.

Plate 1. The milt or gonads of *Clarias gariepinus*

2.3 Isolation of Bacteria and Purification

Isolation of bacteria from the collected semen of the cultured broodstocks was carried out aseptically using different media. These media included tryptic soya broth at 25 °C and at 37 °C for 18-24 hours, then followed by pouring it onto tryptic soya agar, blood agar, Rimler-Shoots agar, Thiosulfate Citrate Bilesalt Sucrose agar (TCBS), and finally incubate at the same time and temperature. The isolated bacterial strains were purified in accordance to the documented guideline in literature [7].

2.4 Characterization of Bacterial Isolates

Bacterial isolates were characterized by their morphological/macroscopic and microscopic characteristics and

identification using molecular means.

2.5 RAPD-PCR Analysis and DNA Extraction

Isolation of DNA from broth culture of bacteria at log phase was done by following procedure described by Murray and Thompson [8] with little modifications. The modified protocol without the use of proteinase K has given good result, yielding quality DNA of approximately 20 µg from a 2 mL bacterial culture.

2.5.1 Primers and PCR Amplification and Resolution of RAPD Markers

For PCR amplification of bacterial DNA template, a panel of 2 numbers of decamer random primers was used. The PCR cocktail mix consisted of 1 µL of 25 mm $MgCl_2$, 1 µL each of forward primer and reverse primer, 2.5 µL of 10x PCR buffer, 1 µL of DMSO, 2 µL of 2.5 mm DNTPs, 0.1 µL of 5 u/µL Taq DNA polymerase, and 3 µL of 10 ng/µL DNA. However, using 13.4 µL Nuclease free water, the total reaction volume was made up to 25 µL.

2.5.2 Identification by 16S rRNA

Primers used in the present study targeted the variable regions of 16S rRNA of bacterial community. However, a pair of universal primers (17F and 1525R) succeeded to amplify the 16S rRNA gene in the PCR reaction and the resulting sequences covered variable regions 1 (V1) to 7 (V7) of 16S rRNA in bacterial isolates in order to accurately identify the bacterial species. Comparing the nucleotide sequences of 16S rRNA gene using BLAST.

2.5.3 Polymerase Chain Reaction Cycling Parameter

Initial denaturation was done at 94 ºC for 5 mins. Immediately after the initial denature, 36 cycles of denaturation at 94 ºC for 30 secs, annealing at 56 ºC for 30 secs and elongation at 72 ºC for 45 secs respectively the follows. Thereafter, a final elongation of step at 72 ºC for 7 minutes and hold temperature at 10 ºC forever was attained. Amplified fragment were observed on ethidium bromide-stained 1.5% agarose electrophoresis gels. The size of the amplicon is about 1500 bp and the DNA ladder is 1 kb from NEB. The sequencing was performed using genetic analyzer ABI 3500 from Thermo Fisher.

2.6 Statistical Analyses of Data

Data were analyzed using descriptive statistics. The bacteria nucleotides from sequencing were run using Bio-edit software on data base and were placed on National centre for Biotechnology information (NCBI) data base with the aid of Basic Local Alignment Search Tools (BLAST).

3. Results

3.1 Molecular Bacteria Isolates and Their Characterization

Table 1 depicts the molecular bacteria isolates and characterization. Bacteriological examination of the Milt of eight (8) broodstocks of *Clarias gariepinus* (African catfish) revealed the different bacteria with their accession number, number of nucleotide sequence, % similarity and the bacteria. The organisms were *Aeromonas caviae, Proteus mirabilis, Serratia rubidaea, Acinetobacter soli, Pseudomonas mosselii, Klebsiella variicola* and *Acinetobacter gerneri*. The lowest % similarity of 86% was found in *Aeromonas caviae* while the highest % similarity of 97.04% was associated with *Klebsiella variicola*.

3.2 Genomic DNA Band of the Sequenced Bacteria Isolates

The amplification products of two Random Amplified Polymorphic DNA (RAPD), product in the isolates, types of amplified DNA bands and number of amplified DNA bands generated by these primers. Primers (27F and 1525R) were used. In Plate 2, the molecular base pair

Table 1. Molecular bacteria isolates and their characterization

Fish Samples	Accession number	Number of nucleotide sequence	% similarity	Genomic identification
1	MK598335.1	1383	86	*Aeromonas caviae* strain ACDMC1235
2	MH396745.1	1322	96.94	*Proteus mirabilis* strain WWv278
3	AB860302.1	1081	92.71	*Acinetobacter gerneri*
4	NA	NA	NA	NA
5	LR590463.1	1337	96.78	*Serratia rubidaea* strain NCTC12971
6	MG757398.1	966	88.56	*Pseudomonas mosselii* strain CIPMRG-3
7	MT394056.1	1149	95.99	*Acinetobacter soli* strain OsEp-Plm-30P2
8	CP050958.1	1181	97.04	*Klebsiella variicola* strain FDAARGOS-628

NA: No nucleotide sequence found and it did not blast for molecular characterization

of the PCR products generated by these primers ranged from 1500 bp to 300 bp. Fifty one polymorphic bands were generated by the two primers. The primer 1525R generated 26 unique bands while 27F produced 25 unique bands. The primer 27F divulged clear variations in RAPD products between the studied bacterial isolates.

Table 2. The primer code and its sequences

Primer code	Sequence
27F	AGAGTTTGATCMGGCTCAG
1525R	AAGGAGGTGWTCCARCCGCA

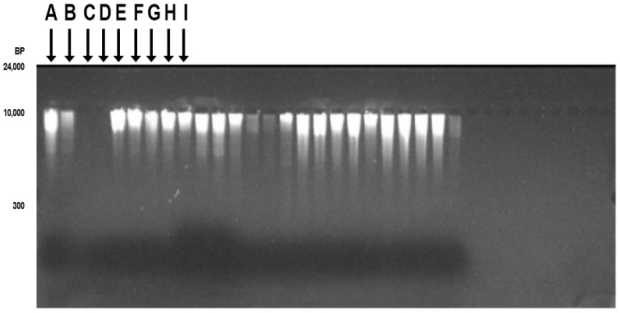

Plate 2. Genomic DNA amplicon observed under ultraviolet light showing the bands

Index: A = Control Ladder; B= Sample 1; C= Sample 2; D= Sample 3; E= Sample 4; F= Sample 5; G= Sample 6; H= Sample 7, I= Sample 8.

4. Discussion

Microorganisms isolated in the Milts used for the study were *Aeromonas caviae*, *Proteus mirabilis*, *Acinetobacter gerneri*, *Serratia rubidaea*, *Pseudomonas mosselii*, *Acinetobacter soli*, and *Klebsiella variicola* species. According to Gennari and Dragotto [9], organisms isolated were classified into various forms; some are spoilage bacteria such as (*Proteus mirabilis*, *Acinetobacter* species and *Pseudomonas mosselii*), two enteric pathogenic organisms (*Serratia rubidaea* and *Aeromonas caviae*) and one opportunistic pathogen (*Klebsiella pneumoniae*).

The reasons for this load of bacteria associated with C. *gariepinuus* from earthen pond may be due to contamination as a result of indiscriminate deposition of waste materials into the ponds through run offs, animal excreta and other environmental wastes. Free roaming animals can also contribute to faecal contamination of fish ponds.

Akinyemi [10] in his work isolated some bacteria from milt of broodstock in hatchery and these were *Salmonella* sp, *Esherichia coli*, *Proteus* sp, *Staphylococcus aureus*, *Vibrio* sp, *Shigella* sp, *Providencia rettgeri* and *Staphylococcus epidermidis*. Awe [11] isolated various bacteria from parts of African Catfish (skin, gills and intestine). The bacteria isolated were *Pseudomonas aeruginosa*, *Aeromonas veronii*, *Bacillus subtilis*, *Staphylococcus aureus* and *Enterococcus faecium*. The bacteria found in the milt for this present were not similar to bacteria [10,11] in the milt of *Clarias gariepinus* broodstocks in the hatchery of farms in Southwestern Nigeria.

The major pathogens associated with the degradation of milt quality as reported by Gram and Huss [12] indicated that bacteria observed in the present study were the major causes of microbial spoilage of fresh fish after capture and the microbial count on the different media. However the putative detrimental effect of bacteria on milt quality is still controversial while some studies have revealed that bacteria most frequently isolated from the milt or genitourinary tracts have no effect on semen quality [13].

Information on milt flora is not readily available and limited; studies involving the digestive system reported the influence of ingested food on bacteria community found in the alimentary canal. The mere presence of these bacteria in the milt of C. *gariepinus* broodstock is of potential pathogenicity. However, the presence of bacteria in fish milt may cause a transfer of these bacteria to the resulting fish seed via vertical transfer to the progeny. Microbial counts in the fish milt samples may also be attributable to transporting and quarantining as well as handling by fisheries personnel. Olufemi [14] reported that bacteria were responsible for many fish diseases especially those associated with environmental stress such as poor handling and transferring. Bacteria Genera and species were aerobes or facultative anaerobes. This explains why they could be found in the spermatozoa of the broodstock fish which is also in agreement with Bairagi *et al*. [15] who isolated similar bacteria from fish gut. It also suggests that these bacteria are systemic. However, a similar work by the author on fish hematological bacteriology showed no significant difference in both infected and non-infected broodstock milt [10].

Although, the total bacterial count on fish milt could rarely indicate the quality of the semen, however, it could give an indication of the risk of low capacitation [12]. These bacteria have the capability of reducing trimethylamine and produce hydrogen sulphide from sodium thiosulphate which represent a secondary metabolite that constitutes fresh fish spoilage. *Klebsiella variicola* being present in the milt of fish samples in this study indicated that the

water used for culturing was faecally contaminated, and this may be due to the faecal waste from surrounding water through run-off.

Findings have shown that *Pseudomonas mosselii* was the sixth most common bacteria isolated. However, the observed numbers of *P. mosselii* in the present study was low compared to previous reports [12]. The reason for low occurrence could be due to the fact that during storage at 0 ºC they had fewer isolates. Therefore, *P. mosselii* is the major pathogen associated with fresh fish spoilage during refrigeration as divulged [12]. The genus *Aeromonas* observed in this study is known to contain a number of opportunistic pathogens causing diseases of aquatic and terrestrial animals, including human beings [16]. Herein, *A. caviae* bacterium was isolated from diseased *C. gariepinus*. The presence of *Aeromonas* spp. in fish milt may be due to environmental stress factors, such as high organic load, overcrowding, and sub-lethal oxygen levels, consequently causing infection after host injury or stress response [17]. Another bacteria recorded in this study is *Proteus mirabilis* which has been identified as commensal in warm bodied animals [18]. Therefore, its present in the milt of the sampled *C. gariepinus* might be due to faecal contamination released by the fishes in the pond. *P. mirabilis* is also an opportunistic pathogen that could primarily affect an individual whose immune system is compromised.

Presence of *Serratia rubidaea* in this study may be due to fish wound from peer bite in the pond which subsequently lead to an abscess in an open fracture. In addition, it is also possible that the bacteria were transmitted to the fish via water, since poor water quality condition may also affect the development of the disease. *Serratia rubidaea* is an *enterobacterium* described as a new species of *Serratia* and was first isolated from water and soil [19]. This bacterium was recognized to be a human pathogen. It was reported that *S. rubidaea* has an extensive distribution in aquatic environments but no report yet in fish [20].

Two different species of *Acinetobacter* were isolated in the milt of *Clarias gariepinus* used in this present study. The isolation of these pathogens from the milt might be due to contamination coming from waste materials present in the pond. However, the role of A. *baumanii* for channel catfish, *Channa striatus, Ictalurus punctatus*, and snakehead, as the fish pathogen has been well documented but studies on A. *gerneri* and *A. soli* in fish milt are yet to be reported [21]. The potential spreading and persistence of *Acinetobacter* species in the environment are well known. It is obvious that *Acinetobacter* spp. is often isolated from healthy or diseased fish as the component of mixed bacterial flora because most bacteria prevailing in water environment colonize gills, skin and digestive tract of the aquatic animals.

5. Conclusions

This study has brought to light, the bacterial species associated with milt of *Clarias gariepinus* cultured in the pond. The presence of these microbes in large population indicates high levels of faecal contamination which might have been contracted from the pond and from the environment.

Conflict of Interest

There is no conflict of interest.

References

[1] FAO, 2017. Fishery and Aquaculture Statistics.Global Aquaculture Production 1950-2015 (FishstatJ). FAO Fisheries and Aquaculture Department. Rome.

[2] Udo, I.U., Umanah, S.I., 2017. Current Status of the Nigerian Aqua Feeds Industry: A Review. International Journal of Innovative Studies in Aquatic Biology and Fisheries. 3(1), 14-22.

[3] Adelakun, K.M., Oguniwin, D.I., Ajagbe, S.O., et al., 2012. Sustainable Aquaculture Practise: A Profitable Venture in Nigeria. In: Handzic, M., Subasi, A. and Goksu, A. (eds), Green Information Technologies and Strategies. Proceedings of the 3rd International Symposium on Sustainable Development, ISSD 2012. Sarajevo. 3, 265-272.

[4] Ochokwu, I.J., Apollos, T.G., Oshoke, J.O., 2015. Effect of Egg and Sperm Quality in Successful Fish Breeding. IOSR. Journal of Agriculture and Veterinary Science. 8(8V.II), 48-57.

[5] Taborsky, M., 2008. Sperm competition in fish: 'bourgeois' males and parasitic spawning. Trends Ecology Evolution. 13, 222-227.

[6] Obiajuru, I.O.C., 1991. Intestinal microflora of tilapia and claria fishes in Ezere and Ekpe -Obia streams Orisuihiteukwa, Orlu, HND project, Federal Polytechnic, Nekede Owerri, Imo state. pp. 59.

[7] Austin, B., Austin, D.A., 2007. Bacterial fish pathogens. Disease of farmed and wild fish Praxis publishing, U.K. pp. 581.

[8] Murray, M.G., Thompson, W.F., 1980. Rapid Isolation of high Molecular Weight Plant DNA. Nucleic Acids Research. 8(19), 4321-4325.

[9] Gennari, M., Dragotto, F., 1992. Isolation and characterization of *Acinetobacter calcoacetisus* from raw, washed and frozen vegetables. 37, 131-137.

[10] Akinyemi, A.A., 2009. Microorganisms associated with fish hatchery systems and their effects on hematological parameters of cultured *Clarias gariepinus* (Burchell, 1822) broodstock PhD Fish pathology Thesis. University of Agriculture, Abeokuta. Nigeria. pp. 221.

[11] Awe, F.A., Hammed, A.M., Olarinmoye, O.M., et al., 2021. Isolation and characterization of Bacteria isolated from Sub-Adult African Mud-Catfish*Clarias gariepinus* from selected fish farms in Ogun-state, Nigeria. Journal of Fisheries International. 16(1), 1-8.

[12] Gram, L., Huss, H.H., 2000. Fresh and processed fish and shellfish, in: The microbiological safety and quality of foods. Lund, B.M. A.C. Baird Parker and G.W. Grould (Eds.) Champinan and Hall, London. pp. 472-506.

[13] Maciejewska, R., Kchaou, W., Chaari, C., et al., 2005. *Ureaplasma urealyticum*, *Ureaplasmaparvum*, *Mycoplasmahominis* and *Mycoplasmagenitalium* infections and semen quality of infertile men. BMC Infectious Diseases. 7, 129.
DOI: https://doi.org/10.1186/1471-2334-7-129

[14] Olufemi, A.A., 1998. Bacteriological studies and chemical analysis of public well water in Samaru and Zaria city in Northern Nigeria. Journal of Microbiology. 8(1-2), 88-98.

[15] Bairagi, V., Ansede-Bermejo, J., RodriguezCastro, A., et al., 2002. Evaluation of different procedures for the optimized detection of Vibrio parahaemolyticus in mussels and environmental samples. International Journal of Food Microbiology. 129, 229-236.

[16] Van der Marel, M., Schroers, V., Neuhaus, H., et al., 2008. Chemotaxis towards, adhesion to, and growth in carp gut mucus of two *Aeromonashydrophila* strains with different pathogenicity for common carp, *Cyprinuscarpio* L. Journal of Fish Disease. 31, 321-330.

[17] Jeney, C., Jeney, E., 1995. Influence of diseases on the wild eel stock: the case of Albufera Lake. Aquaculture. 289, 143-149.
DOI: https://doi.org/10.1016/j.aquaculture.2008.12.015

[18] Markey, B., Leonard, F., Archambault, M., et al., 2013. Clinical Veterinary Microbiology, Oxford University Press, New York, NY, USA, 2nd edition.

[19] Gavini, F., Ferragut, C., Izard, D., et al., 1979. *Serratia fonticola*, a new species from water. International Journal of Systematic Bacteriology. 29, 92-101.

[20] Farmer, J.J., Davis, B.R., Hickman-Brenner, F.W., et al., 1985. Biochemical identification of new species and biogroups of Enterobacteriaceae isolated from clinical specimens. Journal of Clinical Microbiology. 21,46-76.

[21] Rauta, P.R., Kumar, K., Sahoo, P.K., 2011. Emerging new multi-drug resistant bacteria pathogen, *Acinetobacterbaumannii* associated with snakehead *Channa striatus* eye infection. Science. 101, 548-553.

