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Research Article

Optimization of dugout fisheries for climate change adaptation in Northern Region, Ghana

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Abstract
The fisheries sector is one of the climate sensitive areas that could be impacted by climate change. Increases in temperature, floods or drought will alter water level/availability for growth and survival of most fishes in dugouts. Adaptation strategies are needed to respond or cope with actual and projected dwindling of inland fish stock. Northern Ghana abounds with numerous dugouts and reservoirs which could be harnessed for higher fish production in view of climate change. A Tilapia is proliferous fish that can tolerate harsh climatic conditions including fluctuating water levels and high temperature. This paper assesses Tilapia; *Oreochromis niloticus* for fish stock enhancement in water stress dugouts. Effects on fish stocks was determined through fish catch assessment and water quality monitoring. Total fish catch was sorted into species, enumerated and weighed. Results showed that the survival rate of the Tilapia *(O. niloticus)* stocked under extensive culture system was 99.6% excluding predation. This study indicates that *O. niloticus* was ideal for fish stock enhancement and could be adopted to increase fish yield, improve adaptation to climate change and increase economic returns from dugout fisheries. The study also revealed that water quality of dugouts improved due to good fishery management intervention.

Keywords
Fish stocks — Tilapia — Dugout — Climate change — fish catch

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Content

Introduction

Tilapia is the most cultured fish native to Africa. The fish is a delicacy and serves as significant nutritional source of protein-rich food. Ghana's fisheries sector employs over 2.2 % of the total national workforce compared to 1% from commerce and industry [18]. Two million people are said to be involved in the fisheries sector. Ghana is purported to be among the highest fish consuming countries in the world, with per capita fish consumption of 25 kilograms, while the world average is 13 kilograms. The Ghana government imports fish to the tune of $157 million dollars to make up for the shortfall in national production, despite having marine, brackish and numerous inland freshwater bodies in the country. National fish production interest is usually based on resources from Marine, Volta and Bosumtwi lakes, lagoons, rivers, dams, reservoirs and aquaculture. Average contribution of reservoir fisheries (culture-based) to national fish production is 150 kg/ha/yr. The estimated production from the commercial cage culture facility is 200 tonnes/ha/yr valued at US$ 0.316 million [11]. Estimated growth rate of Gross Domestic Product (GDP) by fishing sector declined by 8.7 percent in 2011 [12]. Little attention is paid to enhancement of depleting fish stock and management of water bodies including dugouts. Dugouts are 3-sided embankment troughs filled with water runoffs that flow along the slope of open side. In water stress areas, dugouts provide potable water and serve as receptacles for fish stock that have strayed into spillover water from flooded reservoirs, rivers, rivulets, and streams during rainy season. Global warming/cooling and variability in rainfall pattern causing floods, long dry spells or drought have resultant effects on fish stock. According to the Food and Agriculture Organisation [10], climate change coupled with over-capitalization and recruitment overfishing at lower densities could cause decline in ichthyomass of individual fish species, reduction in population size and possible extinction of less thermal referenda fish species. In Ghana, it is estimated that temperature will continue to rise on average by about 0.8 ^{0}C, 2.5 ^{0}C and 5.4 ^{0}C by the year 2020, 2050 and 2080, respectively [17]. Rainfall is also projected to decrease in all agro-ecological zones [16]. Anthropogenic activities such as recruitment over-fishing, crop farming, bush burning, deforestation and over-grazing on the embankment and catchment areas have exacerbated the impacts of climate change on water storage systems like reservoirs and dugouts. The availability of high quality protein foods like fish presents uncertainties triggered in extreme ways by climate change. Adaptation is needed as a response strategy to adjust to actual or expected climate and its effects, in order to moderate harm or harness potential opportunities [13], [6]. Adaptation to climate change in Ghana is in its early stages, especially in relations to fisheries and the aquatic ecosystem. Thus, no comprehensive fishery policies exist on tilapia culture for climate change adaptation. As a preliminary study, the paper aims to assess the performance of capture fish production with the introduction of fast growing Tilapia species, improved Akosombo strain of *Oreochromis niloticus* and its associated activities on water quality in water stress dugouts.

