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PREAMBLE

SPECIAL EDITION OF THE BULLETIN OF ANIMAL PRODUCTION AND ANIMAL HEALTH ON FISHERIES AND AQUACULTURE

The Policy Framework and Reform Strategy for fisheries and aquaculture has a policy pillar on enhancing awareness and human resources capacity development. This is to be achieved through the implementation of a suite of activities including building the capacity of the continent in fisheries management and aquaculture planning and development, strengthening the scientific and economic basis for competitive, equitable and sustainable sectors, strengthening the knowledge base systems and regional cooperation. This policy objective is also within the AU-IBAR's Strategic Plan Programme area on animal resources information and knowledge management with the objective to improve the creation, dissemination and utilization of knowledge for effective animal resource development.

As a significant step in the implementation of the provisions of the pan African fisheries and aquaculture policy framework and against the background that Africa has a wealth of experiences and accumulated lessons to be disseminated, AU-IBAR took the logical decision to produce a special edition of the Bulletin of Animal Health and Animal production (BAHPA). The BAHPA is a quarterly publication of AU-IBAR on animal resources development in Africa.

The publication of this special edition on fisheries and aquaculture development in Africa is intended to strengthen capacity and knowledge base for rationale and informed development of the sector. This is in recognition that capacity development is a key building block for creating knowledge, empowerment and enablement for effective participation in decision-making and for improved governance of the sector. However, capacity is limited in several areas in many Member States. Capacity development is, therefore, a high priority, especially with respect to effective implementation of reforms highlighted in the pan Africa policy document.

It is surmised that this special edition would provide the opportunity for a mutual learning process, so that information and knowledge on lessons and best practices in diverse but related disciplines in fisheries management and aquaculture development could be shared vmore efficiently. In putting together this special edition, we take cognizance of the view that capacity is built not just for science but also for management and the needs of all stakeholders.

This is the first edition of a dedicated fisheries and aquaculture BAPHA edition and it is our intention to make the publication of this special edition regular so as to ensure appropriate knowledge in key disciplines of fisheries and aquaculture is widely accessible by all and are routinely utilized.

I sincerely thank all the eminent authors and reviewers who have contributed to make the production of this Special Edition on Fisheries and Aquaculture possible.

Simplice Nouala, PhD
Chief Animal Production Officer,
Editor in Chief of the Bulletin of Animal health and Production in Africa
AU-IBAR

GROWTH PERFORMANCE OF NILE TILAPIA AND AFRICAN CATFISH FED ON RATIONS FORMULATED FROM LOCALLY AVAILABLE FEED RESOURCES, TANZANIA

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Abstract

The study assessed the palatability and effect of home-made feed ration on growth performance of Nile Tilapia (*Oreochromis niloticus*) and the African catfish (*Clarias gariepinus*). It was carried out at Tanzania Fisheries Research Institute (TAFIRI) Mwanza hatcheries for three weeks in April 2013. Two types of feeds were formulated; Taf1 from maize (*Zea mays*) bran, dagaa (Rastrineobola argentea), cotton (*Gossypium spp*) seed cake, mineral premix/multivitamins and Nile perch (*Lates niloticus*) oil; and Taf2 from Soy bean (*Glycine max L.*), rice (*Oryza sativa*) bran, cotton (*Gossypium spp*) seed cakes, mineral premix/multivitamins and Nile perch (*Lates niloticus*) oil. Cassava (*Manihot esculenta*) flour was used as a binder for both feeds. Palatability was higher in Nile tilapia fed on Taf1 than those fed on Taf2 ($t(24) = 5.204$, $P < 0.05$). Similarly, in African catfish, palatability was higher when fed with Taf1 than Taf2 ($t(20) = 2.848$ $P<0.05$). There was no significant difference in the Feed conversion ratio (FCR) for the Nile tilapia fed with Taf1 and Taf2 ($t(24) = 1.672$, $P>0.05$) but, there was a significant difference in FCR for the African catfish fed with Taf1 and Taf2 ($t(20) = -12.454$, $P<0.05$). Live weight gain was significantly different in both Nile tilapia ($t(21) = 2.861$, $p< 0.05$) and African catfish ($t(5) = 9.626$, $p< 0.05$) fed on two test diets. The low palatability of Taf2 and the resultant decline in feed consumption, also resulted into a reduced growth parameters such as average daily gain (ADG), and specific growth rate (SGR) This suggests that Taf1 supports better growth performance of Nile tilapia and African catfish than Taf2.

Key words: Crude protein, Feed intake, Fish growth, Palatability

PERFORMANCE DE CROISSANCE DU TILAPIA DU NIL ET DU POISSON-CHAT AFRICAIN NOURRIS AVEC DES PRÉPARATIONS ALIMENTAIRES À BASE DE RESSOURCES LOCALES EN TANZANIE

Résumé

La présente étude a évalué l'appétence des rations alimentaires à base de ressources locales et leur effet sur la performance de croissance du tilapia du Nil (*Oreochromis niloticus*) et du poisson-chat africain (*Clarias gariepinus*). L'étude a été réalisée pendant trois semaines au cours du mois d'avril 2013, dans les écloseries de Mwanza de l'Institut tanzanien de recherche sur la pêche (TAFIRI : Tanzania Fisheries Research Institute). Deux types de préparations alimentaires ont été utilisés : Taf1 composée de sons de maïs (*Zea mays*), de dagaa (Rastrineobola argentea), de tourteaux de coton (*Gossypium spp*), d'un mélange tout fait de minéraux / multivitamines, et d'huile de perche du Nil (*Lates niloticus*) ; et Taf2 comprenant des graines de soja (*Glycine max L.*), du son de riz (*Oryza sativa*), des tourteaux de coton (*Gossypium spp*), un mélange tout fait de minéraux / multivitamines et d'huile de perche du Nil (*Lates niloticus*). L'étude a utilisé la farine de manioc (*Manihot esculenta*) comme liant pour les deux préparations alimentaires. L'appétence observée chez les tilapias du Nil nourris au régime Taf1 était supérieure à celle des poissons soumis au régime Taf2 ($t(24) = 5,204$, $P <0,05$). De même, le poisson-chat africain a montré une appétence plus élevée pour le régime Taf1 par rapport au régime Taf2 ($t(20) = 2,848$ $P <0,05$). On n'a pas relevé de différence significative au niveau de l'indice de consommation alimentaire pour les tilapias du Nil nourris respectivement aux régimes Taf1 et Taf2 ($t(24) = 1,672$, $P> 0,05$), mais une différence significative a été notée au niveau de l'indice de consommation FCR pour les poissons-chats africains nourris aux régimes

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Taf1 et Taf2 (t(20) = - 12,454, P <0,05). Le gain de poids vif était significativement différent chez les tilapias du Nil (t (21) = 2,861, p <0,05) et les poissons-chats africains (t(5) = 9,626, p <0,05) soumis aux deux régimes d'essai. La faible appétence pour le régime Taf2 et la baisse de la prise alimentaire qui en a résulté ont également entraîné une réduction des paramètres de croissance tels que le gain moyen quotidien (GMQ) et le taux de croissance spécifique (TCS). Ceci porte à croire que le régime Taf1 favorise une meilleure performance de croissance du tilapia du Nil et du poisson-chat africain par rapport au régime Taf2.

Mots-clés : protéine brute, prise alimentaire, croissance des poissons, appétence

Introduction

Tanzania has a great potential for aquaculture to grow and provide many benefits which includes employment, income, food and nutrition security given the good climatic conditions and reliable sources of water in both inland and marine environments. The aquaculture industry in Tanzania is dominated by small scale freshwater fish farming, where farmers practice both extensive and semi-intensive fish farming. With most of the inland capture fisheries are said to fully or over-exploited, aquaculture is considered the future alternative source of fish, which may also reduce fishing pressure on the capture fisheries. However, aquaculture development in Tanzania is still faced with several obstacles, most importantly lack of quality feeds (Mwanja *et al.,* 2006; Shoko *et al.,* 2012).

Fish farmers in Tanzania are having a challenge in accessing quality feeds, in large quantity, since commercial feeds on market are expensive and most fish farmers cannot afford to buy them. Furthermore, Tanzania does not have a reliable factory producing these feeds and most of the commercial feeds used in the country are imported from neighbouring countries, such as Kenya and Uganda. Tanzania, however, is rich in locally available feed ingredients most of which are used in other animal feeds manufacturing or exported to Uganda and Kenya for poultry and fish feed processing. Thus, promoting the use of rations made from locally available feed ingredients would provide an opportunity for cheap alternative feeds for farmers since they can be easily accessed.

Fish, like any other living organism, requires all the important nutrients, such as protein, vitamins, minerals, lipids and carbohydrates to grow and remain healthy (NAERLS, 2002). Fishmeal and cereals are commonly used as protein and energy sources, respectively. Protein is a critical component in a complete fish feed, but the most expensive accounting for 50% of the total feed cost (Thompson *et al.,* 2005). Either animal or plant materials can be used as a source of protein, although animal protein is preferable due to its high quality (Munguti *et al.,* 2006). Fish meal is palatable and rich in amino acids, fatty acids, energy and minerals (Ogunji, 2004). However, using fish as source of protein for cultured fish contradicts the notion of using aquaculture as an alternative in reducing the fishing effort on the capture fisheries. Alternative option therefore to fish meal is to use plants with high contents of protein such as soya beans meal, cotton seedcake and sunflower cake. Development of a feed for fish production involves evaluation of proximate composition, palatability and performance efficiency (Munguti *et al.,* 2006; Mzengereza *et al.,* 2014). This study assessed the effect of home-made feed rations on growth performance of Nile Tilapia (*Oreochromis niloticus*) and African catfish (*Clarias gariepinus*).

Materials and Methods

Ethical statement

This study was not evaluated by an Animal Ethics Committee because there was no such committee in Tanzania during the course of the study. Nevertheless, the research methods used involved neither sacrificing nor

causing any harm to fish. After completion of experiment all fish used in the experiment were released into fish ponds located at the TAFIRI premises.

Proximate analysis

Feed ingredients were selected from locally available materials, which included rice (*Oryza sativa*) bran, maize (*Zea mays*) bran, cotton (*Gossypium spp*) seed cake, dagaa (Rastrineobola argentea), Soy bean (*Glycine max L.*), and Nile perch (*Lates niloticus*) oil. From these ingredients, two types of feeds were formulated; namely, Taf1, composed of cotton seed cake, dagaa, maize bran, mineral premix/ multivitamins and Nile perch oil, and Taf2, composed of Soy bean, cotton seed cake, rice bran, mineral premix/multivitamins and Nile perch oil. Cassava (*Manihot esculenta*) flour was used as a binder and was included in the formulation of the two feeds. Samples of ingredients were sun dried and ground into fine particles and transported to the Department of Animal Science, Sokoine University, for chemical analysis to determine their nutrient contents. Analyses of crude protein (CP), ash contents, ether extract (EE), dry matter and crude fibre (CF) were done in triplicate following the procedure by the Association of Official Analytical Chemists (AOAC, 1995). Crude protein was determined according to Kjeldahl using block digestion and steam distillation. Ash was determined by burning samples at 550°C in a muffle furnace for 3 hours. Dry matter was determined by drying samples in an oven at 105°C for six hours at a constant weight. Ether extract was obtained through the loss in weight after extraction of the sample with petroleum ether at boiling point of 40-60°C. Crude fibre was determined as ash free residues; samples were digested in alkaline and acidic solution.

Ration formulation

Feed formulation was done using Pearson square methods following the procedure by the National Agricultural Extension and Research Liaison Services, Ahmadu Bello University, Zaria (NAERLS 2002). Formulations were made by mixing the selected ground feed ingredients in varying proportions to meet the predetermined nutrient requirement (Table 1). The ingredients were moistened with hot water before passing through a pellet machine. The resulting pellets were sun dried and stored at room temperature. For each type of ration, the formulation was aimed at getting a feed with 35% crude protein. After the formulations, feeds were reanalysed for proximate analysis to determine if they reached a desired crude protein level.

Feed intake and growth

The experiment was set using four tanks of the same size (1m length, 1m width and 0.5m depth), with water flowing in and out. The tanks were transparent to enable observation while feeding. Juveniles of Nile tilapia and African catfish originating from Lake Victoria and raised in TAFIRI ponds. Two tanks were stocked with 22 juvenile Nile tilapia each, while the other two were stocked with 7 juvenile African catfish each. Both Nile tilapia and African catfish were tested with Taf1 and Taf2. The experiment was carried out at the Tanzania Fisheries Research Institute (TAFIRI) Mwanza hatcheries in April 2013. The duration of the feeding experiment for each of the rations lasted for three weeks. Fish were fed a known amount of feeds twice a day, and the feeding schedule was maintained (Morning at 0900 and evening at 1500). Fish were fed slowly while observing their feeding behaviour until they fed no more. At least twenty minutes were used for observation after each meal. Cleaning of tanks by siphoning was done once a day and a flow through system of water was maintained. Relative palatability was determined by letting the fish notify us how much they prefer a particular feed type, and this was done by precisely measuring how much they eat. We assumed that if fish prefer a particular feed type, they tend to eat it more and they grow faster than for the less preferred meal, when other conditions are constant.

For purposes of determining change in growth of fish, weight and length of each fish were taken before stocking and monitoring was done on weekly basis. Weight was measured

Table 1: Formulated ration of Taf1 and Taf2 feed that make 35% crude protein

Ingredients	Taf1	Taf2
Maize bran(kg)	7.6	
Cotton seed cakes (kg)	42.4	48.4
Soya bean (kg)		48.4
Dagaa (kg)	42.4	
Nile perch oil (litre)	6.3	6.3
Vitamin/ Mineral premix (g)	77.5	77.5
Rice bran (kg)		1.6
Cassava flour (kg)	7.6	1.6

Table 2: Proximate composition of raw materials in g/kg (Dry Matter) selected from locally available feed ingredients. Data is presented in Mean ± standard deviation.

Ingredient	Dry Matter	Crude protein	Crude fibre	Ash	Ether extract
Rice Bran	927.8±4.9	70.0±22.7	155.4±66	201.9±4.0	21.1±12.4
Maize Bran	948.3±40.0	122.4±1.9	90.9±12.7	42.4±10.7	73.5±12.1
Dagaa	929.8±3.9	487.8±11.1	13.4±5.5	311.8±93.5	82.5±13.5
Cotton seed cake	930.3±8.9	309.6±39.5	125.8±54.6	72.1±4.8	113.2±15.2
Soy bean	946.4±45.3	369.0±65.7	48.8±9.9	55.8±0.8	79.2±15.2
Cassava flour	909.1	14.7	3.1	12.9	2.2

Table 3: Proximate analysis (%) of the formulated feeds used in this study

Feed type	Crude protein	Crude fibre	Ash	Dry matter	Ether E
Taf1	34.78	7.43	9.7	93.7	13.73
Taf2	34.70	10.70	6.6	94.9	12.6

to the nearest gram by using a weighing scale Model Scout Pro SPU 2001, China, while length was measured to the nearest millimetre by using a 30cm measuring plate. Fish growth and nutrient utilization were determined in terms of Feed intake (FI), Average Daily Gain (ADG), Specific Growth Rate (SGR), Feed Conversion Ratio (FCR) and Protein Efficiency Ratio (PER):

FI (g fish-1 day-1) = total feed intake per fish/ number of days

ADG (g fish-1 day-1) = weight gain per day/ number of days

SGR (% day-1) = 100 × (ln [final body weight] – ln [initial body weight])/number of days

FCR = feed intake/live weight gain

PER = live weight gain/crude protein intake
Where protein intake (g) = protein (%) in feed x total weight (g) of the diet consumed/ 100

Physicochemical conditions of the tanks

Physicochemical parameters such as water temperature, dissolved oxygen and pH were measured in the morning and evening to ensure that the conditions are suitable for fish growth. The pH and water temperature were measured using a portable pH-temperature meter (HI991300 pH/EC,TDS/ temperature, USA). Dissolved oxygen was measured using oxygen meter (HI9143 Microprocessor Oxygen meter HANNA, USA). Results (mean

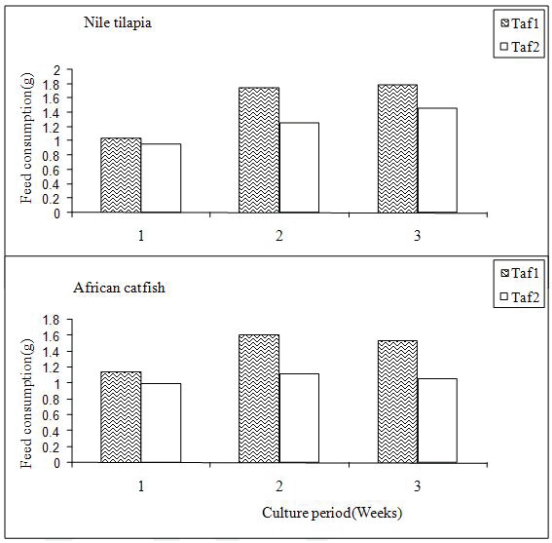

Figure 1: Feed intake/ consumption of Taf1 and Taf2 feeds using Nile tilapia and African catfish. There were significant difference in feed intake of the two formulated feeds tested using Nile tilapia (t (24) =5.204, P <0.05) and African catfish (t (20) = 2.848, P< 0.05).