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ARTICLE

Effects of Dietary Replacement of Maize with Sweet Potato Peel in the Diet of African Catfish *Clarias gariepinus* (Burchell, 1822)

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ABSTRACT

This study was carried out to evaluate the effects of dietary replacement of maize with sweet potato peel in the diet of *Clarias gariepinus* juveniles. The levels of the SPP inclusion in the experimental diets were 0%, 25%, 50%, 75% and 100%. All the diets were iso-nitrogenous. One hundred and fifty (150) *C. gariepinus* juveniles (33 g ~ 35 g) were randomly distributed to five treatments with three replicates each and 5% of their body weight for 12 weeks. Fish carcass proximate compositions analyzed before and after feeding with the experimental diets shows that CP and EE differed significantly ($p<0.05$) among the experimental fish and the control, except the percentage CP of the fish fed SPP0% and SPP50% in which there was no significant difference ($p>0.05$). Highest MWG of 207.70±25.95 g was obtained in the fish fed SPP100% followed by 191.30±16.15 g obtained in the fish fed SPP75%. The least MWG of 149.83±16.01 g was recorded in fish fed SPP25%. The highest FCR of 3.61±0.45 g was recorded in the fish fed SPP100%. A steady decrease in FCR was observed with decreasing inclusion levels of SPP meal. However, higher FW, FL, SGR and PER were observed in the experimental fish as from 50% inclusion levels of the SPP. The cost of feed per kg was reduced and the NP and WG increased with increasing levels of SPP and the profitability was enhanced at 100% SPP inclusion level. The results revealed that *C. gariepinus* juvenile could tolerate up to 50%, 75% and 100% inclusion levels of SPP. The best growth performance was recorded in the fish fed SPP100%, therefore, sweet potato peel can replace maize in the diet of *C. gariepinus* without any inauspicious effect on the growth performance and nutrient utilization.

1. Introduction

The increasing prohibitive cost and scarcity of maize necessitated the need to search for underutilized energy feed ingredients [1]. FAO [2] reported that shortage of maize in Nigeria caused a hike in its price up to 89%. Aside the cost, its use in feed formulation cuts down its availability as food for man. Large quantities of sweet potato peels are

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generated which represent a severe disposal problem to the processing industries. Sweet potato peel can serve as a good source of energy due to its high carbohydrate level of about 77.36% which is comparable to the carbohydrate level of maize of about 77.46% [3]. Incorporating sweet potato peels as a replacement for maize in fish feed would not only help to get rid of waste from environment, it will also serve as source of revenue to local farmers. In view of the high cost of conventional feed ingredients, the increasing demand for fish, the competition for maize by both human beings and animals and the international concern for conservation of resources, it is necessary to look into the possibility of using SPP as a replacement for maize in *C. gariepinus* diet. Therefore, this study aimed to evaluate the effects of dietary replacement of maize with sweet potato peel in the diet of *Clarias gariepinus* juveniles.

2. Materials and Methods

2.1 Experimental Site

The experiment was carried out in the Fisheries Research Laboratory of Biology, Ahmadu Bello University, Zaria which is located at Latitude: 11º 03' 60.00" N and Longitude: 7º 41' 59.99" E in Kaduna state of Nigeria.

2.2 Experimental Fish

One hundred and fifty mixed-sex juveniles of *C. gariepinus* were obtained from Umfatas Ventures Farm, Dam Road, Dagace Zaria, Nigeria for the investigation.

2.3 Collection and Preparation of the Sweet Potato Peel

The sweet potato peels were obtained from restaurateurs in ABU Zaria main campus. The fresh sweet potato peels were washed and sun-dried properly under hygienic conditions, the peels were winnowed and sieved to get rid of any unwanted materials, after which were milled into a fine powder and sieved through a mesh screen of 0.5 mm.

2.4 Determination of Nutrient Contents

The proximate composition of sweet potato peels and carcass composition of the fish were determined using the methods of the AOAC (2019) [4].

2.4.1 Moisture Content

A clean crucible was dried to a constant weight in an air oven at 110 ^{o}C, cooled in a desiccator and weighed (W_1). 2 g of finely pulverized sample was weighed in the crucible and then re-weighed (W_2). The crucible and its content were dried in an oven to a constant weight (W_3). The percentage moisture was calculated thus

$$\% \text{ Moisture content} = \{(W2–W3)/(W_2–W_1)\} \times 100$$

2.4.2 Ash Content

The porcelain crucible was dried in an oven at 100 ^{o}C for 10 minutes, cooled in a desiccator and weighed (W_1). 2 g of finely pulverized sample was weighed (W_2) into the previously weighed clean crucible which was ignited in the muffle furnace at 550 ^{o}C for 1 hour and cooled in a desiccator. The crucible and its content were transferred into the muffle furnace and the temperature was gradually increased until it reached 550 ^{o}C. The sample was left in the furnace for 8 hrs to ensure proper ashing. The crucible containing the ash was allowed to cool to 200 ^{o}C, the crucible was removed and cooled in a desiccator until constant weight is obtained (W_3).

$$\% \text{ Ash content} = \{(W_2–W_3)/(W_2–W_1)\} \times 100$$

2.4.3 Crude Lipid Content

Four grams of sample was weighed (W_1) into a clean, dried 500 mL round bottom flask containing few anti-bumping granules was weighed (W_2) and 300 mL of petroleum ether (40 ^{o}C-60 ^{o}C) for the extraction was poured into the flask fitted with soxhlet extraction unit. The round bottom flask and a condenser were connected to the soxhlet extractor, and cold water circulation was put on. The heating mantle was switched on and the heating rate adjusted until the solvent was refluxing at a steady rate. Extraction was carried out for 6 hours. The solvent will be recovered and the oil was dried in the oven at 70 ^{o}C for 1 hour. The round bottom flask and oil were cooled and then weighed (W_3).

$$\% \text{ Crude Content} = \{(W_2–W_3)/(W_2–W_1)\} \times 100$$

2.4.4 Crude Fibre

Two grams of finely pulverized sample was weighed into an extraction apparatus, fat was extracted with liquid petroleum spirit (40 ^{o}C-60 ^{o}C) the extracted was removed and dried at 105 ^{o}C for 30 minutes. Two grams of the defatted sample was weighed into a dry 600 cm round bottom flask. 100 cm^3 of (0.023M) sulphuric acid was added and the mixture boiled under reflux for 30 minutes. The hot solution was quickly filtered under suction. The insoluble matter was washed several times with hot water until it is acid free. This was quantitatively transferred into the flask and 100 cm^3 of hot (0.312) sodium hydroxide solution was added and the mixture boiled under reflux

for 30 minutes and quickly filtered under suction. The insoluble residue was washed with boiling water until it was base free. It was dried to constant weight in the oven set at 100 ^{o}C, cooled in a desiccator and weighed (C_2). The weighed residue was incinerated in a muffle furnace at 550 ^{o}C for 2 hours, cooled in a desiccator and reweighed (C_3).

The loss in weight on ashing (incineration) = $C_2 - C_3$

Weight of original sample = W

% Crude Fibre = $\{(C_2–C_3)/W\} \times 100$

2.4.5 Crude Protein

Two grams of the sample was weighed into 100 cm^3 Kjeldahl digestion flask and about l g of catalyst mixture (K_2SO_4 and $CuSO_4$) was added to speed up the reaction. 25 mL of concentrated sulphuric acid was added into the flask. The content in the Kjeldahl digestion flask was heated slowly at first in Kjeldahl heating unit frotting subsides and then more vigorously with occasional rotation of the flask to ensure even digestion and avoid over heating of the content. The heating continued until a clear solution is obtained. After cooling, the solution was transferred into 100 cm^3 volumetric flask and diluted to mark with distilled water. 10 mL aliquot of the diluted solution or digest was pipette into Markham semi macro nitrogen steel and 10 cm^3 of 40% sodium hydroxide solution was added. The liberated ammonia was trapped in a 100 cm^3 conical flask containing l0 cm^3 of 40% boric acid and 2 drops of methyl red indicator. Distillation was allowed to continue until pink colour of the indicator turn green. The content of the conical flask was titrated with 0.1M HCl, with end point indicated by a change from green to pink colour. The volume of the acid used for the distillate as well as the blank was noted.

% Nitrogen = $\{(0.014 \times M \times (V_1–V_0)\}/$

$\{$weight of test sample$\} \times 100$

where M = actual molarity of acid; V_1 = volume of HCl required for 10 mL sample solution, V_0 = volume of HCl required for the blank.

Atomic weight of nitrogen = 0.014

% Crude = % Nitrogen (N_2) × 6.25

2.4.6 Nitrogen Free Extract

The total carbohydrate content was determined by different methods. The sum of the percentage moisture, % ash, %crude lipid, % crude protein and % crude fibre was subtracted from 100.

NFE = 100–(ash+ crude lipid + crude protein + crude fibre)

2.5 Formulation of Experimental Diets

Five iso-nitrogenous diets were formulated at a CP level of 35% using Pearson Square Method in a way that sweet potato peel was use to replace maize progressively at 0%, 25%, 50%, 75% and 100% respectively. The feed ingredients that were used in the experiment include; fish meal (Clupeid), soya bean meal, sweet potato peel, white maize, bone meal, palm oil, salt, vitamin premix, methionine and lysine (Table 1). All the ingredients were separately processed and milled to fine particle size and mixed together for pelleting, the feed was dried after pelleting, and it was stored in a cool dry place.

Table 1. Feed Composition

Ingredients	SSP0%	SSP25%	SSP50%	SSP75%	SSP100%
Maize	15.15	11.36	7.58	3.79	-
Sweet potato peel	-	3.79	7.58	11.36	15.15
Fish meal	24.95	24.95	24.95	24.95	24.95
Soya bean meal	49.90	49.90	49.90	49.90	49.90
Bone meal	1	1	1	1	1
Palm oil	3.5	3.5	3.5	3.5	3.5
Salt	0.8	0.8	0.8	0.8	0.8
Min/Vit premix	0.7	0.7	0.7	0.7	0.7
Methionine	2	2	2	2	2
Lysine	2	2	2	2	2

2.6 Experimental Design

Fifteen plastic tanks with a water holding capacity of 200-litre were utilized for the experiment and a constant water volume of 133 litres was maintained in each tank. The experimental tanks were assigned to five treatments which were allocated as SPP0%, SPP25%, SPP50%, SPP75% and SPP100%, respectively with three replications each. For the experimental trails, 10 *Clarias gariepinus* fingerlings were weighed and introduced into each of the experimental tanks.

2.7 Feeding Trials

The fish were fed at 5% body weight twice daily at 8:00 a.m. (morning) and 5:00 p.m. (evening) throughout the experiment. Fish in each experimental tank was collectively weighed and both the total and standard lengths were measured biweekly using weighing balance

and measuring board respectively, throughout the experimental period. The experimental period lasted for 12 weeks.

2.8 Determination of Growth Performance and Nutrient Utilization Parameters

Data collected was processed to determine the fish growth performance.

2.8.1 Mean Weight Gain

This is the difference between the final weight and the initial weight of the fish that is been cultured. The difference between the final weight and the initial weight was determined as

$$MWG = W_2 - W_1$$

where W_1 = Initial weight; W_2 = Final weight

2.8.2 Specific Growth Rate

It is an index showing the best growth in a set of growth. This will be determined to observe the best growth in a set of growth. It was obtained using the method of Brown [5].

$$SGR\ \% = \frac{\log \text{ of } W_2 - \log \text{ of } W_1}{T_2 - T_1} \times 100$$

where W_1 = Initial weight; W_2 = Final weight; T_1 = Initial time; T_2 = Final time

2.8.3 Protein Efficiency Ratio

It is described as live weight gain per gram of protein fed. This was estimated from the relationship between the increment in weight and the protein consumed by fish.

$$PER = \frac{\text{Total weight gain (g)}}{\text{Crude protein fed (g)}}$$

2.8.4 Feed Conversion Ratio

It is a numerical value used to measure the gross utilization of feed for growth in fish and other animal. It is assuming that weight gain in fish and other animals is due to increase in body weight. A lower FCR therefore implies efficient food utilization by the animal. This was measured as gross utilization of food for growth in fish as described by Olukunle [6].

$$FCR = \frac{\text{Total Weight of diet fed (g)}}{\text{Total weight of fish (g)}}$$

A lower level of feed conversion ratio therefore implies efficient food utilization by fish.

2.8.5 Net Nitrogen Retention

$$NNR = \frac{\text{Initial body protein}}{\text{Final body protein}} \times 100$$

2.8.6 Survival Rate (%)

$$SR = \frac{\text{Number of fish remain at the end of experiment}}{\text{Initial number of fish stocked}} \times 100$$

2.8.7 Mortality

$$M = \frac{\text{Number of fish dead at the end of experiment}}{\text{Initial number of fish stocked}} \times 100$$

2.8.8 Condition factor

$$CF = \frac{\text{Weight gain}}{(\text{Final Length})^3}$$

2.9 Cost Benefit Evaluation

The feed production cost was based on current market prices of ingredients at Zaria, Kaduna, Nigeria. The economic evaluations were calculated employing the methods described by New [7]; Sogbesan and Ugwumba [8]. Feed Cost (N/kg) = Total Cost of ingredients required to produce a kilogram of each diet

$$\text{Profit Index} = \frac{\text{Value of fish (N)}}{\text{Cost of feed (N)}}$$

$$\text{Incidence Cost} = \frac{\text{Cost of feed (N)}}{\text{Weight of fish produced (kg)}}$$

$$\text{Benefit Cost Ratio} = \frac{\text{Total cost(N)}}{\text{Total sales (N)}}$$

Where Total Cost = Total Fixed Cost (N) + Total Variable Cost (N)

2.10 Data Analysis

T-test and one-way Analysis of Variance (ANOVA) were used to test for significant differences between the various treatment means. Least significant difference (LSD) test was used to rank and separate means where ANOVA shows significant differences. SPSS Version 23 was adopted (statistical package) to show mean deviation and standard errors, at 0.05 significant level ($P<0.05$).

3. Results

3.1 Proximate Composition of the Sun-dried Sweet Potato Peel

The mean proximate composition of the sundried sweet potato peel is presented in Table 2.

Table 2. Proximate Composition of Sun-dried Sweet Potato Peel (g/100gDM)

	Moisture	Ash	CP	EE	CF	NFE
SSPP	4.05±0.50	7.63±0.88	5.61±0.58	2.30±0.40	3.05±0.59	77.36±0.51

Key: SSPP= Sun-dried Sweet Potato Peel; CP= Crude Protein**;** EE=Ether Extract**;** CF= Crude Fiber; NFE= Nitrogen Free Extract

3.2 Proximate Composition of Experimental Diets

The proximate composition of the experimental diets is shown in Table 3. The diets were iso-nitrogenous as there was no significant difference (p>0.05) in the protein composition of the diets at 38% crude protein and they all met the dietary requirement for the experiment.

3.3 Growth Performance of *Clarias gariepinus* Juveniles Fed Experimental Diets

The results of growth performance in terms of FW, FL, MWG, SGR, CF and SR of *Clarias gariepinus* juveniles fed experimental diets are presented in Table 4.

3.4 Carcass Composition (g/100g DM)

Fish carcass proximate compositions analyzed before and after feeding with the experimental diets are presented in Table 5.

3.5 Nutrient Utilization of *Clarias gariepinus* Juveniles Fed Experimental Diets

The results of nutrient utilization in terms of PER, FCR, ANPU, NNR, PPV and FCE of *C. gariepinus* fed experimental diets are presented in Table 6.

3.6 Cost and Benefit Analysis of Experimental Diets

Cost and benefit analysis of experimental diets are presented in Table 7. The cost of the diets decreased with dietary inclusion levels of SSP Table 7.

Table 3. Proximate Composition of Experimental Diets (g/100g DM)

Parameters (g/100g DM)	T1 SPP(0%)	T2 SPP(25%)	T3 SPP(50%)	T4 SPP(75%)	T5 SPP(100%)
Moisture	6.95±0.58^{a}	7.90±0.58^{a}	6.00±0.57^{a}	6.25±0.12^{a}	6.10±0.57^{a}
Ash	7.10±0.57^{a}	7.55±0.58^{a}	6.45±0.06^{b}	7.70±0.57^{a}	7.85±0.58^{a}
Ether Extract	5.81±0.52^{a}	4.50±0.57^{b}	5.30±0.17^{a}	5.95±0.57^{a}	4.95±0.58^{b}
Crude Protein	38.79±1.15^{a}	38.77±0.6^{a}	38.76±0.58^{a}	38.78±0.52^{a}	38.69±0.58^{a}
Crude Fibre	3.90±0.58^{a}	3.15±0.57^{a}	2.00±0.57^{b}	2.29±0.37^{b}	2.15±0.52^{b}
NFE	37.35±0.51^{c}	38.24±0.83^{b}	41.29±0.46^{a}	39.03±0.58^{b}	40.26±0.57^{a}

Means with the same superscripts across rows were not significantly different (P>0.05)
Key: T= Treatment; NFE=Nitrogen Free Extract

Table 4. Growth Performance of *Clarias gariepinus* Juveniles Fed Experimental Diets

Parameters	Inclusion levels				
	T1 SPP0%	T2 SPP25%	T3 SPP50%	T4 SPP75%	T5 SPP100%
IW (g)	35.60±1.22^{a}	35.53±1.17^{a}	35.47±0.81^{a}	35.43±1.01^{a}	35.43±0.88^{a}
IL (cm)	17.73±0.37^{a}	17.67±0.99^{a}	17.67±0.85^{a}	17.60±0.60^{a}	17.60±0.76^{a}
FW (g)	187.50±42.85^{c}	185.37±14.84^{c}	188.30±6.78^{c}	226.73±15.62^{b}	243.13±25.49^{a}
FL (cm)	29.67±2.59^{c}	29.67±0.60^{c}	29.83±0.60^{c}	31.83±1.01^{b}	32.00±0.87^{a}
MWG (g)	151.90±43.74^{c}	149.83±16.01^{c}	152.83±6.55^{c}	191.30±16.15^{b}	207.70±25.95^{a}
PWG (%)	81.01±1.37^{c}	80.87±3.73^{c}	81.16±3.07^{c}	84.37±4.62^{b}	85.43±5.41^{a}
SGR (%)	0.88±0.16^{c}	0.82±0.05^{c}	0.86±0.02^{c}	0.96±0.45^{b}	1.00±0.06^{a}
CF	1.81±0.05^{b}	1.91±0.07^{a}	1.89±0.03^{b}	1.91±0.01^{a}	1.91±0.06^{a}
SR (%)	96.67±3.33^{b}	96.67±3.33^{b}	100.00±0.00^{a}	100.00±0.00^{a}	100.00±0.00^{a}

Means with the same superscripts across rows were not significantly different (P>0.05)
Key: SPP=Sweet Potato Peel, IW=Initial Weight, IL=Initial Length, FW=Final Weight, FL=Final Length, MWG=Mean Weight Gain, PWG=Percentage Weight Gain, SGR=Specific Growth Rate, CF=Condition Factor, SR=Survival Rate.