1. Materials and Methods

1.1 Study Area

The Mawulea and Zialuwa dugouts are perennial water resource with an approximate area of 0.5 and 1.2 hectares, respectively. Both dugouts are located in the eastern corridor of the Northern Region of Ghana between Latitude 9^o15’30” N – 9^o15’30” N and 0^o10’30”W – 0^o14’30”W and 00^o – 150^o East (Figure 1). The Greenwich Meridian passes through a number of human settlements around the catchment area of the dugouts. Mean annual rainfall for the area is 1,125 mm (January - December). Mean wet season rainfall (April- October) is 1,150 mm. Mean dry season rainfall (November – March) 75mm. Mean annual deficit is between 500 mm and 600 mm [21]. Rainfall is seasonal and erratic. Atmospheric temperature ranges between 21^oC - 40^oC giving rise to high temperature range. Increasing atmospheric temperature, anthropogenic activities such as excessive bush burning and farming activities close to dugouts affects the ecosystem and ecotone of dugouts.

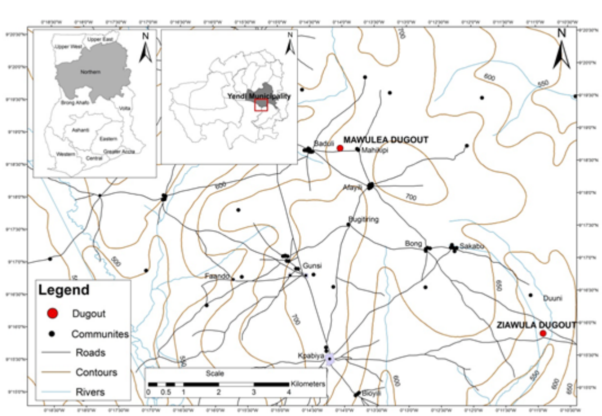

Figure 1. Maps of Ghana showing Northern Region and dugouts studied

1.2 Stocking and Fish Catch Assessment

Tilapia species, *Oreochromis niloticus* was selected based on principles for stock enhancement adopted from [9]. Two dugouts were stocked with a total of 6,500 fingerlings of *Oreochromis niloticus* (improved Akosombo strain) with mean weight 30 g each. Five hundred (500) fingerlings out of the 6,500 were tagged for identification and growth assessment. Capture-Release-Capture method for fish assessment was considered for the tagged fishes. The survival rate (SR) of *O. niloticus* (Improved Akosombo strain) under extensive culture in the dugouts was calculated based on the formula below;

(Number of fish survived / Number of fish stocked) $\times$**100**

Where, number of fish survived represents number of fish caught from fish stocked. Assumption: no predation. Catch assessment was through the determination of fish species weight and composition. Identification of fish species were done with the aid of fish identification guide by [8]. Sampling was done monthly using a drag net 1.5 cm (knot to knot) mesh size and 100 m long after stocking.

1.3 Water quality monitoring

For water quality sampling, the dugout was zoned into upstream, midstream and downstream based on the direction of water flow into the dugout. Water quality data was compiled monthly. Water quality sampling and analysis was done according to [3]. Laboratory analysis was done at Water Research Institute’s laboratories in Tamale. The following water quality parameters were monitored; Dissolved Oxygen (DO), pH, Total alkalinity, turbidity, Conductivity, Total Dissolved Solids (TDS), phosphate - (PO_4-P), nitrate-nitrogen (NO_3-N) and Ammonia (NH_4).

1.4 Statistical Analysis

Computer based program Microsoft Excel 2010 edition was used to calculate percentage composition, mean and standard deviations. Results were presented in tables.

Table 1. Percentage composition (numbers) of fish species caught after stock enhancement

Parameter	Mawulea dugout		Zialuwa dugout	
Species	Occurrence	% composition	Occurrence	% composition
Oreochromis niloticus	†	28.9	†	31.1
Sarotherodon galilaeus	†	21.4	†	15.6
Tilapia zillii	†	2.74	†	0.4
Brycinus nurse	†	13.9	†	15.1
Marcusenius senegalensis	†	11	†	1.6
Mormyrus macrophthalmus	†	1.1	—	0
Synodontis sorex	—	0	†	3.1
Parachanna obscura	†	0.4	—	0
Schilbe intermedius	†	2.5	—	0
Heterobranchus isoptenus	†	1.4	†	0.1
Labeo senegalensis	†	3.3	†	0.4
Schilbe mystus	†	0.8	†	0.4
Clarias gariepinus	†	2.4	†	0.4
Synodontis schall	†	5.1	†	0.4
Synodontis nigrita	†	4.2	†	0.4
Auchenoglanis occidentalis	†	0.5	—	0.4
Ctenopoma petherici	†	0.4	—	0.4