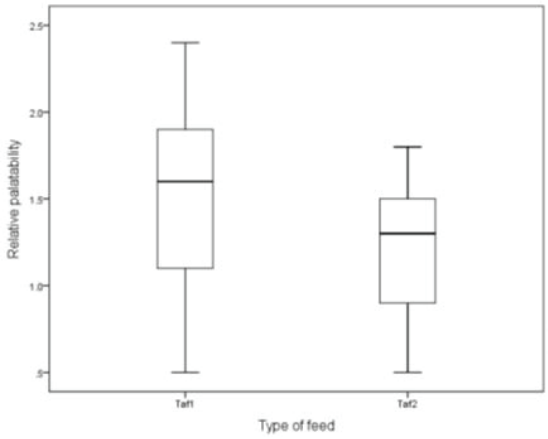

Figure 2: Relative palatability of two formulated feeds (Taf1 and Taf2) using Nile tilapia.

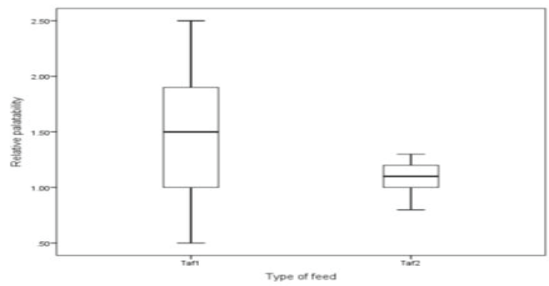

Figure 3: Relative palatability of two formulated feeds (Taf1 and Taf2) using African catfish

± SD) showed that pH was 6.7±0.3 and 6.8±0.2, dissolved oxygen was 7.0± 0.6 mg/l and 6.8 ±0.5 mg/l, while temperature was 23.7±0.7°C and 22.3±1.3°C in the morning and in the evening, respectively.

Data analysis

Paired sample t-test was used at 95% confidence interval to test for significant differences in relative palatability, feed conversion ratio (FRC), feed intake (FI), average daily gain (ADG), specific growth rate (SGR) and protein efficeincy ratio (PER) between Taf1 and Taf2. All statistical tests were performed using SPSS version 21 for Windows.

Results

Biochemical composition

Data on proximate composition of the selected locally available feed materials are presented in table 2. Dagaa had the highest crude protein (CP) of 487.8±11.1g/kg dry matter (DM) followed by Soy bean and Cotton seed cakes, and the protein content of these ingredients was at least four times higher than in Rice bran. Crude fibre (CF) ranged between 13.4±5.5 and 155.4±66 g/kg, and was highest in rice bran and lowest in cassava flour. Ash contents ranged between 42.4±10.7 and 311.8±93.5 g/kg DM, and was lowest in maize bran and highest in dagaa. Ether extract (EE) was highest in cotton seed cake, maize bran, dagaa and soy bean varied slightly. The lowest EE was recorded in rice bran. The two feeds of study had almost similar CP, and they showed major difference in their ash content, CF and EE (Table 3).

Relative palatability and feed intake

Among the two feeds, Taf1 was highly consumed than Taf2 as shown in figure 1. Palatability, measured as a quantity of feed consumed, was higher in Nile tilapia fed on Taf1 than those fed on Taf2 (t (24) =5.204 P < 0.05) (Figure 2). Similarly, in African catfish, palatability was higher when fed with Taf1 than Taf2 (t (20) =2.848, P<0.05) (Figure 3).

Table 4: Growth perfomance and nutrient utilization of Nile tilapia fed with experimental diets. Data is presented as Mean ±Standard Error of the Mean(SEM).

	Taf1	**Taf 2**
Initial body weight (g)	0.97±0.022[a]	0.97±0.024[a]
Final body weight (g)	1.94±0.081[a]	1.64±0.075[b]
Initial length (cm)	3.75±0.086[a]	3.77±0.084[a]
Final body length (cm)	4.69±0.081[a]	4.39±0.069[b]
Feed Conversion Ratio	1.52±0.496[a]	1.75±0.401[a]
Average Daily Gain (g fish-1 day-1)	0.05±0.004[a]	0.03±0.004[b]
Specific Growth Rate (% day-1)	3.23±0.237[a]	2.44±0.22[b]
Protein Efficiency Ratio	0.03±0.002[a]	0.02±0.002[b]
Survival rate (%)	100[a]	100[a]

Values in the same row with different superscripts are significantly different (P<0.05)

Table 5: Growth perfomance of African catfish fed with the experimental diets (Mean ±SEM).

	Taf1	**Taf 2**
Initial body weight (g)	4.93±0.067[a]	4.93±0.117[a]
Final body weight (g)	7.7±0.200[a]	5.82±0.204[b]
Initial length (cm)	9.75±0.177[a]	9.57±0.145[a]
Final body length (cm)	10.98±0.04[a]	10.4±0.165[b]
Feed Conversion Ratio	1.81±0.009[a]	4.17±0.007[b]
Average Daily Gain (g fish-1 day-1)	0.13±0.01[a]	0.04±0.01[b]
Specific Growth Rate (% day-1)	2.11±0.14[a]	0.78±0.20[b]
Protein Efficiency Ratio	0.08±0.07[a]	0.03±0.07[b]
Survival rate (%)	100[a]	100[a]

Values in the same row with different superscripts are significantly different (P<0.05)

Growth performance

Results on differences in growth performance and nutrient utilization are shown on Tables 4 and 5. There was no significant difference in the FCR for the Nile tilapia fed with Taf1 and Taf2 ($t(24) = 1.672$, $P>0.05$) but, there was a significant difference in FCR for the African catfish fed with Taf1 and Taf2 ($t(20) = -12.454$, $P<0.05$). There were significant differences in live weight gain of Nile tilapia fed with Taf1 and Taf2 ($t(21) = 2.861$, $P< 0.05$), the same for African catfish ($t(5) = 9.626$, $P< 0.05$).

Discussion

Feed composition and Formulation

Dagaa had the highest crude protein, which makes it a suitable ingredient candidate in the feed formulation, although its availability faces a challenge of competition as it is directly used for human consumption and periodically scarce in Lake Victoria because of seasonal fishery closure (Munguti *et al.,* 2006). To reduce direct competition, it is recommended to use trash dagaa (second grade dagaa) in fish feeds formulation, which is also used for the poultry feeds. However, due to poor handling at the beach, poor quality dagaa are mainly used in formulation by most farmers, which lead to poor quality feeds. This study reports high ash content in dagaa used in the formulation, and this can be attributed to poor handling and processing of dagaa at the beach through the common method of sun drying on sand along the beaches. It is estimated that over 98% of dagaa from Lake Victoria is processed locally

by drying on sand, rocks, and grass, which in turn compromises the end products' quality and safety (Mhongole *et al.,* 2012). Cotton seed cake and soy bean had crude protein above 30%, which make them potential source of protein in fish feed. However, soy bean is also used for human consumption, which poses a problem of competition. The suitability of cotton seed cake in feed formulation over dagaa and soy bean is that it is not directly used for human consumption. Furthermore, it is highly available and cheap in the market than dagaa, since cotton is widely grown in the Tanzanian side of Lake Victoria region. However, plant protein are reported to be deficient in at least one or more essential amino acids (Munguti et al 2006), thus making it impossible to stand alone in supporting a better growth of fish. It may be used in semi-intensive culture systems, where a supply of essential amino acids may come from the phytoplankton and zooplankton.

Rice and maize brans are commonly used as feed supplements by local fish farmers in Tanzania. This leads to poor harvest due to low protein contents in maize and rice bran. For better performance, they can be used in combination with other protein sources such as dagaa and cotton seed cakes. However, rice bran is poorer in nutrient content in comparison to maize bran due to the high crude fibre and lower crude protein it contains (Munguti et al 2006).

Relative palatability and Growth performance

The results have shown that, Taf1 is more palatable than Taf2 despite the fact that all the two feeds had the same crude protein. Both Nile tilapia and African catfish were reluctant to consume Taf2, which contained soy bean and cotton seedcakes as plant protein, and were even observed to spit out pellets in a short time before actual ingestion. This resulted in a significant decline in feed intake which was accompanied by a significant decline in growth. The inclusion of dagaa as one of the ingredients in Taf1 is thought to increase its acceptability to fish as it was revealed in our study. A similar observation of an increase in palatability of the feed after inclusion of dagaa in the diet was reported by (Musiba et al. 2014). Fish meal is reported to have high nutritional quality and biological value, and well-balanced in amino acid profile. Furthermore, fish meal lacks anti-nutritional factors as compared to the plant protein source used in this experiment. As such, fish meal is preferred as protein source by most aqua feed producing industries (El-Sayed, 1998; 2005; FAO, 2010; Aanyu *et al.,* 2012). Literature shows that when fish meal is replaced by soy bean as source of protein it results in reduced weight gain in fish (El-Sayed, 1998; 2005; Silva-Carrillo *et al.,* 2012).

The used plant ingredients as protein source in Taf2 may have lowered its palatability due to the presence of anti- nutritional factors in soya bean and higher crude fibers in the diet. This also affected the growth performance and nutrient utilization. The fibre in plant ingredients is known to reduce feed intake, decrease the time the feed spends in the gut and, consequently diet digestibility and nutrient bio-availability (Espe *et al.,* 1998; Cheng and Hardy 2002; Nyina-wamwiza *et al.,* 2007). However efforts were made to reduce the anti-nutritional factors in soy bean by frying in oven during the preparatory stage. Hot water was always used in mixing and formulation of feedstuff to reduce the toxins and other anti-nutritional factors.

African catfish appear to have performed better than Nile tilapia with Taf1 as opposed to Taf2 in respect to growth rate and nutrient utilization. This could be due to the fact that the feeds used in the experiment were sinking pellets and that African catfish being a demersal fish was able to fully consume and utilize well the feed, and Nile tilapia being a pelagic fish, utilized extra energy and efforts to consume the feeds before it sinks to the bottom. In addition, stocking density was low for African catfish as compared to Nile tilapia and, therefore, the low growth rate of Nile tilapia was related to high densities, which might have caused competition for food and space (Johnson, 1965). The present results are in agreement with the findings of Narejo et al. (2005) and Kohinoor *et al.,* (2012), who achieved best growth at lower stocking

densities in catfish farming.

Conclusions

This study showed that Taf1 was highly accepted and caused a better growth performance in *O. niloticus* and *C. gariepinus* than Taf2. Moreover based on literatures and our findings the quality of ingredients of Taf1 and their availability in the Lake Victoria region is an added advantage. However, there is need for further research to evaluate among others the amino acid profile, digestibility and the possible anti-nutritional factors of the feed.

Authors' contribution

BBK designed the experiments, collected data, analysed data and drafted the manuscript. ME, MJM and EM participated in designing the experiment and reviewed the manuscript. FM participated in data collection and experimental set up. RK designed, supervised the study, analysed data and reviewed the manuscript. All authors read and approved the final manuscript.

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Competing interests

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EFFET DE L'ÂGE AU TRANSFERT EN ÉTANG SUR LA SURVIE ET LA CROISSANCE DES ALEVINS DE *CLARIAS GARIEPINUS* (BURCHELL, 1822)

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Résume

L'étude a été réalisée entre avril et septembre 2010, à la ferme piscicole de l'Institut de Recherche Agricole pour le Développement (IRAD) de Foumban à Koupa Matapit (5°45,826' LN et 10°48,516'LE) dans l'Ouest du Cameroun. Les objectifs de l'étude étaient de déterminer d'une part, l'effet de l'âge au transfert en étang sur le taux de survie et la croissance des alevins, et de proposer d'autre part l'âge optimum de transfert des alevins de *Clarias gariepinus* en étang. A cet effet, 12 lots comparables (âge, longueur totale, poids moyen) de 1750 larves chacun, ont été repartis dans quatre traitements T4, T7, T10 et T13 en 3 répétitions chacun et correspondant respectivement aux transferts à 4, 7, 10 et 13 jours d'âge. A chaque lot a été attribué de manière aléatoire un des 12 étangs simulés aux caractéristiques des comparables. L'essai a duré 30 jours et les principaux résultats ont été les suivants : le taux de survie en fin d'essai a été significativement ($P < 0,05$) le plus élevé chez les alevins transférés à l'âge de 4 jours (21,82 ± 6,54 %), suivi de celui de ceux transférés à 10 jours d'âge (7,27 ± 6 %), le taux de survie le plus faible (3,43 ± 2,39 %) étant enregistré chez les alevins âgés de 13 jours au transfert. L'âge au transfert en étang n'a pas significativement ($P > 0,05$) affecté la longueur moyenne (LM) des alevins de même que la croissance linéaire journalière (CLJ), le poids moyen (PM), la croissance pondérale, le taux de croissance spécifique (TCS) aussi bien que le facteur de condition (K). Toutefois, la LM la plus élevée a été obtenue chez les alevins transférés à l'âge de 13 jours (36 ± 2,80 mm), suivie de ceux transférés à 7 jours d'âge (34,2 ± 1,26 mm), la plus faible étant obtenue chez ceux transférés à 4 jours d'âge (32,10 ± 2,58 mm). Le PM en fin d'essai (401,33 ± 198,56 mg), le TCS de croissance spécifique (17,28 ±1,93 %), de même que le K (1,05 ± 0,43) ont été les plus élevés chez les alevins transférés à 10 jours d'âge, les plus faibles étant enregistrés chez ceux transférés à 7 jours d'âge. Il sera convenable de transférer les alevins au plus tard à 4 - 7 jours d'âge après l'éclosion, mais ceci nécessite d'être confirmé par d'autres études.

Mots-clés : pisciculture, alevinage, âge au transfert, reproduction, croissance, Clariidae.

EFFECT OF AGE AT TRANSFER INTO POND OF *CLARIAS GARIEPINUS* (BURCHELL, 1822) FRY

Abstract

The study was conducted between April and September 2010, in the aquaculture unit of the Institute of Agricultural Research for Development (IRAD) in Foumban, Koupa Matapit (5°45.826" LN and 10°48.516"LE) in Western Cameroon. The main objectives were on the one hand, to assess the effect of the age at transfer into pond on the survival and growth of *Clarias gariepinus* fry and, on the other hand to propose the optimal age at which the fry should be transferred. To this effect, 12 comparable (age, total length, mean weight) groups of 1750 larvae each, were randomly distributed into four treatment groups T4, T7, T10 and T13 with 3 replicates each, corresponding to transfer at the ages of 4, 7, 10 and 13 days respectively. To each group, was randomly assigned, one of the 12 simulated ponds, comparable for their characteristics. The experiment latest 30 days and the main results were as follow: at the end of the rearing period, the survival rate of the larvae transferred at the age of 4 days (21.82 ± 6.54 %) was significantly ($P < 0.05$) higher than those transferred at 7 days (19.21 ± 9.03 %) followed by those transferred at 10

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days (7.27 ± 7.91 %) and at 13 days (3.43 ± 2.39 %) respectively. The age at transfer into pond did not significantly (P > 0.05) affect the total mean length (ML), the daily linear growth (DLG), the mean body weight (BW), the daily mean weight (DMW), the specific growth rate (SGR) nor the condition factor (K). However, the highest ML was from the fry transferred at the age of 13 days (36 ± 2.80 mm) followed by those transferred at 7 days (34.2 ± 1.26 mm), the least value being obtained for the larvae transferred at 4 days (32.10 ± 2.58 mm). The highest BW at the end of the experiment (401.33 ± 198.56 mg) as well as the SGR (17.28 ± 1.93 %) and the K (1.05 ± 0.43) were registered for the fry transferred at the age of 10 days, the lowest being registered for those transferred at 7 days. To conclude, it appears that the larvae should be transferred into pond not later than 4 to 7 days post hatching, but this needs to be confirmed by further studies.