Table 5. Carcass Composition of *Clarias gariepinus* juveniles Before and After Feeding with Experimental Diets (g/100gDM)

Parameters	Initial	Final Carcass Composition				
		T1 SPP0%	T2 SPP25%	T3 SPP50%	T4 SPP75%	T5 SPP100%
Moisture	8.70±0.64[a]	4.15±0.06[b]	4.85±0.52[b]	4.55±0.56[b]	4.50±0.58[b]	4.75±0.06[b]
Ash	6.50±0.58[d]	10.04±0.55[c]	14.20±0.12[b]	15.90±0.58[b]	16.10±0.57[a]	16.30±0.40[a]
EE	17.30±0.40[a]	16.40±0.12[b]	15.60±0.58[c]	12.10±0.64[d]	10.30±0.56[e]	09.20±0.46[f]
CP	46.57±0.12[e]	61.03±0.58[c]	58.95±0.58[d]	61.69±0.57[c]	63.36±0.64[b]	65.29±0.58[a]
NFE	20.93±0.57[a]	8.38±0.06[b]	6.40±0.56[c]	5.76±0.55[d]	5.74±0.58[d]	4.46±0.64[e]
Total	100.00±0.0	100.00±0.0	100.00±0.0	100.00±0.0	100.00±0.0	100.00±0.0

Means with the same superscripts across rows were not significantly different (P>0.05)

Key: SPP= Sweet Potato Peel; EE= Ether Extract; CP= Crude Protein; NFE= Nitrogen Free Extract

Table 6. Nutrient Utilization of *Clarias gariepinus* juveniles Fed Experimental Diets

Parameters	Inclusion levels				
	T1 SPP0%	T2 SPP25%	T3 SPP50%	T4 SPP75%	T5 SPP100%
WG (g)	151.90±43.74[c]	149.83±16.01[c]	152.83±6.55[c]	191.30±16.15[b]	207.70±25.95[a]
FI (cm)	65.79±0.63[b]	66.67±0.64[b]	66.67±0.64[b]	69.44±0.13[a]	68.49±0.63[a]
PER	3.90±1.12[c]	3.85±0.41[c]	3.93±0.17[c]	4.92±0.41[b]	5.30±0.67[a]
FCR	3.28±0.28[c]	3.61±0.45	2.77±0.12[c]	2.75±0.79[b]	2.71±0.50[a]
ANPU (%)	65.47±1.36[c]	60.12±1.79[d]	67.16±1.19[c]	71.46±1.35[b]	76.42±1.78[a]
NNR (%)	58.29±0.48[b]	60.36±0.79[a]	57.67±0.35[b]	56.15±0.39[c]	54.93±0.66[d]
PPV	1.57±0.01[c]	1.52±0.01[d]	1.58±0.01[c]	1.63±0.01[b]	1.67±0.01[a]

Means with the same superscripts across rows were not significantly different (P>0.05)

Key: SPP=Sweet Potato Peel, WG=Weight Gain, FI=Feed Intake, PER=Protein Efficiency Ratio, FCR=Feed Conversion Ratio, ANPU=Apparent Net Protein Utilization, NNR=Net Nitrogen Retention, PPV=Protein Productive Value, FCE=Feed Conversion Efficiency

Table 7. Cost and Benefit Analysis of Experimental Diets

Parameters	Inclusion levels				
	T1 SPP0%	T2 SPP25%	T3 SPP50%	T4 SPP75%	T5 SPP100%
Weight Gain (g)	151.90	149.83	152.83	191.30	207.70
Cost of Feed (₦)	2,200	2,100	2,000	1,900	1,800
Cost of Juvenile (₦)	2,250	2,250	2,250	2,250	2,250
Cost of Water (₦)	2,000	2,000	2,000	2,000	2,000
Cost of Feeding (₦)	900	900	900	900	900
Total Input Cost (₦)	7,350	7,250	7,150	7,050	6,950
Number of Juveniles	10	10	10	10	10
Unit Price of Fish/kg	1,000	1,000	1,000	1,000	1,000
Total Value of Fish (₦)	10,000	10,000	10,000	10,000	10,000
Net Profit (₦)	2,650	2,750	2,850	2,950	3,050
Incidence Cost (₦)	14.48	14.02	13.09	9.93	8.67
Profit Index	4.5	4.8	5.0	5.3	5.6
Benefit Cost Ratio	0.22	0.21	0.20	0.19	0.18

4. Discussion

The proximate composition of the SSPP indicates a high amount of NFE of 77.36%. The NFE obtained in this study is higher than 71.16% and 74.60% reported by Solomon *et al.* [9] and El-Nadi *et al.* [10] for SSPP, respectively. The difference obtained could be as a result of variety of the SPP used in this experiment. The CP obtained for the SSPP in this experiment is higher than 4.64% reported by Faramarzi *et al.* [11], but is lower than 5.91% reported by Solomon *et al.* [9]. The ash content (7.63%) obtained is higher than 4.56%, 6.02% and 4.53% reported by Faramarzi *et al.*; Solomon *et al.* and El-Nadi *et al.*, [9-11] respectively. The differences observed in this study may be as a result of differences in geographical location, harvesting time and the variety the sweet potato peel used.

The growth performance of *C. gariepinus* juveniles fed varying inclusion levels of sweet potato peel indicates the mean initial weight (35.43 g ~ 35.60 g) was not significantly different (p>0.05) among the experimental

treatments, showing uniformity in size at onset of the experiment as recommended by previous studies [12]. MWG generally increased with increasing inclusion levels of SPP in diets. The fish fed containing 100% inclusion level of SPP recorded the best WG (207.70 g) which was significantly different ($p<0.05$) from the WG of fish fed diet containing 25%, 50%, 75% SPP and the control. Similarly, the SGR also displayed an increasing trend with increasing levels of SPP in the diets. The best performance (1.00%/day) was obtained in fish fed 100% SPP followed by fish fed SPP75% (0.96%/day) while the lowest value (0.82%/day) was recorded in fish fed (SPP25%). Percentage weight gain, also revealed similar trend with those of FW and SGR.

The increasing trend in growth performance could be due to high mineral concentrations present in the SPP. However, minerals are component of hormones and enzymes, and they activate enzyme, as reported by Zaijie [13] which could also lead to the increased and better growth performance recorded with increasing inclusion levels of sweet potato peel in the diets. The increasing trend in growth performance observed in this study contradicts with findings of Olukunle [6] who replaced sweet potato peel with maize at 0%, 25%, 50% and 75% in diet of *C. gariepinus* advanced fry and stated that growth performance decreased with increase in the sweet potato peel meal inclusion. However, Solomon *et al.* [16] replaced sweet potato peel for maize in the diet of *C. gariepinus* fingerling at 0%, 25%, 50%, 75% and 100% inclusion levels and concluded that growth parameters were maximum at 50% and 75% inclusion levels of sweet potato peel in the diet. Faramarzi *et al*. [11] had also carried out a similar research on replacing maize with SPP at 0%, 5%, 10%, 15%, 20% and 25% inclusion levels in iso-nitrogenous diet (31.23% crude protein) of *Cyprinus carpio,* these authors concluded that *C. carpio* could tolerate up to 15% inclusion levels of sweet potato peel.

The condition factors (1.81 – 1.91) of fish fed the dietary treatments were not significant different ($p>0.05$) indicating that dietary inclusion of SPP did not influence the welfare of the experimental fish. Survival rate of *C. gariepinus* juvenile fed the experimental diets showed similar performances (96.67% - 100.00%) among the experimental treatments as no significant difference ($p>0.05$) was observed.

The nutrient utilization of *C. gariepinus* fed diets containing different dietary levels of SPP did not show significant differences ($p>0.05$) in PER, feed and ANPU among the experimental diets and the control except for the fish fed SPP75% and SPP100% which have higher values compared to the other treatments this could be as a result of activation of digestive enzymes by the high mineral concentrations present in the SPP. Protein efficiency ratio differed significantly ($p<0.05$) among the experimental fish and the control. The highest PER (5.30) was recorded in the fish fed SPP100% while the least PER of 3.85 was obtained in the fish fed SPP25%, this could be due high weight gain (207.70 g) obtained in the fish fed SPP100% and least weight gain (149.90 g) obtained in the fish fed SPP25%.

The feed conversion ratio recorded in this experiment (2.71-3.61) in which the fish fed SPP100% had the lowest and the fish fed SPP25% had the highest. The highest value of feed conversion ratio (3.61) obtained in this study was similar with the feed conversion ratio value (3.23) reported by David and Afia [14] for *C. gariepinus* fed locally formulated diet for eight (8) weeks.

The carcass crude protein in this experiment increased significantly ($p<0.05$) after the feeding trial. The mean initial crude protein (46.57%) was significantly lower than the values obtained after the feeding trial. High value (65.29) was recorded in fish fed SPP100% which is in line with findings of Cheng and Hardy [15]. However, moisture content did not differ significantly ($p>0.05$) among the fish fed experimental diets and the control. There was no significant difference in the ash content of the fish fed 75% and 100% sweet potato peel but it differed with the other treatments and the control. Ash ranged from 10.04% to 16.30% and moisture ranged from 4.15% to 4.85%. Soluble carbohydrate (nitrogen free extract) did not differ significantly ($p>0.05$) in the fish fed 50% and 100% as well as 25% and 75% sweet potato peel but they differed significantly ($p<0.05$) with the control (0%). The percentage of nitrogen free extract ranged from 5.46% to 8.38%. Moisture content, lipid and nitrogen free extract are significantly higher in the initial carcass composition than after feeding with the experimental diets, while crude protein and ash content are significantly higher after the feeding trial. The carcass crude protein and ash increased while lipid decreased with increasing level of sweet potato peel in the diet.

Cost of feed per kg of feed reduced from ₦2,200 in the control to ₦1,800 in Treatment5. The total input cost (₦7350) was higher in the control compared to the other treatments. Net profit had increased from ₦2650 to ₦3050 in the Control and Treatment5, respectively which was significantly ($p<0.05$) higher to the other treatments. Experimental diet containing 100% sweet potato peel which had lowest cost of feed per kilogram, lowest total input cost, highest net profit and highest profit index (5.6) was therefore more profitable than the other diets.

The economic superiority of Treatment5 (SPP100%)

could be as a highest level of sweet potato peel. The relatively higher cost factor of the control may be attributed to the high cost of maize in the diet. Moreover, the use of sweet potato peel in fish feed production may be economical taken into consideration its availability.

5. Conclusions

Growth and nutrient utilization of the experimental fish increased with increasing levels of sweet potato peel in the diet, suggesting that SPP may be suitable to replace maize in the diet of *C. gariepinus* juvenile from 50% to 100% as the fish fed containing 100% inclusion level of sweet potato peel had the best weight gain (207.70 g) while poor weight gain of 149.83 g and 151.90 g were observed in the diet fed 25% inclusion level and the control. The cost of feed per kg had reduced from ₦2,200 to ₦1,800 and the net profit had increased from ₦2,650 to ₦3,050, the weight gain had also increased (151.90 g-207.70 g) with increasing levels of SPP and the profitability was enhanced at 100% SPP inclusion.

Abbreviations

SPP= sweet potato peel; CP= crude protein; EE= ether extract; MWG= mean weight gain; FCR= feed conversion ratio; FW= final weight; FL=final length; NP= net profit; WG= weight gain

Authors' Contributions

Abdurrazzaq Ibrahim Abdullahi conceived the work, designed the experiment and carried out the experiment. Dr. Bolanle Silas Bawa and Prof. S. A. Abdullahi supervised the work and also read and approved the manuscript.

Conflict of Interest

The authors have declared no conflict of interest for this work.

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References

[1] Jimoh, W.A., Sodamola, M.O., Ayeloja, A.A., et al., 2014. The influence of replacing maize with *Chrysophyllum albidum* seed meal on growth response and nutrient utilization in *C. gariepinus*. Agrosearch. 14(1), 54-61.

[2] FAO, 2020. Selected daily news on food chain distributions and countries responses to the COVID-19 impact on food chains. Available online at hppt:// www.fao.org/datalab/ website/web/digest/news-digest-24112020.

[3] Ape, D.I., Nwogu, N.A., Uwakwe, E.I., et al., 2016. Comparative Proximate Analysis of Maize and Sorghum Bought from Ogbete Main Market of Enugu State, Nigeria. Greener Journal of Agricultural Sciences. 6(9), 272-275.

[4] AOAC, 2019. Official Methods of Analysis of Association of Official Analytical Chemists: Official Methods of Analysis of AOAC International. 21st edition, AOAC, Washington DC.

[5] Brown, M.E., 1957. Experimental studies on growth. The Physiology of Fisheries. Academic Press, New York. 1, 361-400.

[6] Olukunle, O., 2006. Nutritive potential of sweet potato peel meal and root replacement value for maize in diets of African catfish (*Clarias gariepinus*) advanced fry. Journal of Food Technology. 4(4), 289-293.

[7] New, M.B., 1989. Formulated aquaculture feeds in Asia: some thoughts on comparative economics, industrial potential, problems and research needs in relation to small-scale farmers. Bahru, J. (Ed) Report of the Workshop on Shrimps and Finfish Feed Development, ASEAN/SF/89/GEN/11.

[8] Sogbesan, A.O., Ugwumba, A.A., 2008. Nutritional evaluation of termite (*Macrotermes Subhyalinus*) meal as animal protein supplement in the diet of *Heterobranchus longifilis* (Valenciennes, 1840) fingerlings. Turkish Journal of Fisheries and Aquatic Sciences. 8, 149-157.

[9] Solomon, S.G., Okomoda, V.T., Oloche, J.A., 2015. Evaluation of Sweet Potato (*Ipomea batatas*) Peel as a Replacement for Maize Meal in the Diet of *C. gariepinus* Fingerling. Journal of Fisheries Science. 9(4), 063-068.

[10] El-Nadi, A.S.M., Abozaid, H., Zeinhom, M.M., 2017. Graded levels of potato peels effects as partial replacement for corn in diet of Common carp (*Cyprinus carpio*). International Journal of Chemical Technology Research. 10(2), 566-572.

[11] Faramarzi, M., Lashkarboloki, M., Kiaalvandi, S., et al., 2012. Influences of different levels of sweet potato peels on growth and feeding parameters and biochemical responses of *Cyprinus carpio*. Ameri-

can-Eurasian Journal of Agricultural and Environmental Science. 12(4), 449-455.

[12] Jegede, T., Fagbenro, O., 2008. Dietary neem (*Azadirachta indica*) leaf meal as reproductive inhibitor in redbelly tilapia, tilapia zillii 8th International Symposium on Tilapia in Aquaculture. 365-373.

[13] Zai-jie, D., 2007. Fish Nutrition and Feeds. Freshwater Fisheries Research Centre, Chinese Academy of Fishery Sciences. dongzj@ffrc.cn http://wxfc .fish. cn/ Prof/ dongzj /de fault.html. 1-275.

[14] David, G.S., Afia, O.A., 2017. Growth performance, nutrient utilization and survival of sharptooth catfish (*Clarias gariepinus*) fed locally formulated and commercial pelleted diets reaed in tarpaulin tanks. International Journal of Agricultural Research and Food Production. 1(2), 13-39.

[15] Cheng, Z.J., Hardy, R.W., 2002. Apparent digestibility coefficients and nutritional value of cottonseed meal for rainbow trout (*Onchorhynchus mykiss*). Aquaculture. 212, 361-371.

Appendix

Feed formulation

Fixed Ingredients (%):	Bone meal	1
	Salt	0.8
	Min/vit premix	0.7
	Palm oil	3.5
	Methionine	2
	Lysine	2
		10%

Maize = 8.75% CP

Sweet potato peel = $\frac{5.37\%\ CP}{\mathbf{14.12\%}}$ = $\frac{14.12}{2}$ = **7.06%**

One (1) part Fish meal = 60% CP

Two (2) part SBM = 38% CP × 2 = $\frac{76\%}{\mathbf{136\%}}$ = $\frac{136}{3}$ = **45.33%**

100% - 10% = 90%

35/90 × 100 = **38.89% CP**

Energy source 7.06 6.44

38.89

Protein source 45.33 31.88

38.27%

Energy source = $\frac{6.44}{38.27}$ × 90 = **15.15%**

Protein source= $\frac{31.82}{38.27}$ × 90 = **74.85%**

1 part Fish meal = **24.95%**

2 part SBM = **49.90%**

At 0% SSP = 0%

100% Maize= 15.15

At 100% SPP = 15.15%

0% Maize= 0%

At 25% SPP = 25/100 × 15.15 =**3.79%**

75% Maize = 75/100 × 15.15 = **11.36%**

At 50% SPP = 50/100 × 15.15 = **7.58%**

50% Maize = 50/100 × 15.15 = **7.58%**

At **75% SPP =** 75/100 × 15.15 = **11.36**%

25% Maize = 25/100 × 15.15 = **3.79**%

Plate 1. Watching of sweet potato peel

Plate 2. Side view of hand pelletizer

Plate 3. Sun drying of sweet potato peel

Plate 5. Sun drying of the experimental feed

Plate 4. Grinding of sweet potato peel

Plate 6: Treatment set up in the Lab.

