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Water Quality Dynamics and Plankton Estimation of Integrated Rice and Fish Farming System Under Two Distinct Agro-Ecological Zone in Nigeria

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ABSTRACT

Options for farm diversification through integrated aquaculture-agriculture (IAA) are being gradually embraced as a competitive alternative to traditional agriculture because of resource use efficiency and overall productivity. This study was carried out on the MSU/USAID/FAO IRF plot (22m by 15m) for 16 weeks in Ebonyi and Kebbi State. Water sample was collected biweekly to determine water quality and plankton estimation. Statistical analysis was carried out through analysis of variance (ANOVA) and Ducan multiple range test to find the difference at 5% ($p < 0.05$) levels. The result showed that all the water quality parameters were within the recommended range except high dissolved oxygen that was recorded in Kebbi State. The most dominant plankton recorded were *Chlamydomona*, *Scenedemus quadricauda*, *Bacillariophyca*, *Cyanobacteria*, *Scenedesmus.* It was concluded that better understanding of the water quality dynamics and biological productivity of IRF could improve overall food production.

Keywords:
Water, Plankton, Integrated, Diversity

Introduction

Food security and rural livelihood are one of the challenges facing due to the increasing world population (Godfray et al., 2010), restrains on agriculture resources like land and water (Kim and Arnhold, 2018), and climate change (Brown and Funk, 2008). An increasing number of various Agri-chemicals are applied in the conventional rice production since rice is the staple food for more than half of the world's population (Muthayya et al., 2014). It is detrimental to the ecosystem, such as pollution in ground water and eutrophication in lakes and oceans, soil consolidation, loss of biodiversity, and environmental degradation (Abe et al., 2016). Therefore, the integrated Agri-aquaculture systems are effective in reducing chemical fertilizer and pesticide use, minimizing environmental health degradation, and enhancing farm productivity and income (Stankus and Halwart, 2017).

Integrated fish farming is a system of producing fish in combination with other agricultural/livestock farming operations centered around the fish pond. The farming subsystems e.g., fish, crop and livestock are linked to each other in such a way that the byproducts/wastes from one sub-system become the valuable inputs to another sub-system and thus ensures total utilization of land and water resources of the farm resulting in maximum and diversified farm output with minimum financial and labor costs.

The production of rice and fish do not need to be integrated by always producing the two crops simultaneously, but may be done by alternating production: rice can be grown in the rainy season and fish in the dry season, or the other way around. In areas where rice production is not profitable in all seasons, fish production forms an alternative source of income from the field. However, in order to meet the global demand of food and nutrition for the increasing populations, there is therefore a need to increase rice and fish production simultaneously.

Integrated rice-fish farming can play an important role in increasing food production as this system is better than rice monoculture. Integrated rice fish systems contribute to increase the diversified food supply, helps in resource utilization, minimize extra labor, Fish control weeds by feeding on weed roots and offer an extra service by tilling the soil around the rice plants, fish faeces are used as organic manure that provide essential nutrients required to grow healthy rice plants, it provides efficient production of high carbohydrate (rice) and high protein (fish) food from same area of land, Higher level of water management for fish improve conditions for plant crop, Integration of fish in paddy fields is ecologically sound because fish improves soil fertility by generating nitrogen and phosphorus. Furthermore, integrated rice and fish culture optimizes the benefits of scarce land and water resources through complementary use, and exploits the synergies between fish and plant. Stocking of fish and paddy fields more effectively uses the available food and space.

Materials and Method

Study area

The study was conducted for 16 weeks in four selected adaptive research sites in each of the three communities selected in the two project states (Ebonyi and Kebbi states) representing upland and lowland rice farming systems.

Experimental layout

A pond with the dimension of 22m by 15m (inside was trench) was constructed for culture of fish with 3 inlet pipes that supply the ponds with water from the borehole and with 1 outlet pipe which released the water out and the rice paddy with a dimension of 21m by 14m was also constructed inside the pond.

Fish and rice culture of integrated rice and fish farming

1500 pieces of catfish (*Clarias gariepinus*) were stocked with an average weight of 4grams with 5fish/m^2 in the adaptive plots. Faro 44 (Low land rice) was cultivated in this study. The rice plants

were transplanted after 14days in the nursery to the rice paddy (2-3 tiller per hill) with the line spacing of 20cm by 20cm for the production.