Key-words: Fish farming, nursery, age at transfer into pond, reproduction, growth, Clariidae.

Introduction

En Afrique subsaharienne, la malnutrition reste un défi majeur. Dans la plupart des cas, cette situation de malnutrition est due à une insuffisance en protéines animales, nutriments dont la source principale en Afrique tropicale est le poisson (Pouomogne, 1998). Au Cameroun, plusieurs analyses rapportent que le poisson représente la protéine la plus consommée ; constituant même, selon Grosse (2009), l'essentiel (88 à 94 %) des apports en protéines animales. Cependant cette importante contribution du poisson ne se justifie pas par une production nationale (pêche et pisciculture) conséquente. Selon Scilife-Cameroun (2010), la pisciculture camerounaise ne produit qu'environ 1000 tonnes de poisson par an.

Pourtant, le Cameroun possède de nombreuses potentialités piscicoles dont 4 milliards de plan d'eau intérieur (Pouomogne, 1998) pour un potentiel estimé à 20 000 tonnes par an (Satia, 1980). L'exploitation de ce capital contribuerait à terme à satisfaire les besoins croissants de la population, tout en réduisant les importations, sources de perte de devises pour le pays. Malheureusement, une kyrielle de contraintes freine encore l'essor de la pisciculture camerounaise. Selon la FAO, (2005) la mauvaise qualité et l'offre insuffisante des juvéniles sont l'une des principales contraintes.

Clarias gariepinus est une espèce dont les atouts zootechniques ont été établis. En effet, *Clarias gariepinus* présente de nombreux avantages (rusticité, régime alimentaire diversifié, sa chair très appréciée) par rapport à d'autres espèces piscicoles au Cameroun (Tiogué *et al.,* 2008). Or, son expansion reste encore limitée par la disponibilité et l'accessibilité en alevins de qualité. Des techniques d'induction hormonale de reproduction sont aujourd'hui maîtrisées (Hecht, 1988; Legendre, 1991), mais l'élevage des alevins en étang reste un goulot d'étranglement, du fait des faibles taux de survie généralement enregistrés. L'âge des alevins au moment de leur transfert en étang serait l'une des causes responsables de ces faibles performances. Ainsi, après avoir produit les larves, les transférer au moment propice est nécessaire. Transférés plus tôt, les alevins seraient encore fragiles du point des vues anatomique, physiologique et comportementale, et incapables de résister aux conditions de l'étang. Trop tard, il serait probablement difficile pour les petites écloseries de supporter les coûts de production (structures d'élevage et alimentation). La littérature disponible ne révèle aucune étude détaillée sur cet important aspect d'élevage d'où l'intérêt de ce travail.

L'objectif général est de contribuer à l'amélioration de la production et la productivité de la pisciculture du Clarias au Cameroun. Plus spécifiquement il s'agira d'une part, de déterminer l'effet de l'âge au transfert sur le taux de survie et sur la croissance et d'autre part de proposer l'âge optimum de transfert des alevins de *Clarias gariepinus* en étang.

Materiels et Methode

Localisation de la zone d'étude

L'étude s'est déroulée entre avril et septembre 2010 à l'IRAD de Foumban, au sein de sa ferme d'expérimentation piscicole de Koupa Matapit. Koupa Matapit est situé à une dizaine de kilomètres de Foumban (Chef lieu du Département du Noun) dans la Région de l'Ouest Cameroun. Selon un relevé GPS, la localisation exacte de la station de Koupa Matapit est 5°45,826' de latitude Nord et 10°48,516' longitude Est, à une altitude de 1147 m (Mikolasek *et al.,* 2006).

Matériel animal

Un total de 21 000 alevins âgés de 3,5 à 4 jours (post-éclosion) d'une longueur totale moyenne de 6,6 ± 0,38 mm et de poids moyen de 2,03 ± 0,05 mg, ont été utilisés. Ils provenaient d'un stock de géniteurs produits et élevés à la ferme piscicole de Koupa Matapit, nourris à base d'un aliment contenant 35% de protéine brute. Les alevins ont été obtenus par la reproduction artificielle de 9 géniteurs (préalablement sélectionnés) dont 4 femelles et 5 males. Les femelles (400 g chacune) ont été induites par injection de l'hormone LH-RHa (Luteinizing Hormone-realising Hormone analog) à la dose de 20 µg.kg-1, associée au dompéridone (Motilium: 10 mg.kg-1). Le prélèvement des testicules était effectué selon la méthode proposée par Nguenga (2000), résumée ainsi qu'il suit : anesthésie des géniteurs mâles (0,5 ml de 2-phényléthanol par litre d'eau) ; dissection, prélèvement des gonades et suture; désinfection et remise dans l'eau.

Dispositif expérimental et conduite de l'essai

Un plan expérimental mono factoriel (âge au transfert), avec trois (3) répétitions par traitement a été employé. Quatre traitements T4, T7, T10 et T13 correspondant à 4, 7, 10, et 13 jours d'âge au transfert ont été utilisés

Structures d'élevage

Compte tenu de l'absence d'une alimentation adéquate (Artemia ou zooplanctons), des températures faibles (22 ± 1 °C en moyenne), et un PH bas (<6,5) pour pouvoir maintenir et élever les différents lots d'alevins dans l'écloserie (de la résorption vitelline jusqu'à la date de leur transfert respectif), 3 hapas couverts de (2,5×1,5×1 m) implantés dans un étang en terre (transparence 50 cm ; température 22-27 °C ; PH 6,4-6,5) ont été utilisés comme substitut. Les hapas (1mm de mailles) étaient soutenus par des bambous de chine implantés dans l'assiette. La transparence, la température, le PH et le taux d'ammonium de l'eau de l'étang en terre y étaient respectivement de 40–60 cm ; 22 – 29 °C ; 6,5 – 6,8 ; <0,025 mg/l.

Douze (12) bacs bétonnés (photo 1) d'environ 700 l chacun (longueur 2 m ; largeur 0,7 m ; hauteur 0,5 ± 0,1m) ont été utilisés. Chaque bac a reçu en moyenne 5 cm de terre provenant de l'assiette d'un même étang afin de simuler les conditions d'un étang en terre, et de stimuler leur productivité naturelle. Pour chaque étang simulé, un tuyau PVC (36 mm de diamètre) coupé à une hauteur de 37 ± 1 cm a été installé pour y maintenir un volume d'eau constant de 350 l. Un système d'amenée d'eau, constitué d'un tuyau PVC et des vannes disposées en parallèle, ont été installés pour

Photo 1 : Vue générale du dispositif expérimental (a) et d'un étang simulé (b).

contrôler le débit dans chaque étang simulé. Le lac André situé à environ 720 m en amont alimente l'ensemble par l'intermédiaire d'un canal de dérivation. Une grille (maille 1 mm) a été installée à l'entrée du tuyau d'amener contre l'entrée des prédateurs, et une autre à l'ouverture supérieure du trop plein pour empêcher les alevins de s'échapper.

Avant la mise en eau, chaque étang simulé a reçu de la chaux vive à la dose de 10 kg.are-1 14 jours avant le début de l'essai comme recommandé par Viveen *et al.,* (1985). A la fin de ce vide sanitaire, 3 étangs simulés choisis au hasard, étaient mis en eau et recevaient immédiatement une fertilisation de base, 4 jours avant la date du transfert. La fertilisation journalière a été réalisée lorsque la transparence était supérieure à 37 cm et en fonction du taux d'ammonium et de nitrite. Le tableau 1 résume le schéma de la fertilisation utilisé pour chaque étang simulé (1,4 m²). L'eau était partiellement renouvelée chaque fois que des valeurs critiques de la transparence (< 20 cm), de PH (> 8), d'ammonium, de nitrite étaient obtenues.

Mise en charge et alimentation

Tous les transferts se faisaient entre 6h30 et 9h du matin. A la fin de la résorption vitelline (3,5-4 jours post-éclosion), les lots ont été préconstitués et répartis de la manière suivante :

- trois (3) lots (T4.1, T4.2, et T4.3) de 1750 alevins (5 alevins/l) ont été immédiatement transférés dans les étangs simulés, choisis au hasard puis,
- trois (3) groupes de 5250 alevins chacun, correspondant aux traitements T7, T10 et T13 ont été stockés dans trois hapas, d'où des lots étaient reconstitués à partir des alevins présents (survivants) dans chaque hapa, à la date du transfert (Photo 2).

Les alevins recevaient 4 fois par jour un aliment composé (tableau 2), contenant 52 % de protéine brute et 14 % de matière grasse. Les ingrédients ont préalablement été écrasés, puis tamisés avec un tamis de 425 mm de maille avant d'être mélangés. La ration était de 25 % de la biomasse (en moyenne) pour toute la durée de l'essai, en se référant au tableau 2 de rationnement proposé par Gilles *et al.,*. (2001). Pour chaque étang simulé, les quantités d'aliment étaient ajustées en estimant leur charge respective. Au cours des pêches de contrôle, les alevins étaient observés afin de détecter d'éventuelle anomalie. Tous les jours entre 6h00 et 6h30 du matin, les alevins étaient observés en surface, avant le début de la respiration aérienne, ce qui permettait d'avoir une idée approximative sur l'effectif dans chaque étang simulé.

Collecte des données et paramètres étudiés
Paramètres physicochimiques de l'eau

Les caractéristiques physicochimiques de l'eau telles que la température, la transparence, le PH, la concentration d'ammonium et de nitrite, la dureté totale ont été mesurées. La température était mesurée 2 fois tous les jours à 6h30-7h00 et 15h30-16h00, grâce à un thermomètre de marque JBL, gradué au degré près. Tous les autres paramètres étaient collectés une fois par jour, à 1 jour d'intervalle. Faute d'un réfractomètre, la transparence de l'eau a été mesurée à l'aide d'un disque de Secchi ayant une graduation de 20 cm. Le PH, la concentration ammonium et de nitrate étaient mesurés grâce aux réactifs fournis par le kit d'analyse de laboratoire de marque JBL. Les échantillons d'eau à analyser

Tableau 1 : Quantités d'engrais utilisées pour chaque fertilisation.

Fertilisation	Fiente de poules (g)	Superphosphate Triple (g)	Urée (g)	20-10-10 (g)
départ	300	7	7	7
journalière	42	0,7	1,4	1,4

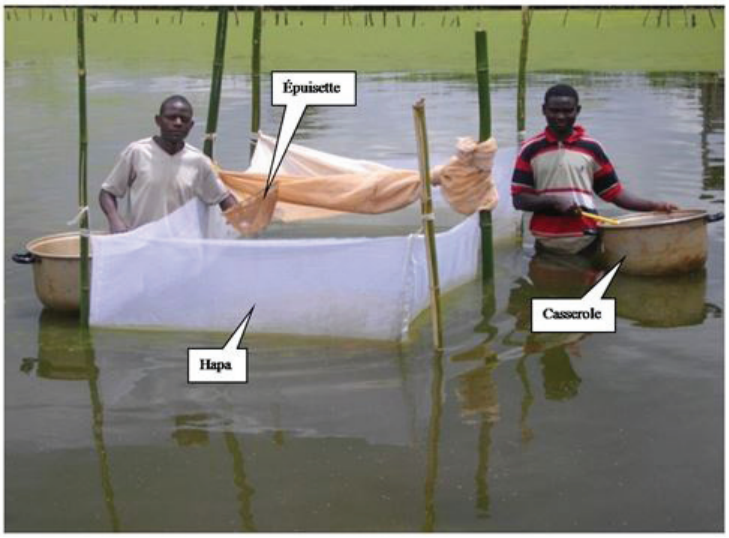

Photo 2 : Pêche des alevins dans l'hapa avant le transfert (Photo Ego, août 2010).

Tableau 2 : Composition pour 100 kg d'aliment.

Ingrédients	Quantité pour 100 kg	Caractéristiques (% matière sèche)
Farine de poisson	60	Farine de poisson, composition maximale (Fabricant): [65 % protéine brute ; 15 % graisse ; 4,5 % Calcium ; 3,5 % phosphore ; 10 % sodium].
Tourteaux de coton	15	45 % protéine brute*
Tourteaux de soja	9	49 % protéine brute (fabriquant)
Farine de maïs	3	9 % protéine brute*
Drêchede brasserie	4	22 % protéine brute*
Sel	0,15	-
Farine d'os	0,25	-
Huile de palme	4,6	-
Prémix	4	CMAV 2% chair [humidité 97,6 g/kg ; énergie métabolisable 2150 kcal/kg 420 g/kg protéines brutes (max) ; cendres brutes 218 g/kg (Fabricant)].

**Valeurs moyennes (FAO, 2005) Protein content, availability and price of major fish feed ingredients in Cameroun (2005).*
Source : Adapté de Pouomogne (1998) et de Gilles et al. (2001).

Tableau 3 : Variation des caractéristiques physicochimiques de l'eau dans les étangs simulés en fonction de l'âge des alevins au transfert.

	Ages au transfert (jours)			
Paramètres	**T4**	**T7**	**T10**	**T13**
Température (°C)	22,6 ± 3 [a]	22,6 ± 3[a]	22,6 ± 3[a]	22,6 ± 3[a]
PH	7,5[a]	7,48[a]	7,46[ab]	7,29[b]
Transparence (cm)	28,67[a]	32,67[ab]	38[b]	37,67[b]
GH (°d)	3 [a]	3 [a]	3 [a]	3 [a]
Ammonium (mg/l)	0,325[a]	0,445[a]	1,513[b]	1,81[b]
Nitrite (mg/l)	0,03[a]	0,045[a]	0,043[ab]	0,055[b]

a et b : sur la même ligne, les valeurs affectées de la même lettre ne diffèrent pas significativement (P > 0,05).

étaient prélevés (avant la première distribution d'aliment de 8h00) dans tous les étangs simulés, et maintenus dans des bols plastiques (étiquetés) jusqu' au moment de l'analyse.

Les variations des caractéristiques physicochimiques de l'eau durant l'expérimentation sont résumées au tableau 3.

Les températures moyennes ont variée de 23 à 27°C dans les hapas, et de 19,6 à 25,6°C dans les étangs simulés. En dehors de la dureté totale (GH), tous les autres paramètres physicochimiques ont significativement varié entre les traitements ($p < 0,05$). Les concentrations les plus élevées en ammonium et en nitrite ont été enregistrées chez les larves transférées à 13 jours d'âge suivi de celles des transférés à 10 jours d'âge, les plus faibles ayant été enregistrées chez ceux transférés à 7 et 4 jours d'âge.