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ARTICLE

Aspects of Impacts of Proposed Badagry Deep Sea Port on the Ecosystem and Livelihood of Fishing Communities in Badagry, Lagos State, Nigeria

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ABSTRACT

Federal government of Nigeria, in collaboration with Lagos State Government proposed development of a seaport in Badagry. This research examined and documented the current state of the ecosystem and livelihood of thirteen communities that will be impacted by the proposed deep-sea port. Qualitative and quantitative approaches were used for the study. Review of secondary data was used to investigate the demographic data of the community while Participatory Rural Appraisal was conducted for 300 households in the communities. Majority of the sampled respondents were in the age range of 45 years and above with females (60%) more than males (40%) in the entire population sampled. Educational levels of the respondents are relatively low. The majority of the sampled households have multiple livelihood systems that keep them engaged throughout all seasons of the year. Capture fisheries is the major occupation in the study area and it is complemented with aquaculture. Existing groups are not strong enough to operate as a pressure group to influence policies and regulate market prices, which has been identified as a major limitation in the study area. There was no regular training or capacity building. Hence the groups were not operating as a business enterprise and could not expand or increase capacity. Consequently not able to contribute significantly to poverty alleviation and increase employment opportunities in their localities. This document will serve as one of the guides to the government for decision-making and compensation to the communities.

1. Introduction

The ancient city of Badagry was founded in 1425 [1]. It is located along the ancient coast of West Africa, now known as the Bight of Benin. By the 1600s, this ancient city had become a thriving community reputed for trade in salt produced by evaporation at Gberefu. This legitimate trade soon gave way to the obnoxious slave trade and for four hundred years, slave trade dominated all other interests in Badagry [2]. By 1740, Badagry had become

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a thriving town for its sole industry - the slave trade, courtesy of the Europeans and Americans, exporting through the Creeks and Lagoon and across Atlantic to Europe and America.Badagry is presently a thriving tourist site that attracts people from all over the world [3]. It is equally well known for fishing.

Over 200 rural fishing communities are adjoined to this ancient city and some of the prominent ones are Apa, Ajido, Kweme, Ibereko, Iworo, Ilogbo, Ikoga, Igborosun, Ilado, Imeke, Topo-Idale, Aradagun, Toga, Ajara, Imeke, Gbaji-Yekke, Ganyaingbo, Koga, Pota, Tohun, Erikiti, Mosafejo, Iragbo, Wesere; Gberefu, Yovoyan, Gayingbo, Agonvi, Agonrin, Hoke-daho, Kujinada, Aivoji, Asakpo, Sheik modawa, Agonvi town, Ganyingbo town and Gbaji yeke tome [3].

Recently, federal government in collaboration with Lagos State Government, proposed to site a sea port in Badagry. The proposed port will thus serve as a primary catalyst for the economic development of Lagos State. It will provide a quality solution for the shortage of multi-cargo capacity and ensure that the infrastructure of Lagos State is aligned to and sufficient enough to support the growing Nigerian and West African markets for the future. The project area covers 13 communities and by implication will require access to land to explore, develop and operate the sea port project. This land is already occupied in some manner, as people physically reside there and uses free land as a means of livelihood. As a result, acquiring land by the project will lead to physical displacement, and loss of other assets that might lead to loss of means of livelihood.

The study is essential due to the following problems that have been identified: This project is of international importance between Nigeria and the Republic of Benin, and it would displace thirteen (13) fishing communities. The Lagoon within this area and sea beaches are breeding grounds for sea turtles that have been placed on the danger list. Besides, shrimps from this beach contribute to the over $56,000,000 realized from shrimp export. The project will have a great impact on the sustainable livelihoods of local communities. The project will impact the physico-chemical characteristics of the Lagoon and the Sea beach. Collapsing of thriving fisheries will occur. Destruction of the ecosystem and natural habitats of endemic fauna and flora, destruction of nesting and breeding grounds of endangered biodiversity like sea turtles would also occur.

Despite the economic, ecological and socio-cultural importance of this area, there is no baseline data for future reference and scenario development for policy formulation and implementation. Hence, this study aims to investigate aspects of the impacts of the seaport on: Livelihood of the people; Farming system; Crops being propagated, harvested and processed; Fishing/aquaculture inputs and outputs; Farming inputs and output; Fishing crafts and gears; Catch compositions; Earnings from fisheries and sources of income.

2. Literature Review

Construction of port facilities involves considerable modification of estuarine and coastal habitats through reclamation, physical alteration of the shoreline, dredging and disposal of soil [4]. Environmental impacts include destruction of aquatic habitats, loss of seagrass beds, salt marshes and mangroves and sedimentation or erosion caused by altered bathymetry and water circulation patterns [5]. Permanent loss of habitat and biological productivity occurs where structures occupy the foreshore or seabed, or where major dredging works are performed to establish harbours and shipping channels [6].Changes in benthic communities also result from the replacement of native habitats with artificial structures. These artificial substrates attract exotic fouling communities that may subsequently invade other habitats in the port environment, resulting in reduced diversity of native communities [7]. Sediment transport processes are altered at coastal ports both through reflection of waves from port structures and hydrographical modifications caused by dredging. This has led to changes in seabed habitats and marine communities in areas such as Portland Harbour in Victoria, where protective works are required to prevent ongoing erosion of the adjacent coast [8]. Construction of marinas has similar impacts to those outlined for port development, although generally at a smaller and more localized scale [4]. In some areas, such as the Gipps land Lakes in Victoria, the proliferation of marinas and related facilities has grossly altered the nature of the shoreline and inshore habitats [8].

3. Materials and Methods

3.1 Study Area

The study was carried out in Badagry within latitude 6°25N 2°53/6.42°67°N and longitude 2.88°E [9]. It shares boundaries with Ogun State both in the North and in East and is bounded on the west by the Republic of Benin. In the South, it stretches for 180 kilometers along the coast of the Atlantic Ocean. It consists of Lagoons and Creeks. The sampling stations are thirteen communities (13) namely Gberefu, Yovoyan, Gayingbo, Agonvi, Agonrin, Hoke-daho, Kujinada, Aivoji, Asakpo, Sheik modawa, Agonvi town, Ganyingbo town and Gbaji yeke tome.

3.2 Data Collection

The project was carried out using secondary data and primary data. The secondary data involved a review of proposal documents alongside with the social and environmental impact assessment conducted in affected communities. The study covered a period of twelve (12) months and data were collected using a combination of field studies and survey. A random sampling technique was used for this study. Participatory and structured questionnaires were used for the collection of primary data. The population of the study comprises of focus groups (youths, Chiefs and Baales, women, men, children, and disabled/handicapped) some of which also double as stakeholders/head of households within the study areas. A total of 300 households were sampled in the communities for the administration of questionnaire and interview. The sample size was selected using standard method described by Yamane [10].

Field studies were carried out to determine the following: General farming system; types of technology being adopted; number of people involved in the activities; types of crops; fishing/farming inputs and outputs; types of fishing crafts/ gears, uses and sizes; catch compositions; catch per unit effort; earnings from fisheries and other sources of income.

Survey work included reconnaissance visits, administration of structured questionnaires and group discussions to ascertain the existing socio-economic conditions and livelihood of the indigenous people.

4. Results and Discussion

Based on the structured questionnaires adopted for this study, some responses are qualitative in nature such as those that indicate availability or none availability, while some questions required quantitative answers. In addition some respondents were unwilling to give estimate in term of quantity of what they possess. The relative impact of the project on the visited communities is as presented in Table 1. The communities that are going to be completely displaced and relocated are Gberefu, Yovoyan, Agonvi sea beach, Gayingbo sea beach, Hoke daho, Kujinada, Agorin town and Mudawa community. The displacement will result in their loss of forest, access to the ocean, creek, lagoon, fishing and farm land. In relative terms, fishing will be the most harshly affected (lagoon, creek and marine). This kind of displacement of people of their main livelihood has been documented in regards to how oil sector generally has negative impacts on fisheries livelihoods and coastal communities, however these effects and their mechanisms vary across locations, ecosystems, species, and specific activities and groups [11].

As recorded during this study, more male headed households (MHH) will be impacted than female headed households (FHH) although the margin of impact is not significant (p=0.5). This insignificant gender difference indicated that both males and females are active in the social economy of the communities. Members of the community that will be mostly affected (49%) are those that have all their means of livelihood within the community. This group does not have alternative income source outside the community and are mostly aged men and women. Those moderately impacted constitute about 27% of the community members and are those that have access to financial facilities (bank, cooperative loans etc.) and have alternative livelihoods. About 24% of the community members will be least affected. These groups are literate that have access to financial facilities such as bank and cooperative loans. In addition, they have alternative livelihoods with dual homes within and outside the community.

Table 1. Relative impact of the project on the communities

Level/pattern of impact	Communities/groups
(a) Communities that will lose land but not be resettled	i. Gbaji yeke ii. Gayingbo town iii. Agonvi town etc
(b) Communities that will be resettled and lose land	i. Gberefu ii. Yovoyan iii. Agonvi sea beach iv. Gayingbo sea beach v. Hoke daho vi. Kujinada vii. Agorin town viii. Mudawa community
(c) Those at the resettlement sites who will lose land for the resettlement sites	i. Gberefu
(d) Not lose land and not be resettled but who may otherwise be affected	i. Tenants to land owners ii. Market associations iii. Producers associations iv. Transport associations

Table 2 contains the total number of livelihood encountered in the fishing communities. The total number of livelihood encountered was 73. The numbers contained in the table indicate the relative importance of the livelihood. N/A indicates that the livelihood is not available within the community. When available in very low significance it is simply classified as available. The top 5 livelihood activities for the Project Area are coconut farming, capture fishing, cassava farming, vegetables farming and mat weaving. In general, the first five livelihoods can be summary as:

i. The types of coconut planted in the affected communities are improved and local varieties.
ii. The type of fisheries in the affected communities

are categorized into marine artisanal capture fisheries, lagoon capture fisheries, creek/swamp capture fisheries while the aquaculture systems in practice are earthen ponds, concrete ponds and cage based.

iii. The types of cassava planted in the affected communities are the 7 months, 9 months and 12 months varieties.

iv. The 5 main types of vegetables planted in the affected communities are Amaranthus, tomato, pepper, okro and fluted pumpkin.

v. The types of mart weaving produced in the affected communities can be categorized as big, medium and small size.

Table 3 showed the synopsis of the livelihood analysis for the communities. Households surveyed shows the community employ a range of different livelihood strategies such as tree and arable crop farming (coconut, cassava, maize, cowpea, palm tree, raffia palm, vegetables, water melon, melon bread fruit, guava, sweet potato, yam, ground nut, pineapple, etc), fishing (ocean, marine, lagoon, creek, swamp and aquaculture), livestock (cow, pig, chicken, duck, rabbit, cat, dog, pigeon, grass cutter etc.) trading (food stuff, provisions, cosmetics, beer parlor, restaurant, etc.), artisans (brick laying, furniture, electrician, plumbing, photography, etc), including paid employment, casual labour, government and complementary family supports. In most cases, households benefit from more than one income generating activities in order to keep with the semi-urban economy. Coconut farmers and fisher folks appear to be the richest among other agricultural enterprises. Coconut farming is the largest sources of income in all the communities surveyed as shown in the ranking status. However, no household is specific with their earning income from agricultural activities.

There is no cultural restriction to gender on the type of livelihood activities. However, apart from few women who function effectively in the on-farm activity, most women engage in the off farm, marketing and nonfarm activities. Mostly, the male adults are into tree and arable crop farming, artisanal fishing and livestock (cow, pig, dog, grass cutter and pigeon) farming. The adult females are into fish processing, mat weaving and off-farm activities. The youth apart from few, who engage in farming and processing, they function majorly at the non-farm activities. Coconut, cassava and capture fisheries are the three major livelihoods common to all the affected communities. Some of the observations in this study especially on the fisheries were not too far distinct from the reported proposed impacts of oil exploration on wetlands in the Niger Delta of Nigeria [12].

The seasonal calendar of Gberefu community for livelihoods planning was shown in Table 4. The most frequent activities (engage in throughout the year) were livestock /fishing, off farm activities, marketing and non-farm activities.

Table 2. Livelihood systems of the communities

S/n	Livelihood	Gberefu	Yovoyan	Ganyingbo sea beach	Kujinada	Agonrin town	Agonvi town	Agonvi sea beach	Gbaji yeke tome	Hoke daho	Sheik modawa	Ganyingbo town
1	Coconut	13	7	14	Available	Available	Available	Available	Available	57	Available	Available
2	Cassava	30	46	11	Available	Available	Available	Available	Available	59	Available	Available
3	Maize	25	7	9	Available	Available	Available	Available	Available	18	Available	Available
4	Palm tree	Available	Available	4	Available	Available	Available	Available	Available	46	Available	Available
5	Marine fishing	Available	43	Available	Available	Available	N/A	Available	N/A	N/A	N/A	N/A
6	Lagoon fishing	Available	N/A	5	Available	Available	Available	N/A	N/A	Available	N/A	Available
7	Creek fishing	Available	N/A	N/A	Available	N/A	Available	N/A	N/A	Available	N/A	N/A
8	Swamp fishing	N/A	N/A	N/A	N/A	Available	Available	Available	Available	N/A	N/A	Available
9	Aquaculture	Available	1	Available	Available	Available	Available	N/A	Available	7	Available	Available
10	Amarantus	Available	Available	Available	Available	Available	Available	Available	Available	23	Available	Available
11	Tomato	8	10	9	Available	Available	Available	Available	Available	25	Available	Available
12	Pepper	12	3	9	Available	Available	Available	Available	Available	16	Available	Available
13	Chochorous	Available	2	9	Available	Available	Available	Available	Available	Available	Available	Available
14	Pumpkin	Available	N/A	9	Available	Available	Available	Available	Available	Available	Available	Available
15	Okro	15	10	9	Available	Available	Available	Available	Available	13	Available	Available
16	Water leave	Available	N/A	Available	N/A	Available	Available	Available	Available	N/A	Available	Available
17	Bitter leave	Available	N/A	Available	N/A	Available	Available	Available	Available	29	Available	Available
18	Saint leave	Available	N/A	Available	N/A	Available	Available	Available	Available	10	Available	Available
19	Yam	11	N/A	Available	Available	Available	Available	Available	Available	2	Available	Available