Data collection

Data were collected biweekly on water quality parameters and biological parameters such as zooplankton and phytoplankton during the production span of rice and fish after stocking the adaptive research plots with rice seedling and fish seeds. These production cycles were replicated twice during which, data were collected on the following.

Water quality parameters of integrated rice and fish farming

Sample bottles were rinsed with water inside the pond and the collection of the was done between the hour of 7:00am and 7:30am.

Water quality parameters such as pH, DO, total alkalinity, nitrite, nitrate, ammonia, were done biweekly according APHA, 1989 procedure.

Plankton estimation of integrated rice and fish farming

This was done by collecting plankton (phytoplankton and zooplankton) sample through plankton net. The net was rinsed with sample water and the net was lowered horizontally and dragged throughout the pond. The planktons were collected in a sample bottle by opening the cod end above it by turning the valve horizontally. After the sample water has been collected, the sampled water was fixed with 4% of formaldehyde and it was analysed with the use of microscopic to identify the type of zooplankton and phytoplankton and a cell count was done to determine the plankton number and abundance of the water source (Tuney, 2016).

Statistical analysis

Statistical analysis was carried out through analysis of variance (ANOVA). Means were compared using Ducan Multiple range test to find the difference at 5% ($p < 0.05$) levels (Ducan, 1995)

Result

Figure 1 shows that all water quality parameters were within the recommended range.