Taux de survie

Le TS à la vidange, a été calculé par la formule suivante :

$$TS = \frac{\text{Nombre d' alevin à la vidange}}{\text{(Nombre d^' alevin initial}} \times 100$$

La croissance linéaire journalière (CLJ)

Tous les 3 jours, des pêches de contrôle étaient réalisées à l'aide d'une épuisette (1 mm de maille). Un échantillon de 5 alevin, pêchés dans chaque étang simulé, étaient préalablement observés en vue de déceler d'éventuelles anomalies puis, mesuré à l'aide d'un papier millimétré fixé sur la face inférieure d'une boite de pétri (Photo 3). Au début de l'essai, un échantillon de 60 alevins collectés au hasard a préalablement été mesuré pour déterminer la longueur totale initiale. La CLJ a été calculée par la formule suivante :

$$CLJ\ (mm/jr) = \frac{\text{Longueur totale finale – Longueur totale initiale}}{\text{Période d^' élevage}}$$

(mg/jr) = Millimètre par jour

La croissance pondérale ou gain moyen quotidien (GMQ)

La croissance pondérale a été déterminée par une pesée groupée de tous les alevins de chaque lot à la vidange. Au début de l'essai, un échantillon de 500 larves par traitement avait également été pesé en groupe avec une balance (10-3 g) pour déterminer leur poids moyen initial. Ainsi, le gain moyen quotidien a été calculé par la formule suivante :

$$GMQ\ (mg/jr) = \frac{\text{Poids moyen final – poids moyen initial}}{\text{Période d'élevage}}$$

(mg/jr) = Milligramme par jour

Le Taux de croissance spécifique (TCS)

Le TCS a été évalué par la formule proposée par Tabaro *et al.,*. (2005).

TCS=

$$\frac{(\ln(\text{poids moyen final}) - \ln(\text{poids moyen initial})) \times 100}{\text{Nombre de jour de suivi}}$$

Le facteur de condition (K)

Le facteur de condition a été calculé par la formule de Hecht (1982) et Hecht et Viljeon (1982). $K = 100M / (LT)^3$ avec M = poids final (mg) et LT = longueur moyenne totale (mm).

Photo 3 : Mesure de la longueur totale des alevins.

Analyse statistique

L'analyse de la variance (ANOVA) à un facteur a été utilisée pour analyser les données. Les taux de survie ont préalablement été soumis à la transformation angulaire avant d'être analysé. Le test de Duncan au seuil de signification P <5 % a permis de séparer les moyennes lorsque les différences étaient significatives.

Resultats

Comportement des alevins

L'aliment utilisé dans cet essai a été consommé dès le début du nourrissage dans tous les traitements. Dans les étangs simulés, les larves s'alimentaient beaucoup plus au niveau des abris, aussi bien en surface qu'au fond de l'étang. Tous les matins entre 6-6h30, la majorité des alevins étaient observées en surface et ce, jusqu'au 18-20 jours d'élevage, et par la suite ils devenaient rares à partir du début de la respiration aérienne.

Une importante mortalité (environ 160 alevins) a été enregistrée pendant les opérations de transfert des alevins âgés de 13 jours, ce qui nous a contraints à continuer le transfert le 14ème jour. Les individus les plus vigoureux dont la longueur totale était comprise entre15 et 20 mm mouraient le plus.

A 25 jours d'âge, 2 alevins présentant un ventre ballonné, laissant apparaître leur tube digestif ont été collectés dans deux lots des alevins transférés à 13 jours pendant la pêche de contrôle. De même, 1 alevin présentant les mêmes caractéristiques susmentionnées a été identifié chez transférés à 31 jours d'âge.

Effet de l'âge au transfert sur le taux de survie à la vidange

- En hapa

Au moment du transfert, les taux de survie dans les hapas (milieu contrôlé) étaient de 99,44 ; 99,14 et 95,44 % respectivement pour les alevins transférés à 7, 10 et 13 jours d'âge respectivement. Le taux de survie des alevins transférés à l'âge de 7 jours est supérieur à celui de ceux ayant 10 jours au transfert, et de ceux transférés à 13 jours d'âge. La présence de fragments d'alevins (sans queue) observés dans l'hapa au moment du transfert des alevins à 13 jours d'âge est un signe qui suggère que la plupart y seraient mort de suite d'un cannibalisme de type I.

- En étang simulé

L'effet de l'âge au transfert sur la survie a été significatif ($P < 0,05$). Le tableau 4 résume le résultat de la comparaison des moyennes. Il ressort du tableau 4, que le taux de mortalité a été en général très élevé (supérieure à 88 %) dans tous les lots. Le taux de mortalité a été d'autant plus élevé que l'âge au transfert en étang était plus grand.

Effet de l'âge au transfert en étang sur la croissance

- Effet de l'âge au transfert sur l'évolution de la croissance linéaire (figure1)

Ainsi qu'il ressort de la figure 1, la tendance et le profil des courbes de la longueur totale sont comparables pour tous les traitements. Les variations les plus importantes étant enregistrées chez les alevins transférés

Tableau 4 : Effet de l'âge au transfert sur la survie des alevins de *C. gariepinus*.

Age au transfert (Jours)	Survie (%)
Transfert à 4 jours d'âge	21,82 ± 6,54 [a]
Transfert à 7 jours d'âge	19,21 ± 9,03 [ab]
Transfert à 10 jours d'âge	7,27 ± 7,91 [bc]
Transfert à 13 jours d'âge	3,43 ± 2,39 [c]

a, b et c : sur la même colonne les valeurs affectées de la même lettre ne différent pas significativement (P > 0,05).

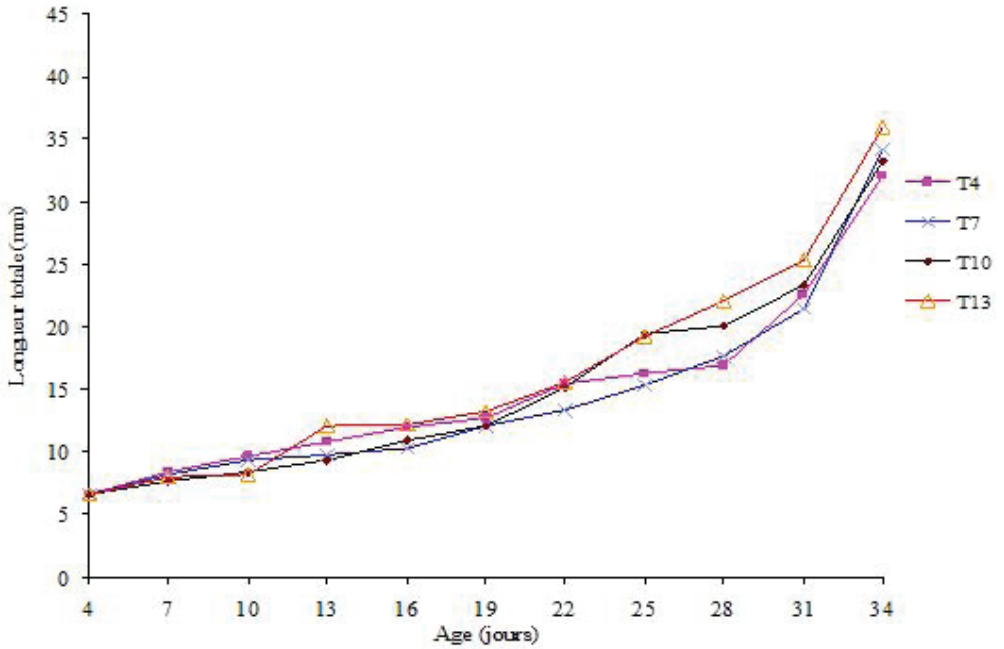

Figure 1 : Evolution de la longueur totale en fonction de l'âge au transfert.

Tableau 5 : Effet de l'âge au transfert sur les paramètres de croissance.

	Ages au transfert (jours)			
Paramètres	**T4**	**T7**	**T10**	**T13**
Longueur moyenne finale (mm)	32,10 ± 2,58 [a]	34,20 ± 1,26[a]	33,21 ± 2,83[a]	36 ± 2,80[a]
Accroissement ΔLT/Δt (mm/jour)	1,10 [a]	1,14[a]	1,10[a]	1,20[a]
Poids moyen final (mg)	274,33 ±12,50[a]	241,33 ±38,28[a]	401,33 ± 198,56[a]	350,33 ± 0,57[a]
Gain de poids journalier (mg/jour)	8,93[a]	7,60[a]	13,37[a]	11,60[a]
TCS (%)	16,35 ±0,16[a]	16,70 ±1,35[a]	17,28 ±1,93[a]	17,17 ±0,00[a]
Facteur de condition K	0,84 ±0,17[a]	0,60 ±0,10[a]	1,05 ±0,43[a]	0,78 ±0,26[a]

(a) = sur la même ligne, les valeurs affectées de la même lettre ne diffèrent pas significativement (P >0,05).

à 13 jours d'âge entre le 10 et 19ème jour, ensuite chez ceux transférés à 4 jours d'âge entre le 22 et le 31ème jour, et enfin chez les alevins transférés à 10 jours d'âge entre le 25 et le 31ème jour. Le lot ayant eu la croissance la plus régulière est celui des alevins transférés à 7 jours d'âge.

- Effet de l'âge au transfert sur les paramètres de croissance

L'ANOVA n'a révélé aucune différence significative ($P > 0,05$) entre les âges au transfert pour l'ensemble des paramètres de croissance énumérés au tableau 5. Il apparaît du tableau 5 que les valeurs moyennes que ce soit de la longueur moyenne finale, de la croissance linéaire journalière, du poids moyen final ou encore du taux de croissance spécifique sont comparables quel que soit l'âge au transfert effectué. Il faut cependant remarquer que la variation la plus élevée de poids (±198,56 mg) a été enregistrée chez alevins transférés à 10 jours d'âge, alors que les alevins transférés à l'âge de 13 jours ont été beaucoup plus homogènes (± 0,57 mg, seulement).

Discussion

De nos résultats, il s'est révélé des mortalités importantes au moment du transfert des alevins à 13 jours d'âge. Elles seraient dues au stress. En effet, les alevins les plus vigoureux présentaient un estomac rempli d'aliment, signe de satiété. La manipulation (pêche, comptage et stockage) des alevins dans cette condition aurai ainsi causée des disfonctionnements digestifs qui ont été préjudiciables pour certains d'entre eux. Il se dégage qu'à cet âge, les alevins doivent être mis à jeun 24 heures environ avant toute manipulation.

Il est apparut que le taux de survie diminue au fur et à mesure que l'âge au transfert augmente, le taux de survie le plus élevés étant obtenu lorsque les alevins sont transférés à 4 jours d'âge, dès la fin de la résorption vitelline. Nos observations sont similaires à celles rapportées par Legendre (1991). En effet, ce dernier avait également trouvé que l'âge le plus favorable en termes de survie pour le transfert des larves de *H. longifilis* vers les cages implantées en étang se situe à l'âge de 2 jours (fin résorption vitelline). Ainsi, il se pourrait que les alevins transférés à un âge proche de la résorption vitelline s'adaptent mieux aux conditions d'élevage de l'étang, par rapport à ceux qui y sont introduits un peu plus tard. Dans cet essai, cela pourrait d'une part s'expliqué par le taux d'ammonium. C'est ainsi que dans les étangs ou ce taux a été le plus élevé, les taux de survie ont également été les plus faibles. D'autre part, cette diminution du taux de survie avec le report de l'âge de transfert serait également liée à la concentration en nitrite. En effet l'on remarque que la concentration en nitrite a cependant été significativement plus élevée chez les alevins transférés à 7 jours d'âge (avec un taux de survie inférieur à celui des alevins transférés à 4 jours d'âge), par rapport à celle de ceux transférés à 4 jours d'âge. L'ammonium devient en effet très toxique s'il s'accumule in vivo même à de très faibles concentrations (Das et Ratha, 1996). De plus, selon le fabricant du kit d'analyse, des concentrations de 4 et 5 mg/l telles que enregistrées dans les lots transférés à 10 et à 13 jours d'âge sont aussi bien mortelles pour les jeunes que pour les poissons adultes. Certes *C. gariepinus* est reconnue comme étant particulièrement très résistant à NH4, mais les larves ou les alevins âgés de moins de 18 jours y seraient encore très sensibles, car n'exercent pas encore la respiration aérienne.

En terme de performance d'élevage, le taux de survie le plus élevé obtenu chez les alevins transférés à 4 jours d'âge est inférieur à 36,85 et 29,65 % enregistrés par Tabaro *et al.,* (2005) en étang simulé. Ces différences peuvent être associées à la densité qui était beaucoup plus élevée dans cet essai (5 larves/l), comparée aux densités utilisées par cet auteur (0,8 et 1,6 larve/l). En plus de ce facteur, la présence des prédateurs par ailleurs absents chez cet auteur aurait également affecté nos résultats. En effet, une importante activité de prédation a été observée dans les lots transférés à l'âge de 4 et 7 jours par les larves de moustiques. Ce qui voudrait dire qu'à 4 et 7 jours d'âge, les alevins sont toujours des proies faciles, même pour les

plus petits prédateurs. Les prédateurs présents dans les étangs simulés étaient: les larves et nymphes de moustiques, les larves d'Odonate et de Chironomus, les tubifex. Les têtards et les crapauds n'ont pas été observés au cours de cet essai. En revanche, la prédation par les oiseaux piscivores bien que n'ayant pas été observés, n'est pas à exclure.

Hecht (1982), avait rapporté des mortalités de 70 à 80 % trois semaines après que les alevins par ailleurs âgés de 16 jours et mesurant 14,5 ± 3 mm ont été transférés dans les étangs en terre, et avait par conséquent suggéré que les alevins ne devraient pas être transférés en étang avant une taille minimale de 25-30 mm. Le taux de mortalité enregistré chez les alevins transférés à 13 jours d'âge (12,07 ± 0,45 mm), au terme de 21 jours d'élevage en étang simulé est de 21,5 % plus élevé que ceux obtenus par Hecht. Pour ce dernier, la prédation par les crapauds était la principale cause responsable de ces mortalités élevées. Par contre, dans cet essai, ces mortalités seraient dues à la maladie. En effet, des symptômes similaires à ceux que l'on a observés chez les alevins dans T7 et T13 ont été rapportés par Boon et Huisman (1996) à ce stade de développement, phase de croissance rapide chez les alevins. Il s'agirait du syndrome de la rupture intestinale, qui est une maladie à étiologie mal connue. En revanche, le cannibalisme n'aurait pas joué un rôle important sur les taux de survie obtenus car une faible hauteur de l'eau (30 cm) ne permet pas l'installation d'une hiérarchie liée au comportement d'agressivité qui cependant se développe dans les bassins plus profonds chez *C. gariepinus* (Tabaro *et al.,* 2005).

Ainsi qu'il ressort des résultats de l'effet de l'âge au transfert sur la croissance linéaire et pondérale des alevins en étang simulés, il est apparut que la croissance des alevins de *C. gariepinus* ne serait pas fonction de l'âge au transfert en étang. Malheureusement la littérature disponible ne fourni aucun essai similaire, réalisé à ce sujet et qui aurait permis de comparer nos résultât. En revanche, sur la base des performances d'élevage, nos résultats en terme de croissance linéaire sont de 10-16 mm supérieurs à 20 mm rapportée par Greenwood (1957) après un mois d'élevage des larves de *C. gariepinus* ; se situent entre la longueur totale de 3-6 cm, mais très inférieurs au poids de 1-3 g rapportés par de Viveen *et al.* (1985) en 30 jours d'élevage.

En étang simulé, Tabaro *et al.* (2005) rapportent un poids moyen de 7,28 g, un gain de poids moyen de 240 mg/j, et un taux de croissance spécifique de 18, 17 % après 38 jours d'élevage des larves de *C. gariepinus* stockées à 11 jours d'âge. Nos résultats sont de 6,88 g inférieur au poids moyen de ces auteurs, très inférieur du gain moyen journalier et de 0,89 % inférieur au taux de croissance spécifique de ces auteurs. Ces différences seraient non seulement dues à la densité de stockage mais également à la température des étangs, la durée de la période d'élevage et la qualité biologique des alevins utilisés par ces auteurs. En effet la température moyenne y de était de 26 °C pendant 38 jours, contre seulement 22,6 °C dans le cas de cet étude, en 21 jours d'élevage. En plus, les alevins dans notre essai provenaient de 4 femelles de 0,4 kg chacune, par contre ceux de ces auteurs provenaient de 4 femelles ayant un poids moyen de 4 ± 0,8 Kg.