20	cowpea	Available	6	Available	Available	Available	Available	Available	Available	11	Available	Available
21	Sugarcane	Available	1	Available	N/A	Available	Available	Available	Available	7	Available	N/A
22	Ground nut	Available	2	Available	Available	Available	Available	Available	Available	1	Available	N/A
23	Sweet potato	10	3	Available	Available	Available	Available	Available	Available	3	Available	N/A
24	Banana	Available	1	Available	Available	Available	Available	Available	Available	19	Available	Available
25	Cow	Available	Available	Available	Available	Available	Available	Available	Available	6	Available	Available
26	Plantain	Available	1	Available	Available	Available	Available	Available	Available	24	Available	Available
27	Guava	Available	N/A	N/A		Available	Available	Available	N/A	2	Available	Available
28	Pawpaw	Available	N/A	Available	Available	Available	Available	Available	Available	16	Available	Available
29	Cashew	Available	Available	Available	Available	Available	Available	Available	Available	3	Available	Available
30	Pineapple	Available	N/A	Available	N/A	Available	Available	Available	Available	22	Available	Available
31	Water melon	Available	N/A	Available	N/A	Available	Available	Available	Available		Available	Available
32	Mango	Available	1	Available	Available	Available	Available	Available	Available	43	Available	Available
33	Sheep	Available	Available	N/A	Available	Available	N/A	Available	N/A	N/A	Available	N/A
34	Goat	Available	Available	Available	Available	Available	Available	Available	Available	21	Available	Available
35	Chicken	Available	Available	Available	Available	Available	Available	Available	Available	35	Available	Available
36	Pig	Available	Available	Available	Available	Available	Available	Available	Available	9	N/A	Available
37	Guinea fowl	Available	Available	Available	Available	Available	Available	Available	Available	Available		N/A
38	Duck	Available	Available	Available	Available	Available	Available	Available	Available	19	Available	Available
39	Rabbit	Available	Available	Available	Available	Available	N/A	Available	Available	1	Available	N/A
40	Snail	Available	Available	Available	Available	Available	Available	Available	Available	N/A	Available	N/A
41	Cat	Available	Available	Available	Available	Available	Available	Available	Available	11	Available	Available
42	Dog	Available	Available	Available	Available	Available	Available	Available	Available	19	Available	Available
43	Ram	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Available	N/A
44	Sand mining	Available	N/A	4	N/A	Available	Available	N/A	N/A	Available	N/A	N/A
45	Raffia palm	Available	Available	Available	Available	Available	Available	Available	Available	Available	Available	Available
46	Fish smoking	Available	55	Available	Available	Available	Available	Available	Available	Available	Available	Available
47	Ifin (mart)	Available	Available	Available	Available	Available	Available	Available	Available	Available	Available	Available
48	Trading	35	27	11	46	Available	Available	Available	Available	Available	Available	Available
49	Maize/ cassava processing and mart weaving	Available	2	Available	Available	Available	Available	Available	Available	Available	Available	Available
50	Firewood	Available	5	Available	Available	Available	Available	Available	Available	Available	Available	Available
51	Marketing	Available	Available	Available	Available	Available	Available	Available	Available	Available	Available	Available
52	Artisans	Available	11	5	Available	Available	Available	Available	Available	Available	Available	Available
53	Paid employment	7	14	Available	Available	Available	Available	Available	Available	Available	Available	Available
54	Palm wine tapper	Available	1	Available	N/A	Available	Available	Available	Available	Available	N/A	Available
55	Farm labour	Available	2	Available	Available	Available	Available	Available	Available	Available	N/A	Available
56	Horse	N/A	N/A	N/A	Available	Available	N/A	Available	N/A	N/A	N/A	N/A
57	Giant rat	N/A	N/A	Available	Available	N/A	Available	Available	N/A	N/A	Available	N/A
58	Bread fruits	N/A	N/A	N/A	N/A	Available	Available	N/A	N/A	3	N/A	Available
59	Citrus	Available	N/A	Available	Available	Available	Available	Available	Available	14	Available	Available
60	Cocoyam	Available	N/A	N/A	Available	Available	Available	Available	N/A	Available	Available	Available
61	Chap-chap	N/A	N/A	N/A	N/A	Available	N/A	N/A	N/A	4	N/A	N/A
62	Turkey	N/A	N/A	N/A	Available	Available	Available	Available	Available	1	Available	N/A
63	Moringa	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Available	Available	Available
64	Pigeon	N/A	N/A	N/A	N/A	Available	N/A	Available	N/A		Available	N/A
65	Grass cutter	N/A	N/A	N/A	Available	Available	N/A	Available	N/A		N/A	N/A
66	Aloe vera	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2	N/A	N/A
67	Lemon grass	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	9	Available	N/A
68	Oyinkekere	N/A	N/A	N/A	N/A	N/A	N/A	Available	N/A		Available	N/A
69	Ahokun	N/A	N/A	N/A	N/A	N/A	N/A	Available	N/A		Available	N/A
70	Ozini	N/A	N/A	N/A	N/A	N/A	N/A	Available	N/A		Available	N/A
71	Onion	N/A	N/A	N/A	N/A	N/A	N/A	Available	N/A		N/A	N/A
72	Isapa	N/A	N/A	N/A	N/A	N/A	N/A	Available	N/A	N/A	Available	N/A
73	Native doctors (herberlist)	Available	Available	Available	Available	Available	Available	Available	Available	2	Available	Available

Table 3. Livelihood Analysis for the Communities

Livelihood Activities	Ranking	Tools and implement	Sources of funding	Market options	Market distance
Rain fed farming		Land	Cooperatives	Agbalata	10km
Cassava	2	Water	Thrift	Seme	20km
Maize	3	Hoe	Pension	Igoga zebe	50km
Sweet potato	8	Tractor	Savings	Agbara	50km
Cowpea	7	Cutlass		Lusada	60km
Yam	9	Fertilizer		Owode	
Melon	13	Herbicides		Agunmo	50km
Ground nut	10	Pesticides		New market Ajara	7km
Pineapple	14	Manure			
Water melon	15	Sprayer			
		Labour			
		Pumping machine			
Irrigation farming					
Tomato	4				
Pepper	4				
Okro	5				
Chochorous	6				
Ugwu	6				
Amarantus	6				
Water leave	6				
Bitter leave	6				
Tree crop					
Coconut	1				
Mango	11				
Pawpaw	15				
Cashew	11				
Palm tree	1				
Plantain	12				
Banana	12				
Livestock		-Pen house	Cooperatives	Agbalata	10km
Cow	1	-Vaccines and	Thrift	Seme	20km
Sheep	7	treatment by	Pension	Igoga zebe	50km
Goat	3	veterinary officer	Savings	Agbara	50km
Pig	2	-Lantern for heating		Lusada	60km
Guinea fowl	4			Owode	
Duck	10			Agunmo	50km
Rabbit	7			New market Ajara	7km
Chicken	4				
Snail	8				
Cat	9				
Dog	5				
Alegator	11				
Fishing		Net	Cooperatives	Farm gate	2km
Marine		Boat/engine	Thrift	Inside the community	
Lagoon		Ponds	Pension		
Creek			Savings		
Aquaculture					
Off-farm activities				Farm gate	2km
-Smoking of fish, cray fish, sea tortoise				Inside the community	
-Cassava processing to garri, apran, fufu					
-Sun drying of cowpea, melon, maize					
Marketing Activities				Farm gate	2km
-Fish catch is sold to women who sell some to traders and process the rest as smoked fish				Inside the community	
-Crop produce is sold to women and also at farm gate. Women process and market the product					
-Produce by youth is sold at farm gate to traders who take it to market					
-Livestock are sold to traders/women who take it to market					

Non-farm activities Tailoring Art and printing Textile design Brick laying Culture design Aluminum Civil servants Teaching Traders Carpentry Plumbing Hair dressing Mechanic Welder Hunting Transportation Clergy Herbalist Sand mining Smuggling Car dealers					

Table 4. Seasonal Calendar of Gberefu community for livelihoods planning

Months	**Mar**	**Apr**	**Ma**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**
Activities 1.Rain fed farming -Land clearing (M/F) -Ridges (M) -Planting (M/F) -weeding (M/F) -Harvesting (M/F)	 * 	 * 	 * * 	 * 	 * 	 * 						
2.Irrigation -Land clearing (M/F) -Planting (M/F) -Weeding (M/F) -Harvesting (M/F)									 * 	 * * 	 *	 *
3. livestock /fishing (M&F)	*	*	*	*	*	*	*	*	*	*	*	*
4. Off-farm Activities ● Drying (F) ● Frying (F) ● Bagging (M&F) ● Store/preserve.(M&W)	 * * * *	 * * * *	 * * * *	 * * * *	 * * * *	 * * * *	 * * * *	 * * * *	 * * * *	 * * * *	 * * * *	 * * * *
5.Marketing Activities (M&W)	*	*	*	*	*	*	*	*	*	*	*	*
6. Non-farm Activities ● Transportation (M) ● Artisans (M&F) ● Abattoir(M&F) ● Trading (M& F) ● Civil servant/pension M&F ● Clergy ● Herbalist	 * * * * * * *	 * * * * * * *	 * * * * * * *	 * * * * * * *	 * * * * * * *	 * * * * * * *	 * * * * * * *	 * * * * * * *	 * * * * * * *	 * * * * * * *	 * * * * * * *	 * * * * * * *
7. Income Expenditure	 *	 *	 *	* *	* *	* *	* *				*	

Although Badagry is a fishing community, the livelihoods are both water and land based as presented in Table 5. The household classification below gives the communities' description of their local criteria on how the project will impact on members of the communities. Some communities believe the project will impact on certain gender and sex differently. Some however, believe the age distribution is a major dividing line for assessing levels of impact while some opined that indigenes of the communities have all their livelihood activities within the communities than non indigenes. Lastly, some communities affirmed that the project would impact more on people who carry out all their livelihood activities in the swamps which are being displaced than others who hardly go to the swamps. The general impacts are itemized below:

i. Youth will no longer be able to mine sand.
ii. Women will have to spend more money and time to access markets.
iii. Capture fishing (marine, lagoon, creeks and swamps) will be restricted in the resettlement site.
iv. Fish smoking by women will be restricted.
v. Loss of income for people doing aquaculture because they cannot stock new fingerlings.
vi. Farmers may not have proportional farm lands taken by the project in the resettlement sites.
vii. No income for crop farmers (coconut, palm tree, cassava, cashew, mango, maize, vegetables etc.) until the first harvest in the resettlement site e.g. coconut- 7 years, cassava- 9 months.
viii. Women will spend more money to buy leaves (ifin) used for making mart until the first harvest in the resettlement site.
ix. There will be high mortality rate for livestock because of adaptability to new environment.
x. Men will spend more money to maintain their social life because the local gin and wine made from their palm tree cannot be accessed until the first harvest in the resettlement site.
xi. Processors (women) will spend more money in buying farm produce (cassava, maize etc.) for processing from the market in place of buying from the communities.
xii. Youth and boys will spend more time in fetching firewood.
xiii. Artisans will spend more time and money on transport to locate their clients.
xiv. No income for native doctors who depend on herbs until the next harvest in the resettlement site.
xv. Gberefu community will lose patronage on their tourist center (slave trade point of no return).
xvi. Agonrin will lose patronage on their tourist center (southern beach).
xvii. Loss of income for local transport associations in the displaced sites.
xviii. Loss of income for people hawking in the displaced site.
xix. Affected communities will spend more time and resources in rebuilding trust and social integrations in the resettlement site.
xx. Traders and farmers will lose financial capital pending the time they are able to rebuild their trust and social integrations in the resettlement site. The above divulged opinion of the respondents in the sampled communities is in line with the report [4,5].

Table 5. Classification by Location of some livelihood activities in the impacted areas

Activities	Land based	Water based
Aquaculture/fish farming		●
Marketing of farm produce	●	
Marine fishing		●
Lagoon fishing		●
Creek/swamp fishing		●
House renting	●	
Fish smoking	●	
Tourism	●	●
Trading	●	
Livestock	●	
Mat weaving	●	
Artisans	●	
Paid employment	●	

4.1 Key Findings around the Value Chain Vis-À-Vis Potential Impacts

Agriculture value chain analysis for this study revealed that all activities (input supply - production - processing-wholesale - retail - consumption) will be impacted by the project. The project is going to disconnect the existing value chains and displace the actors in the chain. This is because chain actors perform functions that are interdependent on each other. They also undertake joint activities (innovation, policy dialogue) and maintain a chain governance system. It was noted that some livelihood are ethnic and village specific as presented in Tables 6 and 7 respectively. In addition, some activities are gender and age related as outlined below:

i. Hawking (boys and girls)
ii. Fish Smoking(women)

iii. Mat weaving (women)
iv. Pap (eko) leaves (women)
v. Marketing of fish(women)
vi. Vigilante groups(odua people congress)
vii. Non farming activities (youth, men and women)
viii. Farming (men and women)
ix. Livestock (men and women)
x. Sand mining (youth)

Table 6. Livelihoods specific to ethnic groups

Livelihood	Ethnic groups
Cattle	Fulani and coconut farmers who are sometimes indigenes
Marine beach seine(Dogbo)	Ghanaian(foreigners)
Marine pelagic and bottom fishing	Ilaje, Egun and Ijaw
Lagoon fishing	Egun
Creek and swamp fishing	Egun
Farming	Yoruba, Egun, Tenants eg Ibos, Edo etc

Table 7. Livelihoods specific to a village

Livelihood	Village
Hatchery	Hoke daho
Islamic school	Sheik Modawa
Marine beach seine (Dogbo)	Gberefu
Tourism	Gberefu, Agonrin

4.2 Potential Project Impacts on Livelihoods

The project will have great impact on financial, social, human, natural and physical assets as described below:

4.2.1 Financial Asset

The financial resources available in the affected community include income, savings, credit, debt, remittances and pension. The assessment observed that livelihood displacement would affect peoples' financial capital thus leading to loss of job and higher transport cost among the challenges. The findings of this study also identified that renting out houses is a means of income for some of residents in the community. This is because Badagry is in the outskirt of Lagos State and houses are affordable to lower income people in the area.

4.2.2 Social Asset

Social assets have implications for sustainable livelihood [13]. Social network was seen to enhance transfer of information, material goods and services in the affected communities. Observation in some communities shows there is the possibility of social disintegration as a result of physical and economic displacement. Specifically, conflicts among households when discussing the project impacts was observed which may likely damage the social networks. It was observed that the communities have long established social asset that used to help them out at a time of hardship. They lived for many years to understand attitudes of neighbour and community members and this has helped them to know each other well and develop culture of reciprocity, support and trust which manifested in child care, looking after homes when they are away, information exchange, borrowing money, borrowing foodstuff etc.

4.2.3 Human Asset

Human asset has both quantitative and qualitative dimension. The former refer to the number of household members and time available to engage in income-earning activities, whereas the later refer to the skills, education, ability to work and health status and physical capital of household member important for the successful pursuit of livelihood [13]. Focus group discussion (FGD) revealed that farm labour is a major livelihood means for unskilled youth. Livelihood displacement will lead to a situation of decline of the number of those household members who were involved in income-earning activity due to new resettlement site that may not be suitable to carry out informal activities and high transport cost to get the former location work place. Time available to take part in income earning activity for households will therefore reduced. However, the number of labour force in household may increase following relocation. This may include people who may have interest in another income-earning activities, such as guard and driver. Also, children either after school hours or by dropping out of school are engaged in income-earning activity to support households' livelihood.

4.2.4 Natural Asset

The project will greatly impact on the natural asset of the communities. This is because most livelihood activities are water and land based which constitute part of the natural asset. Other natural assess to be impacted upon includes natural resource stocks such as soil, air and genetic resources; and environmental services such as hydrological cycle, pollution sinks from which resource flows and services useful for livelihoods are derived.

4.2.5 Physical Asset

Physical asset comprises basic infrastructure and productive goods used in supporting livelihoods such as shops/kiosks, boats, canoes, hooks, nets, buildings, pen houses, farm inputs, affordable transport, secured

shelter and adequate water supply and sanitation, clean and affordable energy and access to information and communication systems. It is pertinent to note that, lower income people rents apartment in the communities. Hence, displacement most especially to places not accessible to main roads could make tenants not to follow the displaced community. The implication therefore, will mean landlords will lose income in this area. Alternatively, one may conclude the project will bring about development in the area. However, development would mean standard accommodations will be given out for rent which the indigenous landlords may not be able to afford.

4.3 Analysis of Current Resettlement Sites

There are five resettlement sites for all the affected communities. These sites have proximity to other neighboring communities which will help to rebuild social market, and financial institutions in the resettlement site. Physical inspection to the sites revealed the possibility of restoring land based livelihoods. However, Gberefu is the only site out of the five sites that has the possibility of restoring capture fishing livelihoods. The study of their value chain in the table below shows the various stakeholders directly or indirectly involved in the chains in the study areas.

Table 8. Value chain classification in the communities

S/n	Category of actors	Description
1.	Main Chain Actors	**Producers** (farmers/fisher folks) **Processors** (small-scale, large-scale) **Traders** (wholesalers, retailers,) **Consumers** (small-scale consumers, industrial consumers)
2.	Chain Supporters	**Finance institutions (**Micro Finance Institutions, Cooperatives, Farmers Association, BOA**)** **Research institutes (**IITA, RTEP**)** **NGOs (** LAPO**)** **Input Suppliers, Haulage services, Extension services from Ministry of Agric/ ADA**
3.	Chain Context.	Government policies, Advocacy, International trade policies

4.3.1 System Efficiency of Cassava Value Chain in the Communities

There are no ready markets for cassava produced by farmers as they have to scout for market although they supply the garri processing unit. The processors on the other hand have a market for their products as they have traders (retailers and wholesalers) who patronize them, buy the processed garri and distribute to peri- urban and urban markets in Lagos. Kraku, Apran and Ajongun are some form of cassava cakes the communities' values as they eat along with pap. The system is not totally efficient as not all products are effectively utilized e.g cassava leaves and peels are left to rot, while a lesser proportion is fed to farm animals. Price fluctuation in the market also plays a huge role in marketing of cassava products, as high handling and transportation costs affect the profitability of the enterprise.

Table 9. Cassava value chain

S/N	Actors	Products
1	**Producers** (farmers)	Stem Cuttings, Cassava Tubers, Cassava Leaves
2	**Processors**	Garri, starch, cassava flour, cassava peels, kraku, apran, ajongun
3	**Traders**	Marketing of product

4.3.2 System Efficiency of Coconut Value Chain in the Communities

There are ready made markets (retailers and wholesalers) for coconut produced by farmers as they often supply lesser quantities to market demand. The trunk and leaves are used for brooms, furniture and fencing. However, the system is not efficient for the value added product most especially the oil. They lack the capacity in terms of expertise and equipment to process the oil. What obtains presently in the communities are the crude form of extraction been process into 'adin-agbon'. The system is not totally efficient as not all products are effectively utilized e.g water coming from coconut can be well packaged and serve as refreshing drink.

Table 10. Coconut value chain

S/N	Actors	Products
1	**Producers** (farmers)	Kernel, coconut water as a refreshing drink, husk, hard shell, leaves and trunk
2	**Processors**	copra, oil, cake, milk, brooms
3	**Traders**	Marketing of product

4.3.3 System Efficiency of Capture Fisheries Value Chain in the Communities

There are ready made markets (retailers and wholesalers) for Capture fish eries and aquaculture. In most cases, traders and consumers pay money ahead before the fish is catch. Most customers prefer the fish fresh but as a result of inefficient electricity supply, women process it inform of smoking, frying and drying. The system is not totally efficient as this fish are not smoked and dried to standard required most especially for international trade.