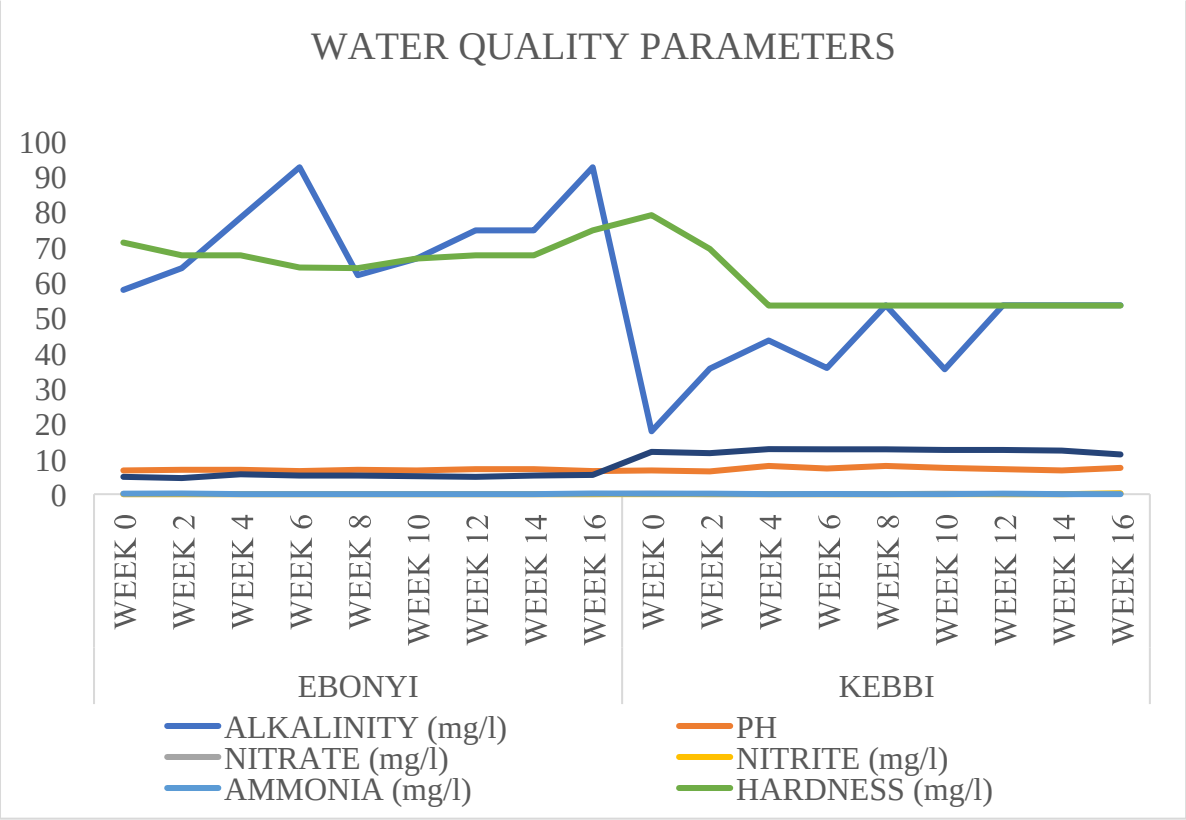

Figure 1: Biweekly water quality parameters result in Ebonyi and Kebbi states

Figure 2 shows that, in Ebonyi, the number of planktons ranged from 150.0±28.3 to 210.5±40.3, and the abundance of plankton, the least 40.6±2.9 to175.3±41.4. of plankton recorded in Kebbi ranged from 50±1.0 to 85±7.1 while the abundance ranged from 13±1.4 to 113.3±20.8.

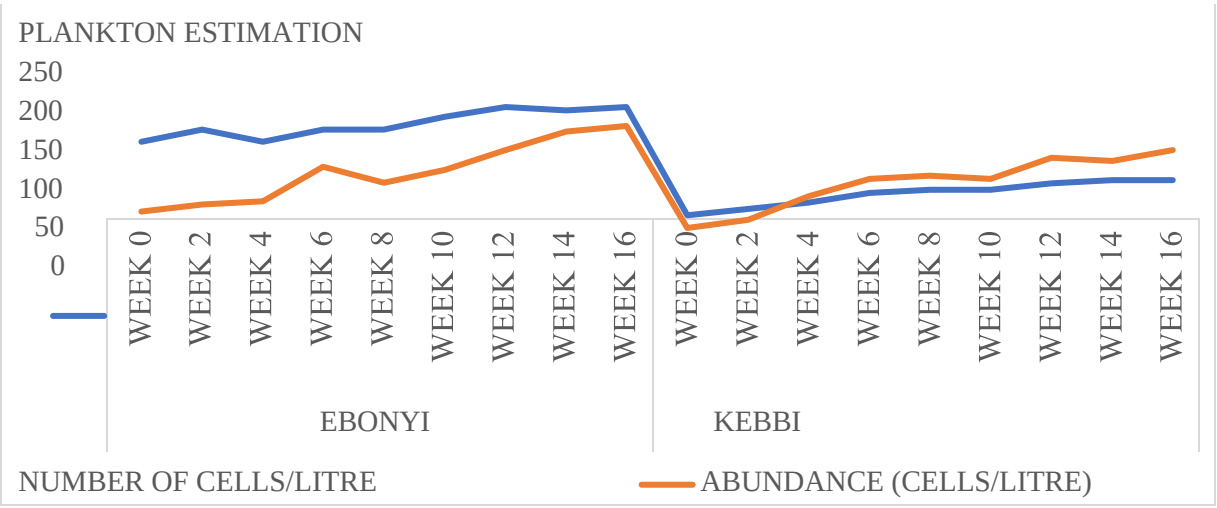

Figure 2: Biweekly plankton estimation in Ebonyi and Kebbi state

Table 1 shows the comparison of mean for the water quality parameters in Ebonyi and Kebbi State. The Highest water quality parameters such as alkalinity, pH, nitrate, nitrite, ammonia, hardness and dissolved oxygen were recorded in Kebbi State. There is a significant difference in alkalinity, nitrite, hardness and dissolved oxygen but there are no significant differences in the remaining water quality parameters between the two states

Table 1: Comparison of mean for water quality parameters

	Ebonyi	Kebbi
Alkalinity(mg/l)	73.2 ± 3.6^{b}	54.1 ± 6.6^{a}
pH	6.8 ± 0.2^{a}	7.2 ± 0.7^{a}
Nitrate(mg/l)	0.1 ± 0^{a}	0.1 ± 0.1^{b}
Nitrite(mg/l)	0±0a	0.4 ± 0.6^{b}
Ammonia(mg/l)	0.1 ± 0.1^{a}	0.1 ± 0.1^{a}
Hardness(mg/l)	67.6 ± 3.2^{a}	69.2 ± 25.2^{a}
D.O(mg/l)	5.2 ± 0.3^{a}	12.2 ± 0.1^{b}

*Mean with the same superscript along the row is not significantly different at $p<0.05$

Discussion

Water quality of integrated rice fish farming

Water quality parameters are essential for the better survival and growth of fish. pH evaluated observed in both states throughout the production was good for pond productivity and this is line with Fafioye *et al.,* 2005 and Abraham *et al.,* 2018 that the pH within this range is good for pond productivity and Organic manure used raise the pH level and accelerate the decomposition of organic matter and activity. Also, according to Ekubo and Abowei, 2011, Fish have an average blood pH of 7.4, a little deviation from this value, generally between 7.0 to 8.5 is more optimum and conducive to fish life. pH between 7 to 8.5 is ideal for biological productivity, fishes can become stressed in water with a pH ranging from 4.0 to 6.5 and 9.0 to 11.0 and death is almost certain at a pH of less than 4.0 or greater than 11.0.