Le facteur de condition a été utilisé par Hecht et Villajoen (1982) pour indiquer la convenance d'une alimentation, ensuite pour juger la 'forme physique' des larves avant leur stockage en étang (Hecht, 1982). Dans ce travail, il a été introduit dans le but d'apprécier le bon état physique des alevins dans les différents traitements au terme de la période d'alevinage. Le meilleur facteur de condition (1,05) a été enregistré chez les alevins transférés à 10 jours d'âge. Cette valeur est supérieure à 1, situation nécessaire pour que l'on considère que les poissons sont en bonne condition (Uys et Hecht, 1985). Ainsi, les conditions d'élevage des alevins transférés à 4, 7 et 13 jours d'âge, n'étaient pas convenables. Toutefois, la bonne condition physique obtenue à la fin de l'essai chez les alevins transférés à 10 jours d'âge, dissimulerait l'effet de la variation des conditions d'élevage notamment les caractéristiques physicochimiques de l'eau qui y ont été enregistrées au cours de l'essai. L'évolution du facteur de condition à travers

des collectes régulières du poids des alevins, nous aurait permis de mieux expliquer ce résultat. Néanmoins, l'on pourrait penser que suite aux fortes mortalités qui ont suivit les transferts à 10 et à 13, l'amélioration des conditions dans ces étangs dont la faible densité, l'augmentation de la disponibilité en zooplancton/alevins, la bonne physicochimie de l'eau, aurait été bénéfique pour les survivants.

Conclusion

Le taux de survie des alevins *Clarias gariepinus* parait être affecté par l'âge au transfert en étang. Ainsi, il est d'autant plus faible que les alevins sont plus âgés au transfert. L'âge de transfert n'a pas semblé affecter de manière significative ($P > 0,05$) l'évolution de la croissance linéaire, pas plus que le poids moyen, le gain moyen de poids, le taux de croissance spécifique aussi bien que le facteur de condition. Ainsi, il sera convenable de transférer les alevins au plus tard 4 à 7 jours d'âge après l'éclosion. Les caractéristiques physicochimiques de l'eau notamment la concentration en ammonium et nitrite semblent affecter le taux de survie. Les hapas couverts installés en étang en terre préalablement fertilisé peuvent être utilisés comme substitut à l'élevage en écloserie dont la principale contrainte est sont coût très élevé.

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GROWTH PERFORMANCE AND SURVIVAL OF THREE STRAINS OF AFRICAN CATFISH (*CLARIAS GARIEPINUS*, BURCHELL 1882) REARED IN HAPAS IN KENYA

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Abstract

This study was conducted to compare the growth performance and survival of three strains of African catfish (*Clarias gariepinus*) cultured in Kenya. Three strains originally from the Netherlands (Dutch), Indonesia, and Kenya, (Lake Victoria) were studied. *C. gariepinus* having an average initial body length of 3.87 cm and weight of 0.51 g were stocked at 6 fish m2 in triplicate in 2.0 m × 2.0 m × 1m hapa nets mounted in an earthen pond. The fish were fed with commercial catfish diet 45% crude protein (Skretting fish feed Ltd). The results showed that the Indonesian strain had the best growth and had significantly ($P < 0.05$) higher final mean body weight (287.20±16.78g) and mean daily weight gain (1.37± 0.06%). Specific growth rate (SGR) was not significantly different in the Dutch and Indonesian strain ($P > 0.05$). The FCR of the Indonesian strain (1.03 ± 0.00) was significantly ($P <0.05$) lower than the Kenyan and the Dutch strains which had similar FCR. The survival of the three strains was not significantly different ($P> 0.05$). However, the survival of the Dutch strain was higher (65.00±12.58%) compared to the other strains with the Kenyan strain exhibiting the lowest survival of 59.52±9.52%. There were no significant differences ($P > 0.05$) in Coefficient of Variation (CV) in the Dutch and the Indonesian strain, and the highest CV was recorded in the Kenyan strain. The overall conclusion is that growth performance between the three strains of *C. gariepinus* was significantly different and thus, it is crucial to select the right strain for production purposes depending on availability.

Keywords: Growth performance, *Clarias gariepinus*, strains

PERFORMANCE DE CROISSANCE ET SURVIE DE TROIS SOUCHES DE POISSON-CHAT AFRICAIN (*CLARIAS GARIEPINUS*, BURCHELL 1882) ÉLEVÉS DANS DES HAPAS AU KENYA

Résumé

La présente étude a été menée dans le but de comparer la performance de croissance et la survie de trois souches de poisson-chat africain (*Clarias gariepinus*) élevés au Kenya. Trois souches originaires des Pays-Bas (hollandaise), d'Indonésie, et du Kenya (lac Victoria) ont été étudiées. Des poissons *C. gariepinus* d'une longueur corporelle initiale moyenne de 3,87 cm et pesant 0,51 g ont été stockés à une densité de 6 poissons par m2 de poissons en trois répétitions dans des filets hapa de 2,0 m × 2,0 m x 1 m montés dans un étang de terre. Les poissons ont été soumis à une alimentation commerciale pour poisson-chat à 45% de protéines brutes (Skretting fish feed Ltd). Les résultats ont révélé que la souche indonésienne avait la meilleure croissance et un poids corporel moyen final significativement ($P <0,05$) plus élevé (287,20 ± 16,78 g) ainsi qu'un gain pondéral quotidien moyen (1,37 ± 0,06%) supérieur par rapport aux autres souches. Le taux de croissance spécifique (TCS) n'était pas significativement différent entre les souches néerlandaise et indonésienne ($P> 0,05$). L'indice de consommation FCR de la souche indonésienne (1,03

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± 0,00) était significativement (P <0,05) inférieure à celle des souches kenyane et néerlandaise qui avaient un indice de consommation semblable. La survie des trois souches n'était pas significativement différente (P> 0,05). Cependant, la survie de la souche hollandaise était plus élevée (65,00 ± 12,58%) que les autres souches, la souche kenyane ayant enregistré la plus faible survie de 59,52 ± 9,52%. On n'a pas relevé de différences significatives (P> 0,05) au niveau du coefficient de variation (CV) dans les souches néerlandaise et indonésienne, et le CV le plus élevé a été enregistré dans la souche kenyane. La conclusion générale est que la performance de croissance était significativement différente entre les trois souches de *C. gariepinus* et, par conséquent, il est crucial de sélectionner la souche appropriée pour la production en fonction de sa disponibilité.

Mots-clés : performance de croissance, *Clarias gariepinus*, souches

Introduction

The African catfish (*Clarias gariepinus*), is found in several countries throughout its native distributional range as well as in Europe (the Netherlands, Germany, and Belgium), Asia (Indonesia and Thailand) and South America (Brazil) (de Graaf and Janssen, 1996; Brummett, 2008). *C. gariepinus* is the second most important freshwater cultured fish (after tilapia) in Africa (Barasa *et al.,* 2014) with the exception of Nigeria where its production far exceeds tilapia production and accounts for 70 - 80 % of the total freshwater fish production (Ponzoni and Nguyen, 2008). In Kenya, *C. gariepinus* is second most cultured fish species (Ogello and Opiyo, 2011) and it represents over 21% of the total aquaculture production in the country (Otieno, 2011). One of the critical limiting factors in *C. gariepinus* culture has been a serious lack of good quality seed to supply farmers and producers (Macharia *et al.,* 2005). This has been as a result of poor performance of available local broodstock and poor management practices at hatcheries, as well as the non-existence of any appropriate breeding structures or improved strains (Ponzoni and Nguyen, 2008). Development of a genetically improved strain of *C. gariepinus* with higher fillet yield which can adapt to a wide range of production environments in Africa has been made a priority by researchers in Africa (Ponzoni and Nguyen, 2008) since *C. gariepinus* is a popular food fish in areas that are not predominantly fish eating, due to the high flesh to bone ratio (Charo-Karisa *et al.,* 2008; Obiero *et al.,* 2014).

There are several strains of *C. gariepinus* in Kenya, drawn from the indigenous strains as well as imported ones. These include Indonesian, Dutch and several local strains including the Lake Victoria and River Ewaso Nyiro strain. The Dutch strain was imported to Kenya because of their improved performance resulting from selective breeding (Fleuren, 2008). Although *C. gariepinus* originated from Africa, the different stocks exported to other countries have been isolated for several generations and genetically divergent strains may have developed through mass or individual selective breeding under domestic conditions (Broussard and Stickney, 1981). It has been established that the development and effective use of genetically improved strains is one of the most powerful technologies to achieve the fast growing strain of catfish for aquaculture development in Africa. In Kenya, proper selective breeding programs for genetic improvement of farmed fish began recently with genetic improvement programs targeting fast growth of the African catfish and Nile tilapia being established in 2011 at National Aquaculture Research Development and Training Centre, Sagana (Charo-Karisa *et al.,* 2012). Selection of the best strains is crucial for efficient breeding program not only to reach the production goal but also to reduce production cost, to improve disease resistance, utilization of feed resources and product quality (Gjedrem, 1997; Ibrahim *et al.,* 2013). Currently, there are no research findings on the growth, survival and feed utilization of the different *C. gariepinus* strains in Kenya. The results from this study would guide farmers in Kenya to make decisions on the best strain for farming in

local conditions and give basic information for genetic improvement of *C. gariepinus* in Kenya.

Materials and Methods

Origin of stock

Three *C. gariepinus* strains of varying genetic and domestication histories were used: 1) Dutch strain obtained from Fleuren and Nooijen Fish farms Ltd, in Netherlands and was bought from Jambo fish Ltd in Kenya. It has undergone several mass selection and individual selective breeding trials (Fleuren, 2008); 2) Indonesian strain was obtained from Main Center for Freshwater Aquaculture Development in Indonesia, the fish was imported from Taiwan in 1985 (Yusuf, 1995) and has undergone selective breeding for more than 3 generations (Sunarma, 2008); and 3) Kenyan strain was obtained from Lake Victoria in 2010. Both the non-indigenous strains of *C. gariepinus* were imported to Kenya in 2011 from Netherlands and Indonesia respectively and domesticated in ponds at National Aquaculture Research Development and Training Centre (NARDTC), Sagana. All the strains consisted of breeders hatched under artificial conditions and matured in captivity at the centre. To ensure populations were not mixed up; brood-fish from each of the different populations were kept separately in liner ponds and fed on formulated diet of 35% crude protein. For the purpose of this experiment, the fish were reared under the same culture environment at NARDTC Sagana (0°39'S, 37°20'E and 1230 m above mean sea level North East of Nairobi). Healthy and active individuals were chosen for breeding.

Fingerling production

Four pure *C. gariepinus* pairs from each strain were used for mating. The *C. gariepinus* females were harvested two days prior to the expected dates of ovulation by seining the pond. The females were selected to receive gonadotropin hormone injections based on secondary sexual characteristics such as well-rounded, distended abdomen, a reddened or swollen urogenital area, or darkened pigmentation. The male broodfish were harvested one day prior to the estimated ovulation date of the selected female stock. The gravid females from each group were injected with OVAPRIM (sGnRHa) hormone to induce them to ovulate. Ripe eggs were collected into a dry plastic bowl by hand stripping. Milt was obtained through surgical removal of testes according to de Graaf and Janssen, (1996). The eggs were fertilized by mixing with 0.2 ml of diluted milt and adding 5 ml of clean hatchery water. The fertilized eggs were shaken gently for 1 min, rinsed to remove excess milt and mucous materials incubated in aquaria incubator under darkness. The aquaria incubators were covered to provide darkness. When African catfish eggs are incubated in darkness the survival is higher since African catfish larvae are photophobic. Water temperature in the incubators was maintained between 27-29°C using aquaria heaters and the eggs were completely hatched over a period of 18 hours.

Yolk sac fry hatched in the aquaria incubators were reared in nursery tanks in the hatchery. The fish were fed ad libitum four times daily with dried decapsulated cysts of Artemia spp for a period of 5 days. This was followed by a gradual introduction of starter feed (55% protein and 13% lipid) (Skretting Fish Feed Ltd) over a 5-day period. During the 3 days weaning period, larvae were fed ad libitum with decapsulated Artemia cysts and starter feed respectively at alternating intervals. This was followed by use of starter feed only for a period of 1 month until fingerling stage (3.8cm; 0.5g). The fingerlings were then harvested graded for uniformity and individual weight and length measured for a sample of 20 fish from each strain before distribution into the experimental hapas.

Experimental set up and feeding

Each strain of *C. gariepinus* fingerlings were stocked at a stocking density of 6 fish m-2 into three hapa nets each 2.0 m × 2.0 m × 1 m mounted in a 2400m2 earthen pond. The experimental fish were fed on 45% CP commercial catfish diet (Skretting fish feed Ltd) at 5% (should be 10-8%) of their body weight

Table 1: Proximate composition of commercial feed used (Skretting fish feed Ltd)

Parameter (% of dry matter)	Composition
Crude protein (%)	45
Crude fat (%)	14
Total Ash (%)	7
Fibre (%)	3
Calcium (%)	1
Sodium (%)	0.40
Phosphorus (%)	0.90
Lysine (%)	1.50
Methionine (%)	0.50
Copper mg/Kg	5

Table 2: Growth parameters of three *C. gariepinus* strains reared in hapas for 210 days at NARDTC Sagana

Parameter	Dutch	Indonesian	Kenyan
Initial length (cm fish -1)	3. 87±0.09[a]	3.85±0.11[a]	3.88±0.07[a]
Initial weight (g fish -1)	0.51±0.03[a]	0.51±0.04[a]	0.50±0.02[a]
Final length(cm fish -1)	32.93±0.61[a]	33.27±0.70 [ab]	29.19±1.09[b]
Final weight (g fish -1)	265.95±14.29[a]	287.20±16.78[a]	190.81±19.63[b]
SGR (% day -1)	3.03±0.04[a]	3.02±0.05[a]	2.84±0.04[c]
FCR	1.05±0.00[a]	1.03±0.00[b]	1.05±0.020[a]
Weight gain (g)	272.16±11.83[a]	288.38±13.54[a]	204.79±14.22[b]
Daily weight gain (g day -1)	1.30±0.06[a]	1.37±0.06[a]	0.98±0.07[b]
Survival (%)	65.00±12.58[a]	63.16±13.18[a]	59.52±9.52[a]
CV (%)	36.44±0.16[a]	32.54±0.35[a]	49.34±0.55[b]

** Values are expressed as mean ± SE. Mean values in the same row having the same letters are not significantly different (P > 0.05).*

daily at four intervals (0800h, 1100h, 1400h and 1300h). The feeding level was reduced to 3% (7-5%) bodyweight at two intervals (0900h and 1500h) after 1 month. The feeding rate was based on the intensity of the system. Since semi intensive system was used, 5% body weight is recommended. The nutritional composition of the commercial diet (Skretting fish feed Ltd) used in the study is shown in Table 1.

Water quality monitoring

Dissolved oxygen (DO) concentrations, temperature and pH were measured bi-weekly using multi-parameter water quality meter, model H19828 (Hanna Instruments Ltd., Chicago, IL., USA). The hapas were mounted in a 2400m^2 which is large enough for adequate water exchange and the pond did not have any other fish. The DO was above 3mg/L which is within the recommended DO levels for Catfish culture in ponds. Ammonium nitrogen ($NH4^{+-}$ N), nitrate nitrogen (NO3- N) and total alkalinity were measured monthly using standard methods (APHA, 1992).

Fish sampling

Fish growth was monitored monthly by recording individual weight of 20 fish collected randomly from each hapa. 20 fish was used as a sample size. The fish were caught using a scoop net and weighed individually by an electronic balance (readability 0.01g; model KERN 572-33, Germany) and total length using a measuring board to the nearest 0.1cm.