Table 11. Capture fisheries value chain

S/N	Actors	Products
1	**Producers** (farmers)	Tilapia, shark,
2	**Processors**	Salting, frying, smoking, drying, storage
3	**Traders**	Marketing of product

Relationships exist between different actors within the chain (e.g. between producers and traders) and within the same process step (e.g. farmer to farmer and fisher folk to fisher folk). The fish and cassava value chains observed in the cause of the field practicum, revealed that there wereSpot market relations between the traders, producers (farmers) and processors, as buyer(traders) and seller (farmers and processors) meet, come to an agreement (or not) and break up the relationship**.** APersistent network relationship was also observed as processors in the cassava processing cluster, and other actors have a preference for transacting with each other time and time again as higher level of trust and some level of interdependence has been established between the actors, although there are no formal contracts between actors. Horizontal integration also exists along the chain as the producers and processors have gone into cooperation, hence both actors share the same (legal) ownership. One and the same organisation deals with different processes throughout the value chains. There is a high level of commitment between the producers and processors along the chains.

The value chains for fish and cassava products describe the flow of produce from harvest to market. Each step in a value chains may be associated with different actors and additional activities through which different fish and cassava products and, added value, is generated. The project impact on fish and cassava products may inadvertently have impacts on the value chain and the actors therein. The nature of the value chains is situation specific; fish processing may occur as a matter of necessity or of choice. While recognizing that for certain fish species the intended (marketable) product is dried fish, in many areas the lack of markets, services (i.e., cold storage, transportation) and utilities (electricity) requires the use of smoking, drying and salting to allow for storage and sale of fish harvests at a later date at more distant fish markets. Markets for fresh and processed fish in the communities includemiddlemen (often local village traders and wives of fisher folks who provide credit, inputs and have cold storage facilities); community fish marketing cooperatives, local fish markets; and established clients, including traders and end users (e.g., restaurants).

4.4 Earning from Capture Fishing in the Affected Communities

The summary of amounts earned daily from capture fishing in the affected communities is presented in Table 12. The figures captured in the table were provided by the communities during the Focus Group Discussion. Some appeared to have been inflated but a mean value as calculated and provided could be a better refection of the reality and be applicable in the absence of further field work to verify the claims. Beach seine was observed to be done exclusively by Ghanaians in Yovoyan and Gberefu communities and it involves adult males, women and youths.

Table 12. Summary of earning from capture fishing in the affected communities

Communities	Income for dragger in beach seine(N)	Income for setter in beach seine(N)	Income for owner in seine net	Income for crew in a medium boat(N)	Income for medium boat owner	Income for crew in a small boat(N)	Income for small boat owner(N)	Lagoon fishing crew)	Owner	Creek fishing(crew)	Owner
Gberefu	2,000	2600	**100,000**	**N/A**	**N/A**	**N/A**	**N/A**	**2,500**	**12,500**	**6,000**	**6,000**
Yovoyan	2,000	2,600	100,000	8,333	33,333	12,333	23,333	N/A	N/A	N/A	N/A
Ganyinbo Sea Beach	2,000	2.6	100,000	11,666	58,300	11,110	33,333	7,777	23,333	10,000	20,000
Gbaji – Yeke – Tome	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1000	3,000
Kujinada	2,000	2,600	100,000	11,666	58,300	11,110	33,333	7,777	23,333	10,000	20,000
Agonrin	2736	3621	136,792	5,000	20,000	3,333	10,000	N/A	N/A	2,166	4,333
Agonvi Town	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	3750	7500
Agonvi Sea Beach	4,000	8,333	**100,000**	**3,444**	**10,333**	**1000**	**3,000**	**N/A**	**N/A**	**7,500**	**15,000**
Ganyinbo Town	N/A	N/A	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**5,000**	**20,000**
Hoke Daho	N/A	N/A	N/A	12,500	37,000	N/A	N/A	3750	7,500	1000	2000
Total	14,736	19,757	636,792	52,609	217,266	38,886	102,999	21,804	66,666	46,416	97,833
Mean	**1,228**	**1,646**	**53,066**	**4,384**	**18,106**	**3,241**	**8,583**	**1,817**	**5,556**	**3,868**	**8,153**
Range	**2,000**	4,733	36,792	9,056	47,967	7,777	30,333	4,027	15,833	9,000	18,000

N/A means not applicable

4.4.1 Women Role in Capture Fishing

The women do the marketing just like any other fishing communities in Nigeria. The fish is usually bought from the husband in cash when there is scarcity but when fish is in excess the women are allowed to buy and pay after sales. The cost price is N500/kg and the women sell to their customers at N750/Kg at the landing site. When in large quantity, the excess is smoked. Table 13 showed what marine fish smoker needed to smoke a 40 kg fish.

Table 13. A typical requirement of a marine fish smoker

Item	Cost(N)	Quantity
Drum	3,000	1
Wire gauze	3,000	2
Wood	3,000	Bulk
Fresh fish	20,000	40kg
Sales	3,000/kg	10kg

5. Recommendations for Resettlement Site Selection Process

The primary means of livelihood in Badagry is agriculture and the communities over the years have been involved in various agricultural enterprises which are either land or water based. Thus, resettlement site selection should consider the various livelihood activities surveyed in the livelihood analysis table in close collaboration with affected communities.

Tree crops such as coconut, palm tree, raffia palm, mango, citrus, cashew, pawpaw, bread fruit and guava constitute major means of livelihood in this area. These crops take a minimum of 3 to 7 years to be raised to fruiting stage. It is therefore recommended that tree crops should be the first set of livelihoods to be restored afterdialogue with the affected communities. This will require high level of interaction with the affected people, in order to develop the most feasible mitigation measures. The agreed mitigation measures, being a form of compensation, will be incorporated into formal collective and/or individual agreements. To the extent possible, the agreed mitigation measures will be described and quantified in these agreements, so the affected people may evaluate what they are getting as compared to what they are giving up.

The goal is that no person will suffer an economic loss due to the project. Thus, mitigation measures will be planned to take account of each individual situation, and not aggregate measures of economic benefits. Individuals within an affected household, for example men, women, youth, boys, girls, aged, will be considered to have equal entitlement to any livelihood restoration measures in as must should be much that they are involved in the livelihood process.

The assumption is that every livelihood actors will benefit and pass through a period of transition before their livelihoods can be restored and improved upon. However, since the affected communities cannot kick start their livelihood activities immediately in the resettlement site; the plan below gives details of transitional activities to be implemented (Appendix A).

A livelihood transitional program is the process of protecting and promoting the livelihoods of affected communities recovering from displacement [14].The objective of the transitional programme is to, provide cash grant and short-term income transfers as a safety measure for the community to help them commence the process of livelihood restoration. There ought to be rebuilding of households, community assets and local institutions.

Livelihood Transition programs are put in place to cushion the effect of the displacement or deprivation of land or any other means of livelihood prior to restoration. In relation to capture fishing payment of daily income should be made to the people below: fishermen, youths, wives who are the marketers, Boat owners. This should take place from the time the boat owner starts moving with his household to the time he is able to return from the first fishing voyage. The cost of moving the household and assets could equally be defrayed.

As for aquaculture,the following are suggested: the salary of workers should be paid, the income of the owner from the farm until the ponds are fully constructed and the first harvest is done.

As for cassava processors (Garri) women are used to buy cassava tubers from their husband and kinsmen in their communities. Displacement would mean they cannot buy cassava tubers from their husband during the period of transition. Thus, alternative would mean buying from outside the community. Therefore, transport allowance would be paid to such processors for the extra distance they will have to cover during the period of transition for cassava producers.

For land based livelihoods, the market value of land of equal productive use or potential land located in the vicinity of the affected land, plus the cost of preparation to levels similar to/or better than those of the affected land, plus the cost of any registration and transfer taxes should be paid as compensation apart from transition allowances. It is noteworthy to divulge that a major challenge encounter during the field work was a glaring lack of skill in the farmers and fishermen including fish farmer who require training in all aspects of fishing and fish farming.

Thus, the followings are recommended:

i. The starting point of the restoration program should be delivery of relevant skill through training in all aspects of land based livelihoods and fishing.

ii. With the construction of a sea port, new opportunities will come up and the youth should be trained in readiness for absorption into the workforce.

iii. Replacement of fish ponds and hatcheries in the new location as well as improved agronomic practices for farming.

iv.Distribution of improved seeds and production of inputs to speed up crop growth

v.Restocking and rebuilding livestock and pen house.

Some other key suggested activities to be executed during the transition, restoration and improvement programs for the affected communities were highlighted in Appendix B while Appendix C proffer recommendations on major activities that can facilitate prompt restoration of the communities'livelihood after displacement

6. Conclusions

This study highly recognized the significance of establishing sea port within the study area, as port development has strong backward and forward linkages to the coastal communities and the national economy at large. In like manner, sustainability of the livelihood of the people, most especially the fishermen and aquaculturist in these communities are very important. Therefore, the study has provided baseline information for government or policy maker to work on before the commencement of this laudable project.

Conflict of Interest

We declare that there are no competing interests.

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References

[1] Hodder, B.W., 1962. Badagry 1:Slave Port and Mission Center in Nigeria. Geographical Journal. 5(2), 75-86.

[2] Simpson, A., 1994. Badagry: The Religious function of Agbalata Market. G.O. Ogunremi, M.O. Opeloye and Suju Oyrweso editors-Badagry: A study on history, culture and tradition of Ancient city.Ibadan Rex. Publication, pp. 305-313.

[3] Simpson, A., 2004. Oral Tradition and Slave Trade in Nigeria,Ghana and Bennin,Paris:United Nation Educational Scientific and Cultural Organization.

[4] Zann, L.P., 1995. Our sea, our future: major findings of the State of the Environment Report for Australia. Great Barrier Reef Marine Park Authority, Ocean Rescue 2000, Department of the Environment, Sport and Territories, Canberra.

[5] Edgar, G.J., Barrett, N.S., Graddon, D.J., 1999. A classification of Tasmanian estuaries and assessment of their conservation significance using ecological and physical attributes, population and land use.Tasmanian Aquaculture and Fisheries Institute, University of Tasmania, Technical Report No. 2.

[6] Coleman, N., Parry, G.D., Cogen, B.F., et al., 1999. Port Phillip Bay: biology, habitats and disturbance history. Hewitt, C.L., Campbell, M.L., Thresher, R.E. and Martin, R.B. (eds.) Marine biological invasions of Port Phillip Bay, Victoria. Centre for Research on Introduced Marine Pests. Technical Report No.20. CSIRO Marine Research, Hobart.

[7] Hewitt, C.L., Campbell, M.L., Thresher, R.E.,et al., 1999. Marine biological invasions of Port Phillip Bay, Victoria. Centre for Research on Introduced Marine Pests. Technical Report No. 20. CSIRO Marine Research, Hobart.

[8] Winstanley, R., 1995. Issues in the Victorian marine environment. Zann, L.P. (ed.) Our sea, our future: major findings of the State of the Environment Report for Australia, Technical Annex 3: State and Territory Issues. Great Barrier Reef Marine Park Authority, Ocean Rescue 2000, Department of the Environment, Sport and Territories, Canberra.

[9] Mekuleyi, G.O., Anetekhai, M.A., Aderinola, O.J.,et al., 2019.Environmental Health Status of Some Aquatic Ecosystems in Badagry Division of Lagos State, Southwest, Nigeria. International Journal of Ecotoxicology and Ecobiology. 4(4), 93-102.

[10] Yamane, T., 1967. Statistics: An Introductory Analysis, 2nd Ed., New York: Harper and Row.

[11] Nathan, A., Nathan, J.B., Philippe, L.B., et al., 2021. Oil, fisheries and coastal communities: A review of impacts on the environment, livelihoods, space and governance. Energy Research and Social Science. 75, 1-15.

[12] Victor, A.A., 2014.A Framework for Determining the Compensable Value of Damages Due to Contamination to Wetlands in the Niger Delta of Nigeria. A Thesis Submitted in Partial Fulfilment of the Requirements for the Award of the Degree of Doctor of Philosophy of the University of Salford, School of the Built Environment, pp. 1-367.

[13] IFRC, 2010. Guidelines for livelihoods programming.A report prepared by International Federation of Red Cross and Red Crescent Societies, Geneva.

[14] World Bank,1988. Resettlement in Development Projects, World Bank Technical Paper No. 80, Annex 1 (Washington, D.C, U.S.A.).

Appendix A. Livelihood Transition Program

Livelihood activity	**Gestation period**	**Size**		**Investment cost ₦**	**Income ₦**	**Profit ₦**
		Minimum holding	Maximum holding			
Cassava	9-12 months	1 plot	2ha	149,500/ha	180,000/ha	30,500/ha
Cassava processing	1 week	1pickup load	2 ton	78,800/tonne	90,000/tonnee	11,200/tonnne
Tomato	3 months	1 plot	2ha	270,000/acre	1,080,000/acre	810,000/acre
Coconut	7 years	3 plots	4 ha	1,001,000/acre	1,920,000/acre	919,000/acre/yr
Maize	3 months	1 plot	2 ha	42, 650/ha	73, 500/ha	30,850/ha
Marine fishing 1.beach seine 2.set net 3.pair trawling	1 week	 1 1 2	 1 65 22	 5,524,000 865,000 1,205,000	 5,000,000 150,000x2/day 105,000/day	

Footnote:

- The gestation period is the period under which the beneficiary will be entitled to transition allowance
- The profit is the allowance he will be entitled to during the period of transition
- Anybody taking cash compensation and is not willing to restore his/her livelihood will not benefit from the transition program

Appendix B. Suggested activities During Transition, Restoration and Improvement Programs

Activities
Transportation of people and assets in the affected communities to the resettlement site
Payment of allowance during transition period
Allocation of farm plots for crops, livestock and aquaculture to displaced households in the resettlement site
restoration of market access, financial services and transportation system
rehabilitation of institutional capacity, including local non-governmental and community-based organizations, and the local government
psychosocial counseling for households in the resettlement site
leadership training and civic education

Appendix C. Livelihood restoration activities

Livelihood restoration activity	**What impact will it address**	**Who will benefit**	**Specific activities**
Establishment of community based enterprises (CBE) through the creation of food processing centers and training	-Sand mining by youth -restricted fish smoking activities of women	-Youth -Women	-Acquisition of food processing machines such as bakery, cassava processing factory, oil mill -skill acquisition in specific trades such as catering, carpentry, fashion design, Masonry, computer training, hair dressing and welding/pipe fittings.
Establishment of a Fishing Terminal	Restricted capture fishing in the resettlement site. -restricted fish smoking activities of women	-Fisher folks -Youth -Women	-Berthing -Fuel dump -Fish processing plant -Cold storage facilities -Marketing& distribution -Boat building and repair -Net making and repair
Aggressive aquaculture development and distribution of fish fingerlings to farmers	Restricted capture fishing in the resettlement site. -restricted fish smoking activities of women Loss of income for people doing aquaculture because they cannot stock new fingerlings again	-Fisher folks -Youth -Women	-Earthen ponds construction with fingerlings and feeds -Concrete ponds construction with fingerlings and feeds -Fish cages with fingerlings and feeds -Training on feeds formulation
Introduction of light mechanization program to reduce drudgery and entice youth to agriculture	Sand mining practices of youth Inaccessibility to proportional farm land taken by the project	-Youth -Farmers	Acquisition of community based tractors, planters and harvesters

Introduction of new land management practices based on soil testing and analysis and introduction of technical innovations	Inaccessibility to proportional farm land taken by the project	-Farmers	-soil test and analysis to identify specific crops for specific communities -Dissemination of appropriate technologies to farmers -Creation of cooperatives and associations to ensure the technical innovations are received, applied, managed and promoted in the best possible ways by the target farmers
Rapid multiplication and distribution of improved high yielding seed varieties of principal food crops that are resistant to pest and disease adapted to local climate and environment introduced by research institutions	Inaccessibility to proportional farm land taken by the project	Farmers	12,000 bundles of improved cassava (CMD resistant) varieties 1000kg of high quality protein seeds 12,000 coconut suckers 12 various indigenous fruit trees
Harnessing the appropriate value chains and endowment of cooperative cottage enterprises with suitable agro-processing equipment for product transformation, value addition and market linkages	More time and money spent by women to access markets Restricted fish smoking activities of women Inaccessibility to proportional farm land taken by the project Sand mining practices of youth More time spent by money to buy leaves (ifin) used for making mart until the first harvest in the resettlement site More time and money spent by processors (women) in buying farm produce (cassava, maize etc.) for processing from the market in place of buying from the communities.	-Women -Youth -Farmers -Livestock farmers -Fisher folks	Value chain mapping for key agricultural commodities (coconut, cassava, vegetables and fisheries) Market mapping Acquisition of processing machines Establishment of agro processing industries
Information transmission on correct utilization of agricultural products, good nutrition and hygiene practices	high mortality rate for livestock because of adaptability to new environment	Livestock farmers	Veterinary services for livestock and distribution of parent stocks
Establishment of community based micro-credit scheme	Loss of income for people hawking in the displaced site More time and resources spent by the affected communities in rebuilding trust and social integrations in the resettlement site Lose of financial capital by traders and farmers pending the time they are able to rebuild their trust and social integrations in the resettlement site	Traders Women Youth Farmers Fisher folks Artisans	-Formation of groups and cooperatives -Introduction of community based seed fund system
Establishing tourist attraction centers	Gberefu community will lose patronage on their tourist center (slave trade point of no return) Agonrin will lose patronage on their tourist center (southern beach).	Gberefu Agonrin	Replication of slave trade point of no return Replication of southern beach

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REVIEW

Ecosystem Restoration: Enhancing Ecosystem Services with Floating Aquaculture

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ABSTRACT

Restoration ecologists recognize the need for restoring ecosystem services in sustainable ways that meet societal needs. In the UK, Ireland, Australia, and some US states the goal is restoring native oyster reefs. In other states, failures at restoration due to poor water quality and predation have focused restoration activities on techniques that work, restoring intertidal reefs and generating living shorelines that reduce or reverse erosion. In the United States, restoring water quality and reducing or reversing erosion are societally accepted entry points for repairing estuarine ecosystems. This study is an overview of the current status of oyster reef restoration and provide a novel approach called "oyster reef in a bag". Combining oyster reef restoration efforts with existing floating oyster aquaculture technology generates novel ecosystems that are a combination of biofouling and oyster reef communities. These novel ecosystems could be a practical beginning to improve water quality, mitigate erosion and restore higher trophic level ecosystem services.