Dissolved oxygen is an important factor influencing fish growth and survival of fish. Dissolved oxygen (DO), as an important abiotic factor in paddy field ecosystems, could affect soil nitrogen conversion and rice nitrogen absorption directly or indirectly (Kogel-Knabner *et al*., 2010) Dissolved oxygen(mg/l) result in the trench (figure 1) varied and it is similar to the study conducted by Abraham *et al*., 2018 on the integrated fish cum rice culture (D.O was 5.13±1.04) and also in agreement with Boyd, 2007 and Omitoyin, 2007. According to Wahab *et al.,* 2008 dissolved oxygen support good production and also essential for growth of bacteria which decompose organic detritus and release of

nutrients which is shared by the paddy. Ahmed *et al.*, 2010 stated Perturbation of the soil leads to high dissolved oxygen needed for the nutrient cycling by the soil microorganisms. The increase in the Dissolved Oxygen levels in Kebbi state may be attributed to the continuous movement of the fish in the rice fields which helps with dissolving atmospheric oxygen into the water; while the decreasing trend in the last half could be attributed to fish feed and the increase of temperature in summer (Zajdband, 2011). Nitrate are of low toxicity and are likely create health hazards when reduced to nitrites. The moderate level of nitrate and nitrite value in all the treatment can be as a result of low build-up of ammonia which can cause through overfeeding or large number of fish stocked in the pond but in this study, there was no overfeeding of the fish which can lead to this problem.

The value of Ammonia observed in this study was tolerable for the growth and the survival of both fish and rice. This is in line with the study carried out by Omitoyin and Ajani (2020). High ammonia can be caused by aerobic bacteria and by the decomposing organic matter in the pond. Alkalinity and hardness observed varied throughout the production period but all found between the tolerable range. This finding is in line with the statement stated by Kumar *et al.*,
2014 that 40 to 200ppm alkalinity and hardness is suitable for fish culture.

Plankton estimation of integrated rice fish farming

Phytoplankton, as the most primitive producer of living organisms in the aquatic ecosystem, underpins the structure, services and functioning of an aquatic ecosystem. The analysis of its diversity reflects the ecological and environmental quality of the surveyed waters (Katsiapi *et al*., 2016). The enhanced percentage of plankton in the coculture system suggests that fish possibly release additional nutrients to the system (Desta *et al*., 2014), and prey on substantial quantities of plankton as feeds (Wang *et al*., 2019; Vidal *et al*., 2019). In this study, high number of phytoplankton and zooplankton were observed in both states. These results suggest the aquatic ecosystem quality in the rice-fish coculture system is better than those in the paddy field without fish (Ulanowicz, 2001).

Although, the number of the plankton fluctuated across the production period in all the sites and this might be due or indicated that the fish fed adequately on the zooplankton in the pond (Vromant and Chau, 2005). The overall result showed that there was an adequate nutrient in the pond which increased the number and abundance of plankton has the days of the production increasing. This is attributed to the use of organic manure used for the cultivation of rice and the faeces released from the fish (Desta *et al*., 2014) during the production. This agrees with Halwart and Gulpta, 2004 that the application of fertilizers promote phytoplankton growth and enhance the natural food web that supports fish. The presence of organic fertilizer in paddy plots and the release of additional nutrient from the fish might have facilitated the growth of the fish food organisms. This observation was in line with that of Kamal *et al*., (2008) who stated that the growth of plankton in culture ponds fluctuated greatly with the temperature and fertilization. The dissolved nutrients, nitrate and phosphate stimulate the growth of phytoplankton and ultimately enhance production of fish.

Conclusion and recommendation

It was revealed from this study that integrated rice and fish farming is environmentally sound in terms of better water utilization, nutrient distribution and water quality than conventional system. Therefore, trainings should be done on the effective application of rice–fish culture, for a wider adoption of this food production system towards a sustainable food production globally.

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