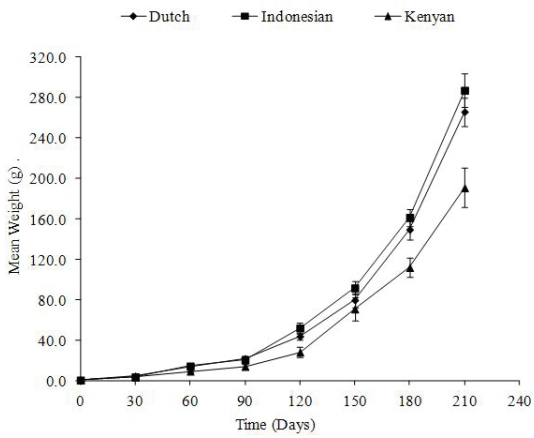

Figure 1: Growth of three different *C. gariepinus* strains reared in hapas

Survival was determined by counting the number of fish remaining in each hapa against the initial stocking number. The performances of the different strains were evaluated based on final weight (g), daily weight gain (g day^{-1}) = 100* (Wt - W0)/t, weight gain (%) = 100* (Wt – W0)/W0, specific growth rate [SGR, % day^{-1} = 100*(lnWt – lnW0 / t], where ln = Natural logarithm, W0 = initial weight (g), Wt = final weight (g) and t = time in days from stocking to harvesting. Survival (%) = number of fish harvested/number of fish stocked) ×100 and feed conversion ratio (FCR) = feed given (g)/body weight gain (g).

Data analysis

All the experimental data including final length, final mean weight, weight gain, SGR, FCR, DWG, and survival, were analyzed using analysis of variance (one-way ANOVA) to determine differences among the strains. Differences between means were further tested for significant differences using Post-Hoc Tukey's HSD tests. Significance level was declared at ($P < 0.05$). SPSS (version 17.0) for windows was used for all statistical analysis.

Results

Growth performance and survival of the fish

Growth performance of different strains of *C. gariepinus* is presented in Table 2 and the growth trends are presented in Figure 1. After 210 days culture period, the final mean weight of Indonesian strain was significantly ($P<0.05$) higher (287.20±16.78 g) compared to the Dutch strain (265.95± 14.29 g) and Kenyan strain (190.81±19.63g), daily weight gain was significantly highest ($P < 0.05$) in Indonesian strain (1.37±0.06 g day -1) followed by the Dutch strain (1.30±0.06 g day -1) and no significant difference was recorded in the daily weight gain of the two strains. The specific growth rate of Indonesia and Dutch strains were significantly higher compared to the Kenyan strain and there was no significant difference between the Dutch and Indonesian strain ($P>0.05$). FCR between strains recorded a significant difference ($P<0.05$) with Indonesian strain being the lowest (1.03±0.00). The Dutch strain exhibited significantly ($P<0.05$) higher survival (65.00±12.58%) while the Kenyan strain had the lowest survival of 59.52±9.52%. The coefficient of variation was higher in the Kenya strain compared to the Dutch and the Indonesian strain, while there were no significant differences ($P>0.05$) recorded in the CV for the Dutch and the Indonesian strain respectively.

Water quality

The ranges of values of the water quality parameters during the experimental period were: pH 7.87 - 7.92; dissolved oxygen 3.78 - 3.91 mg L-1; temperature 23.08 - 23.12 °C; total alkalinity 370.72 - 372.76 mg L-1; Ammonium nitrogen 0.01 - 0.02 mg L-1 and nitrate nitrogen; 0.15 -0.20 mg L-1. All recorded mean values of the water quality parameters were within the acceptable ranges for *C. gariepinus* culture in ponds and were not affected ($P > 0.05$) by the different *C. gariepinus* strains.

Discussion

The current study indicates that Indonesian strain outperformed the Dutch and the Kenyan strain in growth performance. This finding is in line with Giddelo et al. (2002) who indicated considerable variation in growth in

different populations of *C. gariepinus* in the East African region due to geographical separation. Significant morphometric differences have also been established between strains of *C. gariepinus* in the Nile and Lake Victoria (Teugels, 1998) and Lake Kanyaboli (Barasa *et al.,* 2014). The differences in growth among the strains have been reported to result from either competition favouring a particular strain's inherent capacity to grow (Ibrahim *et al.,* 2013). It could also be associated with competition for space and food because of hapa confinement and feed being given at a central feeding point as described by Charo-Karisa et al. (2006) who observed a similar trend in Nile tilapia reared in hapas. The difference in final weight among the different strains observed in this study is similar to findings of Nguenga et al. (2000) on African catfish (*Heterobranchus longifilis*) in Cameroon where the final body weight of the Noun strain was lower than Layo strain reared in controlled hatchery conditions. Difference in final weight among the different strains in this study seem not to be of a direct consequence on social hierarchies in each group where the larger fish suppress the growth of smaller fish but could be as a result of the feeding behavior with the heavier fish having an advantage when feed is limited (Martins *et al.,* 2005; Charo-Karisa *et al.,* 2006). The survival of the different strains in the present study is in line with the work of Nguenga *et al.* (2000) who observed high survival rate of juvenile *H. longifils* in Layo strain and reciprocal crosses of Layo and Noun strains but lower survival in Noun strain cultured in controlled hatchery conditions. The lower survival in the Kenyan strain could be as a result of cannibalism due to heterogeneity in sizes evidenced by the high value of the coefficient of variation (CV) which indicates that the prey was smaller than the cannibal (Hecht and Appelbaum, 1988; Baras and Almeida, 2001).

The differences in growth performance of the fish could also be related to the adaptability of the strains to local farming conditions. In Indonesia the farming of the *C. gariepinus* has been largely based on freshwater systems mainly in earthen ponds where fish are stocked at high stocking densities of 150 fish m-2, while in Kenya the widespread culture system are earthen ponds with low stocking densities of 2-3 fish m-2. By contrast, culture systems in the Netherlands are mainly closed recirculating system with stocking densities of between 25-30 fish m-3. There are also possibilities that the degree of upgrading of the *C. gariepinus* through selective breeding may have occurred to a greater extent in Indonesia compared to the Netherlands and Kenya (Fleuren, 2008; Sunarma, 2008). Selective breeding have been used to increase growth from one generation to another in channel catfish (*Ictalurus punctatus*) whereby 55% of intraspecific crosses resulted in an average increase of 10% body weight above the parental strain (Smitherman and Dunham, 1985; Dunham *et al.,* 1987). Hence, the fish from Indonesia could be having a higher tolerance level of the culture environment in which the study was conducted as a result of selection (Sunarma, 2008). The difference in growth performance could also be linked to the history of domestication of the different strains. Smitherman et al. (1984) defines a strain as a fish having a common geographic origin and history and is considered domesticated if propagated in a hatchery environment for at least 2 generations. Considering the duration each of the strains in this study have been domesticated, the Kenyan strain, captured from the wild in 2010 and reared in earthen ponds hence could be considered a wild strain. On the other hand, the Indonesian and Dutch strain have been used for years under captivity and have been propagated for several generations and could hence be considered domesticated (Yusuf, 1995; Fleuren, 2008; Sunarma, 2008). Burnside et al. (1975) compared wild and domesticated strain of channel catfish grown in brackish water and found out that the domestic strain grew faster than the wild strain. The relatively low growth of the Kenyan strain was similar to the low growth recorded for Noun strain of *H. longifilis* which was captured from the wild and reared in a pond environment before use, compared to the Layo strains which had been used for years under captivity (Nguenga *et al.,* 2000).

The coefficient of variation (CV) of harvest weight can be interpreted as indicating the intensity of the competition among the fish in each tank. Several authors have identified increases in CV as an indication of inter-individual competition and dominance hierarchy in fish (McCarthy *et al.,* 1992; Jobling, 1995; Adams *et al.,* 2000). In the present study, the lowest CV was realized in the Indonesia strain and was an indication of homogeneity in sizes of the Indonesian strain. Selective breeding often lead to homogeneity in sizes by eliminating shooters which lead to high disparity in growth within a population as they grow bigger than other fish in the same cohort (Baras and Jobling, 2002). Size homogeneity is a very important aspect in *C. gariepinus* culture to reduce incidences of cannibalism in the catfish larvae which requires the prey to be slightly smaller than the cannibal (Hecht and Appelbaum, 1988; Baras and Almeida, 2001). Cannibalism is normally reduced in *C. gariepinus* with lower size heterogeneity and lower variability of growth rates (Baras and Almeida, 2001). On the other hand, a low CV is suggestive of less competition and of a good social environment within a population as exhibited by the Indonesian strain.

Conclusion

In conclusion, the Indonesian strain is suitable for grow-out aquaculture in Kenya. Further research is needed to evaluate the growth; survival and reproductive performance of the reciprocal crosses between the different strains of *C. gariepinus* in Kenya to establish a fast growing fish with reduced heterogeneity for improved aquaculture performance in the country. The growth performance of the three different strains may be used as a guideline to form a synthetic base population for genetic selection to improve performance of *C. gariepinus* in Kenya. If the genetic improvement is targeted at the development of a fast growing fish with reduced heterogeneity then the Indonesian strain is appropriate to be included in the population for selective breeding program. At the same time, measures have to be taken to ensure the long-term viability of the strain.

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PROTECTED AREA MAINTAINS HIGH GENETIC DIVERSITY OF *LETHRINOPS TURNERI* OF LAKE MALOMBE, MALAWI

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Abstract

Fish catches from Lake Malombe, have declined significantly with increased use of small meshed nets that target large quantities of immature fish thereby threatening sustainability of the fishery. Establishment of protected fishing area was one of the strategies adopted to sustain the recruitment of fish to fishing areas. Samples from eight sites including the protected fishing area were analysed using five microsatellite markers to determine differences in genetic diversity and level of differentiation, between the heavily fished and lightly fished areas and to determine the relationship between genetic and geographical distances among populations of *Lethrinops turneri* of Lake Malombe. Mean number of alleles per population ranged from 3.8±1.92 to 5.20±3.11 while effective number of alleles ranged from 2.75±0.85 to 3.64±1.64. Observed heterozygosity ranged from 0.62±0.24 to 0.83±0.17 with an average heterozygosity across all loci of 0.647. No significant difference in allele diversity was observed among populations. Pooled populations of southern areas (situated adjacent to protected area) showed higher allelic diversity than northern areas (situated far from protected area). Fst value ranged from 4 % to 9.9 % showing very limited differentiation among populations. Mean migration rate of 4.25 individuals per generation was high to prevent differentiation by genetic drift among populations. Very weak relationship between genetic and geographical distance was observed (Z = 0.06 (t = 0.3742) (p = 0.6459) and multidimensional scaling (MDS) analysis showed no clear pattern.

Keywords: Genetic variation, *Lethrinops turneri*, Microsatellites

LA ZONE DE PROTECTION MAINTIENT UNE DIVERSITÉ GÉNÉTIQUE ÉLEVÉE DES *LETHRINOPS TURNERI* DU LAC MALOMBE, MALAWI

Resume

Les prises de poissons du lac Malombe, ont diminué de façon significative avec l'utilisation accrue des petits filets maillés qui ciblent de grandes quantités de poissons immatures, menaçant ainsi la durabilité de la pêche. La création de la zone de pêche protégée était l'une des stratégies pour soutenir le recrutement de poissons dans les zones de pêche. Les échantillons provenant de huit sites, y compris la zone de pêche protégée ont été analysées à l'aide de cinq marqueurs microsatellites pour déterminer les différences dans la diversité génétique et le niveau de différenciation entre les zones fortement exploitées et zones légèrement pêchées, ainsi que pour déterminer la relation entre les distances génétiques et géographiques entre les populations de *Lethrinops turneri* du Lac Malombe. Le nombre moyen d'allèles par la population a varié de 3,8 ± 1,92 à 5,20 ± 3,11 alors que le nombre effectif d'allèles a varié de 2,75 ± 0,85 à 3,64 ± 1,64. L'hétérozygotie observée a varié de 0,62 ± 0,24 à 0,83 ± 0,17 avec une hétérozygotie moyenne de 0,647 dans tous les loci. Aucune différence significative dans la diversité allèle a été observée chez les populations. Les populations mise en commun situées dans les régions du Sud (à côté du sanctuaire) ont montré une plus grande diversité allélique que les régions du Nord (située loin du sanctuaire). La valeur Fst a varié

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de 4% à 9,9%, ainsi montrant une différenciation très limitée au sein des populations. Le taux moyenne de migration de 4,25 individus par génération était élevé pour empêcher la différenciation par la dérive génétique entre les populations. Une très faible rélation entre la distance génétique et géographique a été observée (Z = 0,06 (t = 0,3742) (p = 0,6459) et l'analyse de la mise à l'échelle multidimensionnelle (MDS) n'a montré aucune tendance claire.

Mots-clés: Variation génétique, *Lethrinops turneri*, microsatellites

Introduction

Fish play important role in food and nutritional security of Malawi nation as it contributes about 70% of animal protein supply and 40% of total protein supply (Malawi Government, 2014). Fisheries resources of the country are mainly derived from Lake Malawi and its river system of which Lake Malombe fishery is a third largest in this system. The Lake Malombe fishery has undergone dramatic changes over the years (Weyl, *et al.* 2001). Catches of Oreochromis species locally known as chambo declined from a peak catch of 8,000 MT/yr in 1982 to less than 200 MT/yr in 2003 (Jamu *et al.* 2011 as cited by Coastal Resource Center, 2015); the catches instead was dominated by small cichlids locally known as kambuzi of which 75% comprised of *Lethrinops turneri*, *O. argyrosoma* 'red' and Copadichromis cf. virginalis (FAO, 1993b). Increase in Kambuzi catches led to influx of small meshed and destructive gears locally known as nkacha (a rectangular net with progression of mesh size from bunt to wing from 19 mm to 39 mm) and kambuzi seines being operated in open waters. The use of these nets has increased and shifted the size distribution (and composition) of species in the lake over the years with about 70 % of Kambuzi fish caught being immature (FAO, 1993). This implies that large proportions of individuals were caught before they started breeding hence recruitment may have been supported by a limited number of mature individuals that may as well be reduced in number with time. *Lethrinops turneri* were likely to have been hard hit as the species is widely distributed in the lake and contributed more than 23 % of the catches in late 1990s (Mwakiyongo and Weyl, 2001). The fish species is among the fishes that faced a great threat of reduction in biodiversity due to over fishing especially during breeding season (Reinthal, 1993).

In order to reverse the trend of the collapse of Lake Malombe fishery, the Government established protected areas as one of the fishery management strategies. It was therefore necessary to assess the benefits of protected areas as a fishery management strategy in Malawi. Specifically, it was of interest to know whether high fishing intensity and limited fishing as is a case in protected area and its adjacent areas of Lake Malombe, has had effect on the genetic variability of various populations of *Lethrinops turneri* in the lake. It was also necessary to know whether fish populations in the protected areas reseeded the adjacent fishing areas. In this study, we determined the level of genetic diversity of *L. turneri* between heavily fished and less fished areas of Lake Malombe that includes the protected area. We also demonstrated the relationship between genetic and geographic distances that exist between the protected and the fishing areas.