1. Introduction

1.1 Perspective

This paper is a selective review and an opinion piece. Our main opinion is that in many regions of the world, oyster reef restoratoin to some former condition is untenable because of water quality and ecosystem changes. We suggest ways to enhance ecosystem services that include oyster reef restoration and that take advantage of the hybrid ecosystems that develop in floating bag oyster aquaculture. The hybrid system is a blend of a biofouling community and some aspects of oyster reef communities. New shellfish regulations in North Carolina, USA set the stage for testing this approach [1].

Some of us have lived long enough to watch environ-

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mental baselines shift sensu Pauly (1995)[2]. In only 70 years or so we've experienced coastal fisheries collapse, massive coastal development, sea level rise and climate change. New baselines ride atop a plethora of natural cycles we are beginning to understand. Although the fact statements we make are supported by science, the concepts are controversial in the larger society making it hard to gain traction. Degraded water quality and erosion are issues where there is concensus among most stakeholders. Thus, restoring water quality and reducing or reversing erosion are accepted physical entry points for repairing estuarine ecosystems. Coincedentally this kind of restoration is central to developing sustainable alternative ecosystem services that support environmental and human health.

Globally, oysters are a popular aquaculture species. Oysters are valuable in the restaurant trade, and have been of academic and mariculture interst since their populations began to decline. There are now well developed technologies for spawning, culturing oyster larve and rearing them to the juvenile stage. Oysters, mussels, scallops and clams, consume so much plankton that practical grow-out is in sounds, estuaries and coastal oceans. Recent advances in oyster aquaculture reduce predation and the risk of smothering or anoxia with floating caging. This simple modification maximizes growth and survival through continuous submersion in the upper region of the water column and is sometimes complemented with use of triploid oysters.

Due to history, philosophy and politics, different regions of the world are taking different approaches to oyster reef restoration. Notable examples are the UK, Australia and the US. The UK and Australia national governments recognize the ecological and societal importance of restoring natural reefs. In the last decade their approach is comprehensive, collaborative, and embraces careful planning, permitting, measurement, comprehensive targeted approaches, monitoring, attention to biosecurity and to education and onboarding of stakeholders [3,4]. The basic approach is to maximize the probability of success by taking advantage of the known science, to provide hard substrate and to seed with living oysters to provide gregarious settlement cues.

In the United States researchers have decades of experience with oysters as subjects of restoration. In the US, it is states, not the US government, that regulate and often with NGO support fund restoration efforts. The politics and philosophies of each state determine the way forward. Thus, there is no comprehensive approach. Often there are extreme restrictions such as prohibition of the use of living oysters, to protect food security and the fishers as well as where and how restoration can be attempted. However, decades of funding and published studies provide a scientific and practical perspective for moving forward.

In addition to reef restoration efforts for shellfish harvesting, oyster reef restoration as living shorelines is accepted in coastal communities for erosion abatement. Living shore-lines in the form of restored oyster reefs are popular and are examples of effective restoration [5]. Successes, where measured, include living oysters, physical increases in reef height that keep up with sea level rise [6] and ecosystem services such as improved water clarity and quality, return of microbial activity and the return of biogeochemical ecosystem services [5,7]. With present methods it takes approximately 6 years to restore a reef in Indian River Lagoon, FL, USA.

This review provides an overview of the current status of conservation and restoration ecology. Methods for restoration of polluted aquatic environments and potetntial solutions for restoration of reefs are based on advances in aquaculture.

1.2 Conservation and Restoration Ecology

Over the last 6 decades conservation science was in a state of "passive monitoring of decline." Passive monitoring of decline is being replaced by practitioners of restoration ecology who actively attempt to restore ecosystems. Many ecologists are hopeful that habitat destruction and biodiversity loss can be reversed. This hope is buoyed by positive restoration outcomes of individual species (whooping cranes, seals, otters, some sea turtles, some whales, bald eagles, turkeys, etc.). Jordan et al. [8] coined the term restoration ecology when they published Restoration Ecology (1st Ed.) and transformed the journal Restoration & Management Notes to Ecological Restoration.

Zhang et al. [9] provide a synopsis of the history of conceptual thinking about coastal conservation and restoration. Restoration ecology and theory began in terrestrial systems and considered physical and abiotic factors and addressed these in restoration efforts. Ecosystem services were first considered from the perspective of three fundamental tenets of ecology, predation, competition and disturbance. The next level of understanding is "facilitation" or the ways to group living components and mix different foundational species to enable restoration [9]. In the US facilitating restoration efforts is limited to physical grouping. However, as illustrated in by recent work in Australia [10] chemical signals from biofilms and adult organisms can enhance recruitment of propagules and restoration of ecosystems [11,12]. The logical next step is facilitating the complex community relationships that are embodied in living reefs.

1.3 Restoration of Polluted Aquatic Environments

Man has the ability to permanently alter and damage environments [13]. A relatively new area is the restoration of chemically impaired environments [14]. A major global problem in all human altered estuarine and coastal aquatic environments is nutrient pollution and the associated blooms of cyanobacteria, phytoplankton and harmful algae [7] which destroy ecosystem services useful to society and replace them with phytoplankton based low biodiversity ecosystems. Often the change in the ecosystem is slow, but other times ecosystem changes can occur in just two or three years [15-18].

With environmental change due to human development came the concepts of hybrid and novel ecosystems. Studies of novel ecosystems in cities are represented by a new discipline, *Urban Ecology* (*c.f.* [19]). Since about 2002, thought-leaders began to talk about designer communities [20,21]. Novel and hybrid ecosystems can arise spontaneously as is the case for communities on marine debris [22,23] or can be intentionally established [24].

In addition to scientific and academic restoration activities is the generation of ecosystems comprised of non-indigenous plants or biologically active structures like plastics [25,26]. These new ecosystems are comprised of resilient often invasive organisms that provide robust ecosystem services. An example of a terrestrial and aquatic hybrid ecosystem is the award winning restoration of Kallang River in Ang Mo Kio Park, Singapore [27]. The Kallang River ecosystem is comprised of tropical fishes from all over the globe including cichlids, carp, walking catfish and snake head, as well as apple snails, African land snails, and red eared sliders. The top predators are indigenous monitor lizzards and river otters that were displaced over the last decade by development in Maylaysia. The displaced otters replaced an extinct Singapore population [28,29].

In coastal regions around the globe, huge areas are closed to shellfish collection and aquaculture because of human health concerns due to pathogens. Estuaries where shell fishing is closed but where the environment still supports shellfish are ideal places to restore shell fish populations. The restablished shellfish improve water quality and ecosystem services and support nearby harvest fisheries by increasing larval supply. This type of restoration could address government mandates for water quality remediation.

In many countries and localities the concept of restoration of estuarine ecosystems to historic conditions is ludicrous. In most cases the starting point is not known due to limited number of investigations. Often the historical condition cannot be reproduced due physical and chemical changes due to massive urban development, huge human populations, wide scale habitat destruction, industrial, agricultural and human waste pollution, changes in dominant land uses, siltation, climate change and sea level rise. For example, if one takes harbors as an example, even small harbors with minimal industrial development, then what is your restoration target? To return a harbor to the condition recorded would require elimination of anthropogenic input, capping toxic sediments, killing the existing communities and reintroducing what was in the harbor the centuary or more before. Additionally, as suggested by recent studies, to regenerate the fauna might require transplantation of the former "natural" biofilms to stimulate settlement of local species [11,12]. One path is generation of a hybrid ecosystem that provides ecosystem services including improving water quality, reducing erosion and supporting higher trophic levels.

Our approach is similar to that of Vanderklift et al. [30] who proposed and support the idea of using advances in aquaculture and genetics to augment natural systems. Exploiting genetic, biological, chemical, ecological, physical, and applied-technologies that impact the development, maintenance and monitoring of oyster reefs should all be considered. Even an invasive multitrophic ecosystem and its services seems preferable to one dominated by microbes.

Our place-based solution is designed for restoration of tide driven estuaries of the South East United States. These estuaries are warm, 10 to 30+ ^{o}C waters, highly productive and eutrophic due upwelling and human derived nutrients. Siltation is a concern due to logging of pine plantations in the coastal plain. Subtidal oyster reefs are subjected to periodic anaerobiosis, smothering by silt and predation from long lived persistent predators including predatory snails and decapod crustaceans. Environmental stress increases the prevalence of disease. A solution is floating aquaculture which confines oysters in floating mesh bags in aerobic surface waters, physically limits predation to small predators that can swim, minimizes siltation and maximizes energy intake with continuous submergence. However, oyster reefs don't usually float and floating aquaculture provides a novel habitat that supports a novel hybrid ecosystem.

2. Restoration of Ecosystem Services: Baseline and Goals

2.1 Guidance

Caution is required in restoration ecology. Will we be able to understand the baseline condition of the system to

be restored, the restoration goal, what should be measured and what would be considered a success. The answers to these questions don't need to be the same for each ecosystem to be restored. What should be the targets for restoration in developed areas? Hobbs et al. (2009) [21] articulated our thoughts:

"Restoration in the future might need to aim more specifically at novel systems as a way of tackling the unprecedented era in which humans dominate all ecosystems.(Aronson and van Andel, 2006) Indeed, removing the requirement to aim for a historic ecosystem increases the range of options available and could enable reduced investment of effort and resources still to achieve valuable outcomes. However, caution is required: will we be capable of understanding what is best in a rapidly changing world? Will such activities be restoration or evolve into new types of intervention that respond to the rise of novel ecosystems? Restoration will involve a complicated set of decisions rooted in historical understanding and open to many potential trajectories. It will probably change its focus from damage control to ecosystem engineering or 'designer ecosystems'.(MacMahon and Holl, 2002)"

2.2 Oysters and Oyster Reefs

The loss of intertidal oyster reefs is attributed to shell mining, harvesting, predation, disease and physical disruption due to waves from storms, winds and boat wakes [7]. Globally, about 85% of oyster reefs have been severely degraded in the last 200 years [31-33]. Subtidal reefs are difficult to restore due to an overabundance of predators, and degraded water quality with periodic anoxia [34,35]. Intertidal reefs survive in a zone with reduced predation by snails and crabs that is above oyster lower temperature limit and below oyster upper lethal temperatures.

Oyster reefs are biodiversity hot spots. Oyster reef communities are organized and informed by the actions of symbiotic microbes and the actions of oyster hosts that manage their microbial communities [36]. The physical structure of living and dead shells alters flow, provides spaces for sedimentation and structural habitat for other organisms. Oysters initiate reef formation through aggregation pheromones and chemical cues that attract community members at many trophic levels. Once established, the entire community generates chemical signals that, structure and maintain it. Thus, oyster reefs are complex multispecies assemblages composed of primary consumers, grazers, and predators, as well as obligates, commensals and parasites. Oyster reefs provide structure and ecosystem services including habitat, pollution reduction, carbon and heavy metal sequestration in shell, storm protection, and food for humans.

Until recently, there has been little recognition of the importance of ecosystem services associated with oyster reefs [31,37]. Australia and the UK provided a big boost to the global interest in restoration ecology when they made shellfish reef restoration a national prioity [3,4,10]. Intertidal oyster reefs provide ecosystem services in lower energy sound and estuarine environments [38]. Intertidal oyster reefs extend off the substrate and undergo succession. Many details of reef communities are well studied [9]. Restoration of oyster reefs has clear societal, economic and environmental benefits especially in mediating eutrophication and acidification from human activities [11,39-45]. Compared to subtidal reefs, intertidal oyster reefs thrive in low energy polluted environments such as in a small tidal creek about a kilometer downstream of a 6.8 million liter a day sewage treatment plant (Figure 1). Food security is always a concern because pathogens, toxic metals or polychlorinated biphenyls in shellfish should not be ignored [46].

Figure 1. *Crassostrea virginica*, oyster reefs in a low energy stretch of Calico Creek, Newport Estuary Morehead City NC. These reefs have been undisturbed by harvest and damaged only by low frequency boat traffic, storms and runoff since 1964, about 55 years [47]. In the background and to the right are oysters reefs that have undergone succession to *Sporobolus alterniflorus* (=*Spartina alterniflora*) by accreting sediments. (Photo, D. Rittschof).

2.3 Ecosystem in a Bag

On the North Carolina coast a floating aquaculture reef can be initiated in warm seasons with living oyster spat in floating mesh bags (Figure 2). Within days the biofouling community composed of barnacles, sea squirts, hydroides and bryozoans [48] forms on floats, bags and oysters [49]. Within months complex communities are found on and within the cages [24,49]. This novel community

(Figure 3) is dramatically different than either an intertidal or subtidal reef. In oyster aquaculture the bags are flipped every two weeks. Exposure to air kills the biofouling and reduces sediments within the bags. Biofouling provides it own ecosystem services and enhances water quality already improved by oyster filtration. Robust oyster rocks (clusters) are generated by natural set in less than a year in warm climates like those on the south east and Gulf of Mexico Coasts of the US. The communites provide prey and structure for fish that live and forage below the floating reefs [50].

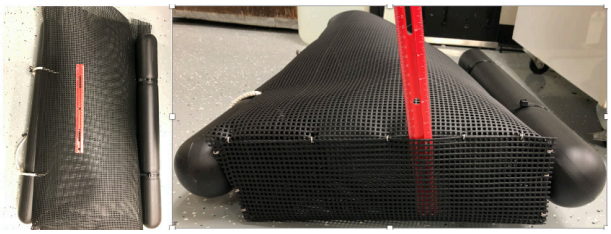

Figure 2. An example of a bag for floating aquaculture when filled to the right amount of oysters the bag floats in the top 10 cm of water. To keep biofouling at moderate levels, the bag is flipped over every two weeks. An anchor line is threaded through the white line attached to the left float. As they are flipped the bags alternate on the left and right ides of the line. (photo Daniel Rittschof)

Figure 3. The robust biofouling community on the underside of an unflipped oyster bag. Oysters in the bag host oyster spat, mussels, barnacles, tube worms,ascidians, mud crabs and jingle shells and an algal turf. Growth on the outside is more extensive than on the inside. Individual oysters become clumps due to natural set in about 4 months. (Photo Lilia Moorman)

The "bag ecosystem" is truly novel. It is comprised of the biofouling community found in the top 30 cm growing on floating objects and a subset of natural reef community members that enter bags as propaguels or small swimming juveniles. In Beaufort NC and around the globe in temperate and tropical harbors about 95% of biofouling organisms are invasive species, many of which arrived with boats and trade before or with the first European settlers [51-53]. Though found in the immediate coastal ocean [24] biofouling communities are particularly adapted to live in polluted harbors [54]. The combined oyster reef community and biofuling community in a bag provides physical and biological ecosystem services.

Figure 4. Floating Aquaculture on a lease in Atlantic Beach NC. Floating oyster Crasostrea virginica aquaculture provides a new hybrid ecosystem. Each floating bag contains 200 to 300 triploid or diploid oysters. Growth to market sized oysters from spat placed in bags in August is 6 to 8 months. (photo Thomas F. Schultz).

Many estuarine areas that historically supported oyster reefs are now areas with high levels of boat traffic and boat wakes that destroy oyster reefs [5,49] and shorelines in general [13,55]. There is a clear need to improve ecosystem services that mediate chronic human impacts on estuaries. This topic was the basis of a SEATAC workshop in 2015 which generated 6 paperson mitigation and restoration of industrially contaminated areas [14]. These papers illustrate what industrialized and developed countries could be targeting with respect to restoration.

With floating aquaculture technology hundreds of floating bags of oysters can be dragged behind a boat and anchored in a new location. Multiple lines of floating oysters (Figure 4) could be used to dampen waves and wakes the way that lane floats dampen waves in swimming pools. If one makes analogies to the routine transport and use of honey bees for pollination, an intriguing option would be to regionally transport floating aquaculture to areas surrounding other habitats being restored like sea grasses where the floating oysters would improve water clarity by reducing particulates and phytoplankton shading the sea grass and dampen wave action. This approach might be costly in the short run, but could generate long-term bene-

fits especially if the oysters can be commercially harvested or these areas can be used for recreational activities.

2.4 Climate Change and Oyster Communities

The combined effect of climate change and pollution can affect, survival and functioning of oyster populations [56,57]. Factors such as ocean acidification, increase of seawater temperatures, sea level rise and changes in ocean gyres and rainfall patterns, will significantly affect all marine ecosystems including Magellana (=*Crasostrea) gigas* oyster reefs [58-62]. In contrast, oysters like *C. virginica* are resilient to pH changes. There is no significant effect of low pH on larval behavior activity and swimming velocity of pre-competent, competent, and post-competent larvae [63]. As temperatures increase, sea levels rise and storm and boat frequency increase wave action, intertidal oyster reefs decline. Regions which have lost most of their natural oyster reefs routinely also have high levels of nutrients from human waste, animal and plant agriculture. All native oysters appear to do less well in stressed environments and are more susceptible to diseases [64,65]. Oysters reflect their historic environments. Their response to change is species-specific and depends upon the environmental history of the population.