Note: † Present, — absent

Table 2. Weight of fish species caught after stock enhancement in Zialuwa dugout

Fish species	Number	Weight (kg)
Oreochromis niloticus	427	59.85
Sarotherodon galilaeus	215	36.6
Tilapia zillii	5	0.5
Brycinus nurse	208	10.5
Marcusenius senegalensis	22	0.5
Synodontis sorex	42	7
Labeo senegalensis	5	1.2
Schilbe mystus	26	1.3
Heterobranchus isoptenus	1	3.5
Clarias gariepinus	39	16.1
Synodontis schall	209	4.8
Synodontis nigrita	175	2.9
Total	1,374	144.75

2. Results

A total of 17 fish species were identified during catch assessment. In Mawulea dugout, 16 fish species were encountered while Zialuwa dugout had 12 fish species. The cichlids; tilapiine species (*Tilapia zillii*, *Oreochromis niloticus* and *Sarotherodon galilaeus*) were the most dominant species in the dugouts. Mean percentage composition of tilapiine species caught before stock enhancement in both dugout was *S. galilaeus* (18.0%), *O. niloticus* (17.9%), *T. zillii* (1.2%). Low fingerling morality was recorded after re-stocking, thus 99.6% of the fingerlings of *Oreochromis niloticus* introduced survived. Re-stocking for fish enhancement changed the order of percentage composition of the dugout, it was *O. niloticus* (30.0%) , *S. galilaeus* (18.5%) , *T. zillii* (1.6%). African mudfish and other fish species encountered included *Brycinus nurse*, *Marcusenius senegalensis*, *Synodontis sorex*, *Schilbe intermedius* and *Synodontis schall.* Percentage composition of fish caught from each dugout after stock enhancement is presented in table 1. *O. niloticus* dominated in terms of numbers in both Mawulea (28.9 %) and Ziawula (31.1 %). The species that recorded the least in numbers was *Ctenopoma petherici*; Mawulea 0.4 % and Ziawulea 0 % (Table 1). Total bulk weight of 363.9 kg of fish was caught through partial harvesting. Higher bulk weight of fish was encountered from Mawulea dugout as compared to Zialuwa dugout (Tables 2 and 3). O. niloticus dominated in both numbers and weight in the Ziawula dugout (Table 2) and in Mawulea dugout (Table 3). The impact of fish stock enhancement on water quality showed that mean concentration for most of the parameters monitored was relatively constant in both dugouts (Table 4). The mean surface water temperatures for the study period in Mawulea and Zialuwa dugouts were 30.08 and 30.07 ^{0}C respectively. Dissolved oxygen (3.07 mg/l) for both dugouts was low. The conductivity and nitrate concentration were both high in Zialuwa than in Mawulea as shown Table 4.

Table 3. Weight of fish species caught after stock enhancement in Mawulea dugout

Fish species	Number	Weight (kg)
Oreochromis niloticus	401	50.45
Sarotherodon galilaeus	297	43.05
Tilapia zillii	38	2.6
Brycinus nurse	192	15.8
Marcusenius senegalensis	153	11.8
Mormyrus macrophthalmus	15	1.5
Parachanna obscura	5	4.5
Schilbe intermedius	35	2.4
Heterobranchus isoptenus	20	41.6
Labeo senegalensis	46	2
Schilbe mystus	11	0.6
Clarias gariepinus	33	34.6
Synodontis schall	70	2.45
Synodontis nigrita	58	1.1
Auchenoglanis occidentalis	7	1.6
Ctenopoma petherici	5	3.1
Total	1,386	219.15

Table 4. Mean concentrations ± SD (standard deviation) of water quality of selected dugouts