Materials and Methods

Fish Sample Collection

The study was carried out in Lake Malombe (Figure 1). Samples of *Lethrinops turneri* were collected from western sites (heavily fished) and eastern sites (less fished areas of Lake Malombe including the protected area. Western areas included Likala, Lundu. Ntanga and Chisumbi while Eastern sites included Sili, Kadewere and Likulungwa, Kadewere and protected area (Figure 1). Samples were collected using fishermen nkacha nets of 19 mm mesh size. Sample sizes for each population are shown in Table 1. The fish samples were identified using keys provided by Eccles and Trewavas (1989), FAO, (1993a), Banda (1995)

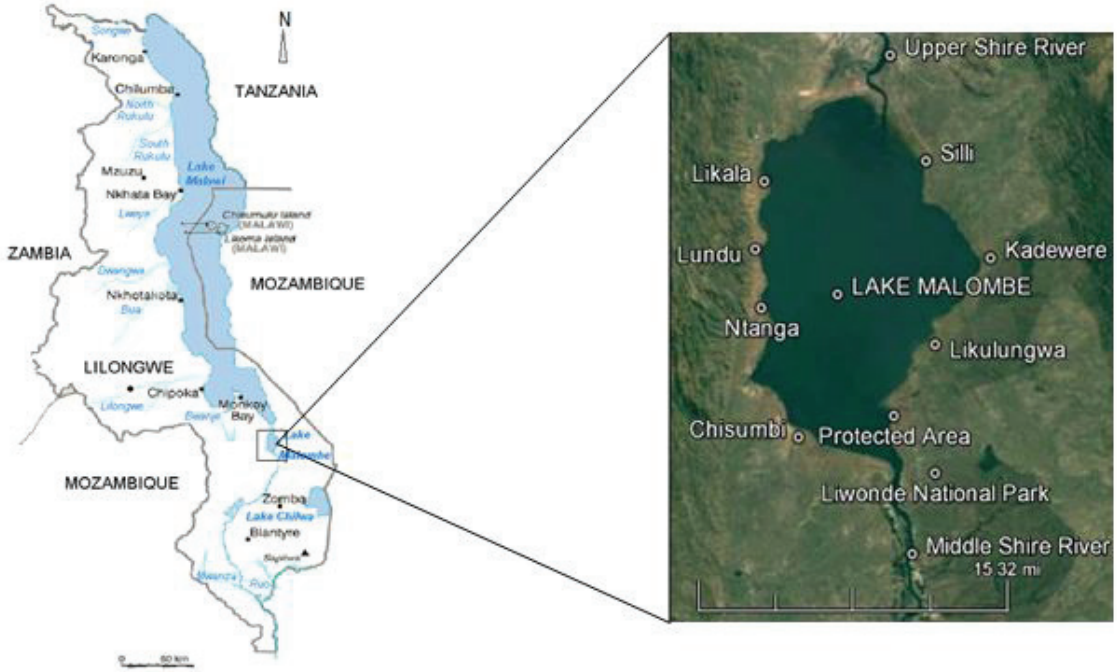

Figure 1: Map of Lake Malawi System showing Lake Malombe and sites

and Jambo (1997).

DNA Analysis

DNA analysis was carried out at DNA Lab at Chancellor College, University of Malawi. DNA was extracted using the procedure outlined in Ambali (1996) and Changadeya 2001). The extracted DNA was subjected to polymerase chain reaction using Perkin Elmer GeneAmp PCR system 9600 and five microsatellite primers, UNH 130, UNH 146, UNH 154, UNH 201, and OS 064 were used (Table 2).

Amplified PCR products were detected using manual gel electrophoresis system using the protocol as outlined in Silver Sequence DNA Sequencing System Technical Manual (Promega, 2000). The DNA bands (products) were sized by comparing with known values from pGEM and © X 174 DNA/Hinf1 markers.

Data Analysis

The microsatellite data were analysed using GENEPOP version 3.3 (Raymond and Rousset, 2000) and POPGENE version 1.31 (Yeh *et al.,* 1999). Test for conformity to Hardy-Weinberg Equilibrium was carried out according to Haldane (1954), Weir (1990) and Guo and Thompson (1992). F_{is} was estimated according to Weir and Cockerham (1984) to determine deviation of genotypic frequencies from panmictic frequencies, F_{st} was also calculated to measure the proportion of total variation that could be ascribed to differences between population allele frequencies. Genotypic linkage disequilibrium test using Fisher's exact test.

Genetic diversity was determined using the following variables; observed number of alleles (na), effective number of alleles (ne), observed heterozygosity (Obs het) and expected heterozygosity (exp het). Nei's (1978) unbiased genetic distance was determined using the POPGENE program. Multidimensional scaling of unbiased genetic distance and Fst values between population pair was carried out using the MDSCALE programme of NTSYS-pc to examine the relationship among populations. Gene flow was determined through multilocus estimation of the effective number of migrants (Nm) using private allele method according to Slatkin (1985).

Table 1. Sample size and sites where samples were collected

Sample Site	Number of Samples Collected
Western Sites	
Likala	40
Lundu	38
Ntanga	40
Chisumbi	40
Eastern Sites	
Sili	32
Kadewere	40
Likulungwa	40
Protected area	40

Table 2: Microsatellite primer sequences and their annealing temperatures (Tann)

Locus	Primer direction	Primer sequence	No of bases	Tann°C
UNH 130	Forward	5'-AGGAAGAATAGCATGTAGCAAGTA-3'	24	54
	Reverse	5'-GTGTGATAAATAAAGAGGCAGAAA-3'	24	
UNH 146	Forward	5'-CCACTCTCGCTGCCCTCTTAT-3'	21	55
	Reverse	5'-AGCTGCGTCAAACTCTCAAAAG-3'	21	
UNH 154	Forward	5'-ACGGAAACAGAAGTTACTT-3'	19	54
	Reverse	5'-TTCCTACTTGTCCACCT-3'	17	
UNH 201	Forward	5'-CTGCTAGACTGCGAAAC-3'	17	54
	Reverse	5'-ACAGTGCAACACCAGAC3'	17	
OS 064	Forward	5'-CAGTGTCTTCAGTTCCTTCG-3'	20	54
	Reverse	5'-CAGAAGCATCTTATTGATGAC-3'	21	

Table 3. Exact test of Hardy-Weinberg Equilibrium at 5 loci for *Lethrinops turneri* of Lake Malombe, p values

Population	UNH 130	UNH 146	UNH 154	OS 064	UNH 201
Chisumbi	0.0083	0.0010	0.0000	0.0000	0.0026
Ntanga	0.0000	0.3625	0.0000	0.0000	0.0002
Likala	0.0107	0.0008	0.0864	0.0000	0.0124
Sili	0.0000	0.0003	0.0123	0.0000	0.0560
Lundu	0.0000	0.5351	0.2630	0.0003	0.0846
Kadewere	0.0000	0.0000	0.0649	0.0000	0.0433
Likulungwa	0.1112	0.0022	0.0009	0.0000	0.0433
Protected Area	0.0029	0.0135	0.0281	0.0000	0.0004

Table 4: Total number of alleles and allele size (bp) at 5 loci in *Lethrinops turneri* of Lake Malombe

Microsatellite marker	Allele size (base pairs)	Number of alleles scored
UNH 130	165 – 225	16
UNH 154	105 – 179	10
UNH 146	121 – 125	3
UNH 201	221 – 265	4
OS 064	95 – 113	2

Results

Hardy Weinberg Equilibrium (HWE)

Most populations did not show conformity to Hardy Weinberg Equilibrium (<0.05) (Table 3). Almost all populations showed heterozygosity excess at 50% of loci and heterozygosity deficiency at the other 50% of loci. Locus pairs for all populations showed no significant linkage disequilibrium ($p>0.05$).

Genetic diversity

All five microsatellite markers were polymorphic in all populations. A total of 35 alleles were scored (Table 4) and high polymorphism was obtained in the Southern sites that included protected sites and its surrounding sites.

Genetic diversity measures presented in Table 5 indicated that mean number of alleles per population ranged from 3.8±1.92 to 5.20±3.11 and effective number of alleles ranged from 2.75± 0.85 to 3.64±1.64 and there was no significant difference in allele diversity among all population analysed ($p>0.05$). However, high effective number of alleles was determined at Chisumbi (southern site closer to protected area) and lowest effective number of alleles was determined Sili (northern site far from protected area).The observed heterozygosity ranged from 0.62±0.24 to 0.83±0.17 while expected heterozygosity values ranged from 0.62±0.12 to 0.69±0.14 and there was no significant difference between observed and expected heterozygosity in all the populations ($p>0.05$).

Genetic diversity analysis carried out on pooled populations of north and south fishing areas (with protected area) indicated that allelic diversity was significantly high in southern areas of the lake, which have protected areas within it compared to northern areas (Figure 2 and 3) and migration rate was 4.25 (Figure 4).

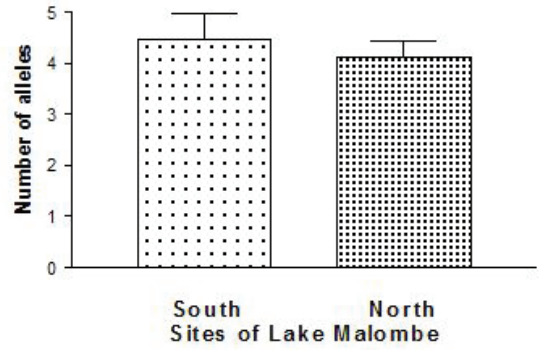

Figure 2: Observed number of alleles between north and south part of Lake Malombe

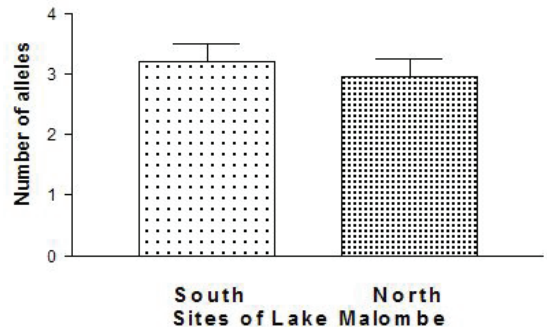

Figure 3. Effective number of alleles of north and south Lake Malombe

Table 5: Mean number of alleles (na), effective number of alleles (ne), observed heterozygosity (obs.het) and expected heterozygosity (exp. het)

	Chisumbi	Ntanga	Likala	Sili	Lundu	Kadewere	Likulungwa	Protected Area
UNH 130								
na	9.00	11.00	6.00	7.00	9.00	6.00	7.00	6.00
ne	5.88	5.82	3.18	3.65	4.88	3.47	4.28	3.58
obs het	0.77	0.44	0.48	0.84	0.47	0.35	0.73	0.54
exp het	0.84	0.83	0.70	0.74	0.81	0.72	0.78	0.73
UNH 154								
na	8.00	5.00	5.00	4.00	5.00	5.00	5.00	7.00
ne	4.78	3.20	3.51	3.64	3.51	3.12	3.48	3.89
obs het	0.57	0.62	1.00	1.00	0.69	0.37	0.87	0.80
exp het	0.80	0.70	0.73	0.74	0.73	0.69	0.72	0.75
UNH 146								
na	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
ne	2.43	2.59	2.42	2.53	2.38	2.75	2.50	2.65
obs het	0.95	0.94	0.80	0.88	0.70	0.77	0.59	0.58
exp het	0.60	0.62	0.60	0.61	0.59	0.65	0.61	0.63
OS 064								
na	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
ne	2.00	1.94	1.98	1.99	1.88	1.98	2.00	1.98
obs het	1.00	0.82	0.89	0.93	0.74	0.89	0.95	0.90
exp het	0.51	0.49	0.50	0.51	0.47	0.50	0.50	0.50
UNH 201								
na	4.00	4.00	4.00	3.00	4.00	4.00	4.00	3.00
ne	3.11	3.24	3.49	1.94	3.35	3.36	3.36	2.66
obs het	0.87	0.77	0.82	0.44	0.66	0.70	0.70	1.00
exp het	0.69	0.70	0.72	0.50	0.71	0.71	0.71	0.64
All loci	5.20+3.11	5.00+3.53	4.00+1.58	3.80+1.92	4.60+2.70	4.00+1.58	4.20+ 1.92	4.20+2.17
	3.64+1.64	3.36+1.47	2.91+ 0.68	2.75+0.85	3.20+ 1.15	2.94+ 0.60	3.12+ 0.89	2.95+ 0.77
	0.83+0.17	0.72+ 0.19	0.80+ 0.19	0.82+0.22	0.65+ 0.11	0.62+0.24	0.77+ 0.14	0.76+ 0.20
	0.69+ 0.14	0.67+0.13	0.64+ 0.10	0.62+0.12	0.66+0.13	0.65+ 0.09	0.66+ 0.11	0.65 +0.10

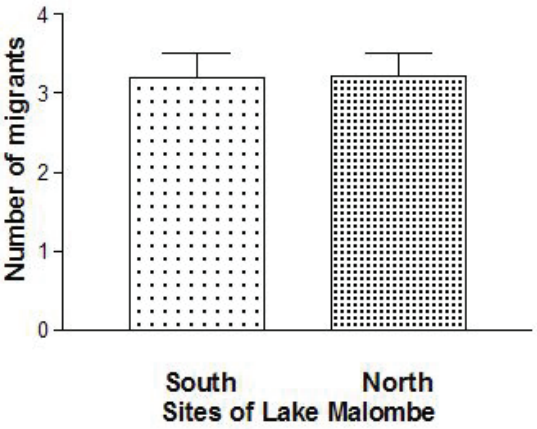

Figure 4: Rate of migration in north and south sites

Discussion

Conformity to HWE is expected in wild populations with large effective population size (ne). Hartl and Clark (1989) suggested population size of greater than 500. In the early 1990s, the estimate annual catch of *Lethrinops turneri* from Lake Malombe was 850,000,000 fish (Turner 1995) and current commercial landings data suggests that their current number (N) must be relatively large. The possible explanation for Departure of populations from HWE could be due to sampling error caused by Wahlund Effect (Hartl and Clark 1989) whereby samples comprise of a mixture of fish stock from different subpopulations within the collection areas. The departure could sometimes occur if there is strong physical linkage between loci but the results suggest that the loci in all populations associated independent of each other. Analysis done on the loci in other related Lethrinops species showed no significant linkage disequilibrium (Changadeya, 2001).

Maintenance of genetic diversity is critical in natural fish populations where they are threatened by over-fishing and deterioration of aquatic environment. Unless genetic diversity is maintained, populations are likely to decline (Wohlfarth, 1986). Genetic variation in *Lethrinops turneri* populations of Lake Malombe was generally moderate with average heterozygosity of 0.647 recorded at all loci. However, the southern part of Lake Malombe, which has protected area contained relatively high genetic diversity compared to northern areas. Fishing intensity in the northern areas might have reduced genetic diversity than the southern areas because of restricted fishing as a result of protected area. In fact, several studies have shown correlation between fishing intensity and heterozygosity (Kafumbata *et al.,* 2001). High migration rate of 4.25 individuals per generation suggests that there is continuous migration between protected area and fishing areas. This was supported by F_{st} values which ranged from 1% to 9.9% suggesting the population in protected areas and other populations in the lake were not differentiated. This was further shown by multidimensional scaling (MDS) analysis that showed unclear pattern and very weak relationship between genetic and geographical distance observed (Z = 0.06 (t = 0.3742) (p = 0.6459). It ultimately implies that protected areas contributed to reseeding to fishing areas thereby cushioned the effect of over fishing pressure through maintenance of genetic diversity.

Conclusion

This study has shown that protected area in Lake Malombe and fishing areas adjacent to it contained relatively high genetic variation implying that protected areas maintained high generic diversity at the same reseeded adjacent areas thereby cushioning the effect of overfishing. We conclude that protected areas, as a fisheries management strategy, offers an opportunity for stock recovery and maintain genetic diversity in Lake Malombe and possibly in other lakes where such protected areas could be established.

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EFFET DE LA SUBSTITUTION DE LA FARINE DE POISSON PAR LA POUDRE DES FEUILLES DE *MORINGA OLEIFERA* SUR LES CARACTÉRISTIQUES ZOOTECHNIQUES ET ÉCONOMIQUES DU TILAPIA DU NIL (*OREOCHROMIS NILOTICUS*)

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Résumé

Une etude portant sur l'effet de la substitution de la farine de poisson par la poudre des feuilles de Moringa sur les performances zootechniques et économiques de *Oreochromis niloticus* a été menée du 01er Juillet au 02 Octobre 2015 dans la Ferme agro-piscicole d'Esse dans le but de contribuer à l'amélioration de la production de *Oreochromis niloticus* par l'incorporation du Moringa dans la formulation de l'aliment. Ainsi, un total de 135 alevins d'un poids moyen initial de 3,04±0,2g répartis en trois traitements a été nourris à base de trois régimes iso protéiques (30 % de protéines brutes) contenant différents taux de poudre de Moringa: 0 % (aliment témoin), 20%, et 40% notés respectivement R0, R20 et R40. Ces aliments ont été testés durant 84 jours. Les résultats ont révélé que les poids moyens finaux des poissons ont atteint des valeurs comprises entre 24,714±1,786g et 26,067±0,532 selon les régimes (R40 et R20 respectivement). Les meilleures croissances et utilisations alimentaires ont été obtenues au niveau des traitements R0 et R20 (taux de croissance spécifique TCS respectifs=2,733±0,295 et 2,613±0,164 ; croissance individuelle journalière CIJ respectives=0,317±0,012 et 0,310±0,00 g/j; indice de conversion IC respectifs=1,985±0,128et 1,972±0,045). Pour le taux de survie toutes les valeurs obtenues sont supérieures à 90% (91,11±3,85 pour le traitement T1et 93,33±6,67% pour les traitements T0 et T2. Concernant la rentabilité économique, les résultats obtenus, ont montré que l'incorporation de la poudre de Moringa à un taux de 20 % entraîne un gain de 4,74% de plus sur la marge bénéficiaire liée à l'alimentation, sans toutefois causer préjudice à la croissance des poissons. Ainsi, la substitution partielle de la farine de poisson par la poudre des feuilles de Moringa est possible et avantageuse à 20%. En outre, elle permet la réduction des charges liées à l'alimentation et à la valorisation des sous-produits locaux.