Expanding oyster restoration and aquaculture would be one major way to stabilize estuaries and expand ecosystem services. Intentionally providing novel habitat through zoning of waterfront structures would be one passive way to augment ecosystem services in polluted environments. For example, requiring concrete building supports rather than toxic metal treated pilings as presented in the unplanned examples (Figure 5) is a passive tactic to enhance ecosystem services.

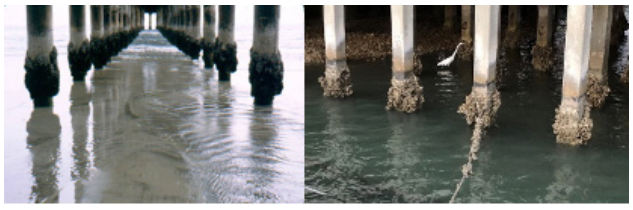

Figure 5. Concrete piling arrays providing habitat for rock oysters and barnacles (Hong Kong) and eastern oysters (North Carolina) expanding ecosystem services. Neither of these locations are recruitment limited. (Photo, Sergey Dobretsov and Daniel Rittschof).

With experiential learning gaining traction in educaton, the next generation of environmental leaders around the world will be versed in hands on experience and theory (Figure 6). Future leaders require both ways of knowing and the ability to synthesize practical solutions.

Figure 6. Part of the next generation of environmental scientists and restoration ecologists. The next cohort of environmental leaders is knowledgeable and dedicated and found all over the globe. They provide hope in turbulent times. (Photo Thomas Fred Schultz).

3. Conclusions

Oyster reefs are important estuarine features whose structure and services are critical to estuarine, cultural, and societal function. Due to anthropogenic activity most oyster reefs have been lost or their former extent significantly reduced. Factors associated with climate change and pollution of coastal waters affect survival of oyster reefs and limit their restoration. Sea water temperature rise and acidification will have more devastating impacts on oyster reefs in the future. With advances in aquaculture and an understanding of ecological relationships, restoration of oyster reefs and their creative management can be used to improve ecosystem services. Combining our knowledge of reef development at the chemical level with genetic, biological, chemical, ecological and physical fundamentals already used in aquaculture provides a novel ecosystem with substantial ecosystem services.

Floating oyster aquaculture is a new tool in the toolbox and provides another way forward to provide stock for restoration of oyster reefs and can work synergistically with seagrass and fish stock restoration efforts. Though not quantified here, restoration of reefs could become an industry that supports fish stock restoration and provides jobs in restoration, monitoring and resource extraction.

Author Contributions

DR developed the idea and wrote the first draft. SD wrote different parts of the manuscript. All authors contributed to the manuscript writing and revision of the text.

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Conflict of Interest

There is no conflict of interest.

References

[1] Coastal Federation, N.C., 2021. Oyster Restoration and Protection Plan for North Carolina: A Blueprint for Action 2015-2020. (Newport, N.C.).

[2] Pauly, D., 1995. Anecdotes and the shifting baseline syndrome of fisheries. Trends in Ecology & Evolution. 10(10), 430.
DOI: https://doi.org/10.1016/S0169-5347(00)89171-5

[3] Preston, J., Gamble, C., Debney, A., et al., 2020. European native oyster habitat restoration handbook, UK and Ireland. pp. 61.

[4] The Nature Conservancy Australia, 2021. Rebuilding Australia's lost shellfish reefs. 2021 Reef builders annual report. pp. 17.

[5] Walters, L., Donnelly, M., Sacks, P., et al., 2017. Lessons learned from living shoreline stabilization in popular tourist areas: boat wakes, volunteer support, and protecting historic structures. Living Shorelines. (Boca Raton, FL: CRC Press), 235-248.

[6] Rodriguez, A.B., Fodrie, F.J., Ridge, J.T., et al., 2014. Oyster reefs can outpace sea-level rise. Nature Climate Change. 4(6), 493-497.

[7] Garvis, S.K., Sacks, P.E., Walters, L.J., 2015. Formation, movement, and restoration of dead intertidal oyster reefs in Canaveral National Seashore and Mosquito Lagoon, Florida. Journal of Shellfish Research. 34(2), 251-258.

[8] Jordan, W.R., Jordan III, W.R., Gilpin, M.E., et al., 1987. Restoration Ecology. Cambridge; New York: Cambridge University Press.

[9] Zhang, Y.S., Cioffi, W.R., Cope, R., et al., 2018. A global synthesis reveals gaps in coastal habitat restoration research. Sustainability. 10(4), 1040.

[10] The Nature Conservancy Australia, 2021. Victoria's lost reefs rediscovered. Restoring shellfish reefs. pp. 9.

[11] Chambers, L.G., Gaspar, S.A., Pilato, C.J., et al., 2018. How Well Do Restored Intertidal Oyster Reefs Support Key Biogeochemical Properties in a Coastal Lagoon? Estuaries and Coasts. 41(3), 784-799.
DOI: https://doi.org/10.1007/s12237-017-0311-5

[12] Cacabelos, E., Ramalhosa, P., Canning-Clode, J., et al., 2020. The Role of Biofilms Developed under Different Anthropogenic Pressure on Recruitment of Macro-Invertebrates. International Journal of Molecular Sciences. 21(6), 2030.

[13] Gittman, R.K., Scyphers, S.B., Smith, C.S., et al., 2016. Ecological consequences of shoreline hardening: a meta-analysis. BioScience. 66(9), 763-773.

[14] Farag, A.M., Hull, R.N., Clements, W.H., et al., 2016. Restoration of impaired ecosystems: An ounce of prevention or a pound of cure? Introduction, overview, and key messages from a SETAC-SER workshop. Integrated Environmental Assessment and Management. 12(2), 247-252.

[15] Den Hartog, C., Polderman, P.J.G., 1975. Changes in the seagrass populations of the Dutch Waddenzee. Aquatic Botany. 1, 141-147.
DOI: https://doi.org/10.1016/0304-3770(75)90019-4

[16] Nienhuis, P.H., De Bree, B.H.H., 1977. Production and ecology of eelgrass (Zostera marinal L.) in the Grevelingen estuary, the Netherlands, before and after the closure. Hydrobiologia. 52(1), 55-66.
DOI: https://doi.org/10.1007/BF02658082

[17] Giesen, W.B.J.T., van Katwijk, M.M., den Hartog, C., 1990. Eelgrass condition and turbidity in the Dutch Wadden Sea. Aquatic Botany. 37(1), 71-85.
DOI: https://doi.org/10.1016/0304-3770(90)90065-S

[18] Moorman, M.C., Augspurger, T., Stanton, J.D., et al., 2017. Where's the Grass? Disappearing Submerged Aquatic Vegetation and Declining Water Quality in Lake Mattamuskeet. Journal of Fish and Wildlife Management. 8(2), 401-417.
DOI: https://doi.org/10.3996/082016-jfwm-068

[19] Pickett, S.T., Burch, W.R., Dalton, S.E., et al., 1997. A conceptual framework for the study of human ecosystems in urban areas. Urban Ecosystems. 1(4), 185-199.

[20] MacMahon, J.A., Holl, K.D., 2002. Designer Communities. Conservation Biology. 3, 3-4.

[21] Hobbs, R.J., Higgs, E., Harris, J.A., 2009. Novel ecosystems: implications for conservation and restoration. Trends in Ecology & Evolution. 24(11), 599-605.

[22] Póvoa, A.A., Skinner, L.F., de Araújo, F.V., 2021. Fouling organisms in marine litter (rafting on abiogenic substrates): A global review of literature. Marine Pollution Bulletin. 166, 112189.
DOI: https://doi.org/10.1016/j.marpolbul.2021.112189

[23] Al-Khayat, J.A., Veerasingam, S., Aboobacker, V.M., et al., 2021. Hitchhiking of encrusting organisms on

floating marine debris alon the west coast of Qataar, Arabian.Persian Gulf. Science of the Total Environment. 776, 145985.
DOI: https://doi.org/10.1016/j.scitotenv.2021.145985

[24] Rech, S., Gusmao, J.B., Kiessling, T., et al., 2021. A desert in the ocean – Depauperate fouling communities on marine litter in the hyper-oligotrophic South Pacific Subtropical Gyre. Science of The Total Environment. 759, 143545.
DOI: https://doi.org/10.1016/j.scitotenv.2020.143545

[25] Neely, K.L., Ziegler, T.A., Peloso, M., et al., 2021. Enhancing artificial reef fish populations by providing invertebrate prey refugia. Fisheries Research. 241, 106003.
DOI: https://doi.org/10.1016/j.fishres.2021.106003

[26] Li, H.X., Orihuela, B., Zhu, M., et al., 2016. Recyclable plastics as substrata for settlement and growth of bryozoans Bugula neritina and barnacles Amphibalanus amphitrite. Environmental Pollution. 218, 973-980.

[27] Qi, Y., Wu, Z., He, J., et al., 2019. Conspecific cues that induce spore settlement in the biofouling and green tide-forming alga Ulva tepida provide a potential aggregation mechanism. International Biodeterioration & Biodegradation. 145, 104807.

[28] Dreiseitl, R.S., 2016. American Society of Landscape Architects: 2016 ASLA Professional Awards (Online). https://www.asla.org/2016awards/index.html. (Accessed 11 May 2020).

[29] Barto, P., 2019. The return of Singapore's urban otters. Jeepneyprojects.org (Online). Available: Jeepneyprojects.org (Accessed 18 Jan 2021).

[30] Turrel, C., 2020. Cheeky otters are thriving in Singapore—and adapting quickly to big city life. nationalgeographic.com (Online). https://www.nationalgeographic.com/animals/2020/03/urban-otters-singapore-wildlife/.

[31] Vanderklift, M.A., Doropoulos, C., Gorman, D., et al., 2020. Using Propagules to Restore Coastal Marine Ecosystems. Frontiers in Marine Science. 7(724).
DOI: https://doi.org/10.3389/fmars.2020.00724

[32] Luckenbach, M.W., Mann, R., Wesson, J.A., 1999. Oyster reef habitat restoration: a synopsis and synthesis of approaches; proceedings from the symposium, Williamsburg, Virginia, April 1995.

[33] Kirby, M.X., 2004. Fishing down the coast: historical expansion and collapse of oyster fisheries along continental margins. Proceedings of the National Academy of Sciences. 101(35), 13096-13099.

[34] Beck, M.W., 2009. Shellfish reefs at risk: a global analysis of problems and solutions. Nature Conservancy.

[35] Lenihan, H.S., Peterson, C.H., 1998. How habitat degradation through fishery disturbance enhances impacts of hypoxia on oyster reefs. Ecological Applications. 8(1), 128-140.
DOI: https://doi.org/10.1890/1051-0761(1998)008[0128:HHDTFD]2.0.CO;2

[36] Powers, S.P., Peterson, C.H., Grabowski, J.H., et al., 2009. Success of constructed oyster reefs in no-harvest sanctuaries: implications for restoration. Marine Ecology Progress Series. 389, 159-170.

[37] Dobretsov, S., Rittschof, D., 2020. Love at First Taste: Induction of Larval Settlement by Marine Microbes. International Journal of Molecular Sciences. 21(3), 731.

[38] Dunn, R.P., Eggleston, D.B., Lindquist, N., 2014. Oyster-sponge interactions and bioerosion of reef-building substrate materials: implications for oyster restoration. Journal of Shellfish Research. 33(3), 727-738.

[39] Kennedy, V.S., Shaw, K.S., Newell, R.I., 2009. Discriminatory predation by three invertebrates on eastern oysters (Crassostrea virginica) compared with non-native Suminoe oysters (C. ariakensis). Invertebrate Biology. 128(1), 16-25.

[40] Meyer, D.L., Townsend, E.C., Thayer, G.W., 1997. Stabilization and erosion control value of oyster cultch for intertidal marsh. Restoration Ecology. 5(1), 93-99.

[41] Dame, R.F., 1984. Oyster reefs as components in estuarine nutrient cycling: Incidental or regulating. Oyster reef habitat restoration: a synopsis and synthesis of approaches. Edited by MW Luckenbach, R. Mann and JA Wesson. Virginia Institute of Marine Science Press, Gloucester Point, eds. M.W. Luckenbach, R. Mann & J.A. Wesson. 267-280.

[42] Newell, R.I., Cornwell, J.C., Owens, M.S., 2002. Influence of simulated bivalve biodeposition and microphytobenthos on sediment nitrogen dynamics: a laboratory study. Limnology and Oceanography. 47(5), 1367-1379.

[43] Peterson, C.H., Grabowski, J.H., Powers, S.P., 2003. Estimated enhancement of fish production resulting from restoring oyster reef habitat: quantitative valuation. Marine Ecology Progress Series. 264, 249-264.

[44] Coen, L.D., Brumbaugh, R.D., Bushek, D., et al., 2007. Ecosystem services related to oyster restoration. Marine Ecology Progress Series. 341, 303-307.

[45] Grabowski, J.H., Brumbaugh, R.D., Conrad, R.F., et

al., 2012. Economic valuation of ecosystem services provided by oyster reefs. Bioscience. 62(10), 900-909.

[46] Kellogg, M.L., Cornwell, J.C., Owens, M.S., et al., 2013. Denitrification and nutrient assimilation on a restored oyster reef. Marine Ecology Progress Series. 480, 1-19.

[47] Freitag, A., Sohn, N., Hooper, M., et al., 2012. The geography of mercury and PCBs in North Carolina's local seafood. Marine Pollution Bulletin. 64(7), 1330-1338.

[48] Nierstedt, R.J., Okun, D.A., O'Melia, C.R., et al., 1980. Wastewater management in coastal North Carolina. Water Resources Research Institute of the University of North Carolina.

[49] Roberts, D., Rittschof, D., Holm, E., et al., 1991. Factors influencing initial larval settlement: temporal, spatial and surface molecular components. Journal of Experimental Marine Biology and Ecology. 150(2), 203-221.
DOI: https://doi.org/10.1016/0022-0981(91)90068-8

[50] Fitridge, I., Dempster, T., Guenther, J., et al., 2012. The impact and control of biofouling in marine aquaculture: a review. Biofouling. 28(7), 649-669.
DOI: https://doi.org/10.1080/08927014.2012.700478

[51] Muething, K.A., Tomas, F., Waldbusser, G., et al., 2020. On the edge: assessing fish habitat use across the boundary between Pacific oyster aquaculture and eelgrass in Willapa Bay, Washington, USA. Aquaculture Environment Interactions. 12, 541-557.

[52] Carlton, J.T., 2021. RE: Personal communication regarding introduction of invasive species by boat.

[53] Rittschof, D., 2017. Off the shelf fouling management. Marine Drugs. 15(6), 176.

[54] Rittschof, D., 2017. Trypsins: Keystone Enzymes in Estuarine Invertebrate Communities. JSM Enzymol. Protein Science. 2(1).

[55] Dobretsov, S., Coutinho, R., Rittschof, D., et al., 2019. The oceans are changing: impact of ocean warming and acidification on biofouling communities. Biofouling. 35(5), 585-595.
DOI: https://doi.org/10.1080/08927014.2019.1624727

[56] Gittman, R.K., Peterson, C.H., Currin, C.A., et al., 2016. Living shorelines can enhance the nursery role of threatened estuarine habitats. Ecological Applications. 26(1), 249-263.

[57] Moreira, A., Figueira, E., Libralato, G., et al., 2018. Comparative sensitivity of Crassostrea angulata and Crassostrea gigas embryo-larval development to As under varying salinity and temperature. Marine Environmental Research. 140, 135-144.
DOI: https://doi.org/10.1016/j.marenvres.2018.06.003

[58] Moreira, A., Freitas, R., Figueira, E., et al., 2018. Combined effects of arsenic, salinity and temperature on Crassostrea gigas embryotoxicity. Ecotoxicology and Environmental Safety. 147, 251-259.
DOI: https://doi.org/10.1016/j.ecoenv.2017.08.043

[59] Ginger, K.W., Vera, C.B., Dineshram, R., et al., 2013. Larval and post-larval stages of Pacific oyster (Crassostrea gigas) are resistant to elevated CO_2. PLoS One. 8(5).

[60] Ko, G.W., Dineshram, R., Campanati, C., et al., 2014. Interactive effects of ocean acidification, elevated temperature, and reduced salinity on early-life stages of the Pacific oyster. Environmental Science & Technology. 48(17), 10079-10088.

[61] Ekstrom, J.A., Suatoni, L., Cooley, S.R., et al., 2015. Vulnerability and adaptation of US shellfisheries to ocean acidification. Nature Climate Change. 5(3), 207-214.

[62] Wei, L., Wang, Q., Wu, H., et al., 2015. Proteomic and metabolomic responses of Pacific oyster Crassostrea gigas to elevated pCO_2 exposure. Journal of Proteomics. 112, 83-94.

[63] Dineshram, R., Chandramouli, K., Ko, G.W.K., et al., 2016. Quantitative analysis of oyster larval proteome provides new insights into the effects of multiple climate change stressors. Global Change Biology. 22(6), 2054-2068.
DOI: https://doi.org/10.1111/gcb.13249

[64] Meyer-Kaiser, K.S., Houlihan, E.P., Wheeler, J.D., et al., 2019. Behavioral response of eastern oyster Crassostrea virginica larvae to a chemical settlement cue is not impaired by low pH. Marine Ecology Progress Series. 623, 13-24.

[65] Sprague, V., 1971. Diseases of oysters. Annual Review of Microbiology. 25, 210-230.
DOI: https://doi.org/10.1146/annurev.mi.25.100171.001235

[66] Pernet, F., Lupo, C., Bacher, C., et al., 2016. Infectious diseases in oyster aquaculture require a new integrated approach. Philosophical Transactions of the Royal Society B: Biological Sciences. 371(1689), 20150213.

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