Parameter	Mawulea dugout		Zialuwa dugout	
Water Temperature (^{0}C)	30.08	± 0.20	30.07	± 0.12
pH	7.7		7.67	
Conductivity (Ĭs/cm)	85.66	± 23.64	164.83	± 17.04
Dissolved Oxygen	3.07	± 0.58	3.07	± 0.60
Nitrate	4.69	± 1.95	5.54	± 2.39
Phosphates	0.71	± 0.26	0.52	± 0.28
Fluoride	0.02	± 0.01	0.03	± 0.01
Calcium	14.51	± 4.91	8.36	± 3.18
Magnesium	3.2	± 1.74	2.59	± 1.14
Sodium	22.53	± 20.72	35.48	± 45.41
Potassium	3.64	± 0.3	3.88	± 0.57
Silica(SiO4)	35.39	± 3.12	23.64	± 2.03
Total Hardness	49.56	± 8.67	31.56	± 10.31
Calcium Hardness	36.29	± 12.26	20.92	± 7.8
Magnesium Hardness	13.28	± 7.22	10.64	± 4.72
Ammonia	4.69	± 0.77	1.31	± 1.53
TDS	51.34	± 14.02	98.84	± 76.27
Total alkalinity	84.46	± 75.72	66	± 35.9
Bicarbonate	101.17	± 75.96	80.23	± 49.26
Sulphate SO4	104.19	± 9.16	19.86	± 1.98
Chloride	21.66	± 22.7	11.44	± 6.07

All parameters are measured in mg/l except pH and those stated

3. Discussion

Fish catch assessment indicated a rich biodiversity of 17 fish species in both dugouts. Dominant fish species was from the fish family; cichlidae. Similar fish species dominance has been reported for most reservoir fishery in northern Ghana [19], [15]. The size of the dugouts did not affect the biodiversity and weight of fish species encountered in each dugout. The larger dugout (Zialuwa, 1.5 hectares) had lesser fish species biodiversity and weight due to the fishing pressure and recruitment over-fishing by migrant fishermen.

[2] asserted that for the last four decades, climatic variability has been positively correlated with fluctuations in the landings of the pelagic species (example Tilapia) upon which majority of Ghana's fisher folk depend. Recruitment over-fishing coupled with environmental challenges like climate change probably dwindle fish population even after stock enhancement intervention. Thus, a sustainable (selective) harvesting strategy adopted in this study allowed fry, fingerlings and juvenile fish to escape for further growth, spawning and replenishing of fish stock in the dugout. The harvesting strategy ensured *O. niloticus* to become the dominant species (30%) coupled with a closed season during peaks of rainfall (August-September) to escape for spawning. *O. niloticus* (Improved Akosombo strain) probably exhibited an extent of auto stocking in the dugout that replenished the stock faster than expected as observed by [4]. The survival rate of *O. niloticus* was 99.6% due to arguably the hardy nature of the improved Akosombo strain, participatory education on stocking of fingerlings, care, and management of the dugout. Many studies have shown that proper management of the inland fishery with native fish boosted the biodiversity and commercial benefits derived from the fishery [20], [5]. As such, fish revenue increased from GHc150.00 in 2011 under outright sale of dugout to migrant fishermen, to GHc308.00 in 2012 under fish stock enhancement with selective harvesting.

The effect of fish stock enhancement on water quality in Zialuwa and Mawulea dugouts was less noticeable. High water temperature (¿30^0C) and low dissolved oxygen (¡3.5mg/l) concentrations recorded in this study were detrimental to fish production over a long period of time. Periodic fish kills may occur under such conditions especially with low dissolved oxygen levels [7]. This did not affect the growth of *O. niloticus*, which recorded an average weight of 140g. Other water quality parameters monitored were fairly good for fish production after fish stock enhancement. According to [14], long-term effects of climate change on water quality are diverse. The observed short-term changes in Zialuwa dugout revealed that nitrate concentration of 5.54 mg/l was slightly high. The nitrate concentrate in Zialuwa dugout could be a result of the oxidation of plants and animal debris and from the decomposition of animal (cow dung) and human excrement. Total monthly rainfall controlled the rate of Nitrate (NO_3-N) and Phosphate (PO_4-P) load into the dugouts. When rainfall intensified, more runoff from the watershed led to the accumulation of nutrient in the dugouts. Increased anthropogenic activities such as farming (using fertilizers) before and during the rainy season could increase nitrate concentrations in both dugouts. The important role of anthropogenic contributions to climate change impacts on water quality cannot be underestimated. Some climate change impact studies have corroborated the intensity of observed changes to anthropogenic activities [1]. The pH values of 7.70 - 7.67 encountered was optimum for fisheries productivity.

4. Conclusion

The study indicates that introduction of Tilapia; *Oreochromis niloticus* (improved Akosombo strain) had considerable positive impact on fisheries and water quality in dugouts. Fish stock enhancement with Tilapia; *O. niloticus* and sustainable (selective) harvesting strategies can revamp fish stock in dugouts. Arguably, dugouts have the ability to augment national fish production and adapt to climate change when given the necessary management interventions.

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