Mots clés : *Oreochromis niloticus*, performances zootechniques, Moringa oleifera, farine de poisson, substitution partielle.

THE EFFECT OF SUBSTITUTING FISH MEAL WITH *MORINGA* LEAF POWDER ON ANIMAL AND ECONOMIC PERFORMANCE OF THE NILE TILAPIA *OREOCHROMIS NILOTICUS*

Abstract

The study on the effect of substitution of fish meal with powder of Moringa leaves on animal and economic performance of *Oreochromis niloticus* was conducted from 01st July to October 2, 2015 in the agro-Fish Farm of esse in order to contribute to improving the production of *Oreochromis niloticus* by the incorporation of Moringa in the formulation of the food. Thus, a total of 135 fingerlings 3.04 average initial weight of ± 0.2g in three treatments was fed on three iso protein diets (30% crude protein) powder containing different levels of Moringa: 0% (control diet), 20% and 40% respectively denoted R0, R20 and R40. These foods have been tested for 84 days. The results revealed that the final average weight of the fish

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have reached values between 24.714 and 26.067 ± 1,786g ± 0.532 according to the plans (R40 and R20 respectively). The best growth and food uses were obtained at the treatment R0 and R20 (SGR specific growth rates = 2.733 ± 0.295 and 2.613 ± 0.164; individual daily growth respective IDG = 0.317 ± 0.012 and 0.310 ± 0.00 g/d; respective CR conversion ratio = 1.985 ± 1.972 ± 0.045 0,128et). For survival all values are greater than 90% (91.11 ± 3.85 to 93.33 ± treatment T1 and 6.67% for T0 and T2 treatments. On the economic profitability, the results obtained, have shown that the incorporation of Moringa powder at a rate of 20% results in a gain of 4.74% above the profit margin related to food, without causing harm to fish growth. Thus, partial substitution of fish meal with powder Moringa leaves is possible and advantageous to 20%. in addition, it allows the reduction of expenses related to food and to promote local byproducts.

Introduction

Le Cameroun dans son Document de Stratégie pour la Croissance et l'Emploi (DSCE) qui en découle met un accent particulier sur la sécurité alimentaire et le développement durable. Dans cet élan, les experts en développement réaffirment sans cesse la place du secteur agricole comme socle du développement du pays (MINEPAT, 2009). Par ailleurs, le Cameroun est doté d'un important réseau hydrographique. Le pays jouit donc des conditions naturelles particulièrement favorables au développement de l'aquaculture. Malgré les nombreux efforts et immenses potentialités naturelles, la production aquacole nationale, provenant essentiellement d'étangs piscicoles, est restée inférieure à 2000 tonnes face à une demande dépassant 360 000 tonnes. Ce qui a entrainé des importations considérables de 162 400 tonnes de poissons en 2012, pour couvrir les besoins toujours croissants au fil des années, avec la démographie galopante (FAO, 2012). Cependant, la production aquacole mondiale en plein essor lors de la dernière décennie (10.6%) (FAO, 2014) laisse croire que l'intensification des systèmes aquacoles serait la solution idoine malgré que celle-ci fait encore face à de nombreuses contraintes (manque de semences de qualité en quantité, absence d'aliment local sur le marché, coût élevé des aliments importés etc…) qui entravent son développement dans le pays notamment le manque, sur le marché local, d'aliments performants à un prix accessible aux pisciculteurs moyens.

En aquaculture intensive, l'alimentation représente une part importante du coût de production des poissons (Azaza *et al.,* 2006). L'intérêt économique de ce type d'élevage est donc très dépendant de la disponibilité et du coût des aliments (Tacon, 1996; Hoffman *et al.,* 1997). De ce fait, la réduction des charges liées à l'alimentation, et par conséquent la diminution du coût total de production des poissons est l'une des priorités en aquaculture (Watanabe, 2002). Par ailleurs, pour la formulation des régimes équilibrés en aquaculture, la farine de poisson est l'ingrédient primordial en termes d'apport en protéines digestibles, Acides Aminés Essentiels (AAE) et autres éléments nutritifs importants pour la croissance du poisson. Cependant, son prix d'achat élevé et sa dépendance à l'importation rendent son accès très limité vis-à-vis des petits producteurs. Dès lors, la recherche en aquaculture se doit de faire recours à d'autres sources alternatives de protéines, d'origine végétale en particulier, qui ne sont pas directement utilisables pour la consommation humaine (Shiau *et al.,* 1987; Jackson *et al.,* 1982), et qui sont à mesure de fournir aux poissons des éléments nécessaires pour leur croissance. Ainsi, à la suite de bien d'autres (bromatologie des feuilles de Moringa (Makkar et Becker, 1996; Fuglie, 2002; Ndong *et al.,* 2007; Adeyinka *et al.,* 2008), substitution partielle de la farine de soja par la poudre des feuilles de moringa dans le régime de la carpe (Yuangsoil and Masumoto, 2012), effet de la substitution de la farine de poisson par les feuilles de Moringa sur le foie, l'intestin et les facteurs de condition chez *Clarias gariepinus* (Odedeyi, 2014), Incorporation de la farine des feuilles de Moringa dans le régime du tilapia du Nil (Richter *et al.,* 2003) la présente étude a vérifié si les performances zootechniques et la rentabilité économique de la production de *O.niloticus* variaient en fonction des proportions

de substitution de la farine de poisson par la poudre de *M. oleifera*; dans son alimentation l'objectif ici étant de contribuer à l'élaboration des régimes locaux pour la production de *Oreochromis niloticus* par l'incorporation de M.oleifera dans la formulation de l'aliment afin de proposer aux pisciculteur un régime efficace et moins couteux.

Matériels et méthodes

Cette étude a été réalisée dans la ferme agro-piscicole d'Esse (FAPE). Les feuilles de Moringa ont été collectées puis séchées, écrasées dans un moulin, tamisées à l'aide d'un tamis de de 400 micromètres de mailles. Parallèlement, les autres ingrédients dits conventionnels ont été achetés dans le marché de Yaoundé, écrasés puis tamisés dans les mêmes conditions. Ainsi, les différentes farines obtenues ont été pesées et mélangées graduellement suivant les proportions fixées dans les trois régimes expérimentaux formulés R0 (poudre de moringa substituée à la farine de poisson à 0%), R20 (poudre de moringa substituée à la farine de poisson à 20%) et R40 (poudre de moringa substituée à la farine de poisson à 40%). Chaque mélange a été mouillé à l'eau au ¾ puis granulé sous forme de spaghettis par un hachoir à viande (TC 22SL). Les teneurs des différents nutritifs (prùotéines brutes, Matières sèches, Matières grasses, Celluloses brutes et des Cendres ont été analysées au laboratoire de nutrition animale de l'Université de Dschang. Le tableau 1 présente les formules des différents régimes et leurs compositions après analyse.

Les alevins de *O.niloticus* utilisés dans le cadre de cette étude ont été produits in situs dans les étangs d'alevinage de la FAPE à partir des géniteurs provenant du Nyong. L'échantillonnage par pesée a permis de sélectionner les individus d'une plage de 2 à 4g dont le poids moyen initial était de 3,04±0,2 g. Au total 135 alevins de sexes confondus ont été pesés individuellement avec une balance de marque ADE de portée 10 kg sensible au gramme près puis répartis dans 09 happas soit 15 individus par unité. Dans les mêmes infrastructures, les alevins ont été acclimatés pendant 5jours durant lesquels ils ont été nourris avec un aliment formulé constitué de 30% de protéines brutes et ne contenant ni farine de poisson ni poudre des feuilles de M.oleifera afin d'éviter que ces derniers ne s'habituent au goût de l'un des ingrédients d'intérêt. Ainsi, les 09 happas organisés en trois traitements T0, T1 et T2 nourris respectivement avec les régimes R0, R20 et R40 soit 03 happas par traitement.

Durant l'expérimentation, les poissons étaient nourris à la main trois fois par jour: 8h, 12h et 16h. Pendant les nourrissages, l'aliment était à nouveau écrasé à la pierre afin de le ramener à la taille de la bouche des poissons à nourrir. Les quantités distribuées étaient ajustées en fonction de la variation du poids moyen vif des poissons après les pêches de contrôle. Ainsi, les poissons ont été nourris à 10% de leurs poids vifs pendant la première période de contrôle, à 6,67% pendant la deuxième période de contrôle, à 5,33% de leurs poids vifs de la troisième période jusqu'à la quatrième période.

Pour la salubrité du milieu expérimental, les bordures de l'étang étaient défrichées toutes les trois semaines, avant les pêches de contrôle ; les happas étaient nettoyés en frottant les parois afin de retirer les algues et les débris d'aliments colmatés. Cette opération avait pour but d'assurer l'aération des happas en favorisant une bonne circulation de l'eau.

Pour contrôler l'état de l'environnement expérimental, quelques paramètres physico-chimiques de l'eau (la température et le pH) étaient prélevés matin et soir (6h 00 et 18h 00 respectivement) grâce à un appareil multifonction de marque ADWA kft modèle AD11 de même la transparence était prélevée chaque jour grâce à un disque de Secchi. Pour faire le prélèvement l'appareil était plongé dans un point quelconque de l'étang.

Analyses statistiques

A l'aide du logiciel IBM SPSS statitics20, l'effet de la substitution graduelle de la farine de poisson par la poudre des feuilles de Moringa a été testé en comparant les différents

Tableau 1: Composition des régimes expérimentaux

Ingrédients (%)	R témoins	R à base de *M. oleifera*	
	R^0	R^{20}	R^{40}
Farine de poisson	20	16	12
Tourteau de coton	3	3,07	5,21
Tourteau de soja	3	3,07	5,21
Tourteau d'arachide	3	3,07	5,21
Poudre des feuilles de *M. oleifera*	0	4	8
Farine de maïs	15,82	15,7	14,10
Son de riz	15,82	15,7	14,10
Son de blé	15,82	15,7	14,10
Tourteau de palmiste	15,82	15,7	14,10
Huile de palme	2	2	2
Huile de soja	1	1	1
Valeurs nutritives			
Matières sèches (%)	88,44	87,75	89,46
Protéines brutes (% MS)	30,23	29,94	29,88
Matières grasses (% MS)	4,23	5,43	5,51
Cellulose brute (% MS)	9,65	9,83	11,59
Cendres (% MS)	23,06	18,54	17,34
Energie (kcal/kg de MS)	1096,80	1091,01	1093,08

paramètres zootechniques et d'utilisation alimentaire obtenus dans les différents traitements par l'analyse de la variance à un facteur (ANOVA 1). Le test LSD a été utilisé pour voir les différences significatives au seuil de 5% des variables au niveau des différents traitements.

Résultats

Les trois régimes testés ont été consommés le long de l'expérimentation. Les résultats des paramètres d'utilisation alimentaire et le taux de survie montrent qu'aucun régime n'a causé de problèmes aux sujets. Le taux de survie a donné une gamme de valeurs oscillant entre 91,11±3,85 et 93,33±6,67%, les plus forts taux étant observés au niveau des traitements nourris à base du régime non substitué (T0) et du régime substitué à 40% (T2) 93,33±6,67% pour ces deux traitements. L'analyse de variance (ANOVA 1) n'a montré aucune différence significative entre les différents traitements ($p>0,05$). Ces grandes valeurs de survie laissent croire que les quelques mortalités observées ont été dues aux manipulations lors des pêches de contrôle et non à l'aliment. L'évolution du poids moyen des poissons en fonction des périodes de contrôle de l'expérimentation est présentée par la figure 1. L'analyse cette figure 1 montre que la croissance est ascendante au niveau des trois traitements durant l'expérience. Par ailleurs, nous constatons qu'à partir de la 2ème période (42ème jour) le traitement T2 est passé en dessous du témoin (T0) et que T1 reste continuellement confondu à T0 durant toute l'expérimentation bien que l'évolution du poids moyen entre les traitements T0, T1, T2 suit presque la même allure. Ainsi dans les trois lots, la croissance devient plus rapide à partir de la deuxième période (42ème) jour.

Le tableau 2 présente la synthèse des paramètres de croissance et d'utilisation alimentaire. Les variables de croissance

obtenues des poissons après avoir été nourris par des régimes contenant des proportions variables de la farine de poisson et la poudre des feuilles de M.oleifera sont présentées dans le tableau 2 . De ce tableau, il ressort que les quatre variables (Pmf, GP, TCS et CIJ) évoluent en fonction des proportions de substitution de la farine de poisson par la poudre des feuilles de Moringa dans les régimes distribués avec des valeurs oscillant entre 27,78±1,62 et 29,33±0,18 g pour le Pmf ; 24,714±1,786 et 26,067±0,532g pour le GPM ; de 2,583±0,245 à 2,733±0,295%/j pour le TCS et de 0,283±0,001 à 0,317±0,012g/j pour la CIJ. L'analyse de la variance (ANOVA 1) montre qu'il existe de différences significatives entre les différents traitements ($P < 0,05$). Le test de LSD montre qu'au niveau du Pmf, GP et TCS, il n'existe pas de différence significative ni entre le témoin (T0) et les traitements tests (T1 et T2), ni entre T1 et T2. Par contre ce test montre qu'au niveau de CIJ, il existe une différence significative entre T0 et T2 de même entre T1 et T2. Pour cette variable, aucune différence significative n'est observée entre les traitements T0 et T1. De même pour les variables d'utilisation alimentaire, le même tableau 2 montre aussi la variation de celles-ci en fonction des traitements. Pour l'indice de consommation (IC) et à l'efficacité protéique CEP, les meilleures valeurs ont été observées au niveau du traitement T1 (1,972±0,045) et (1,695±0,038) respectivement. L'analyse de la variance n'a montré aucune différence significative entre les traitements ($P > 0,05$).

Quant à la rentabilité économique, il ressort que le coût de production d'un kilogramme d'aliment est meilleur au niveau du traitement T1: nourris à base de l'aliment substitué à 20% (666,92 FCFA/ kg) tandis que le régime substitué à 40% s'est avéré plus couteux 696,49 FCFA/ kg.

Discussion

Les valeurs moyennes trouvées à la fin de l'expérimentation montrent que le gain de poids moyen varie entre 24,71±1,42 g et 26,07±0,06 g pour T2 et T1 respectivement. Ces valeurs sont largement supérieures de celles rapportées par Pouomogne *et al.,* (1997) ; 11,1 - 13,3g Ceci peut s'expliquer par le fait que dans la présente étude le taux de protéines brutes de nos régimes est fixé à 30 % contre 28 % pour Pouomogne *et al.,*1997. De plus, ces auteurs ont travaillé dans une température moyenne de 23°C contre 26°C pour cette étude.

Pour le taux de croissance spécifique, Les résultats enregistrés ici (2,583±0,245 à 2,733±0,295 % /j) se rapprochent des chiffres rapportés par plusieurs auteurs pour des régimes incorporant plus de 25 % d'ingrédients

Tableau 2: Paramètres de croissance, d'utilisation alimentaire et de rentabilité économique des juvéniles de *O. niloticus* en fonction des traitements

	T0	T1	T2
Pmf (g)	28,72±0,13[a]	29,33±0,18[a]	27,78±1,62[a]
GPM(g)	25,740±0,247[a]	26,067±0,532[a]	24,714±1,786[a]
TCS (%/j)	2,733±0,295[a]	2,613±0,164[a]	2,583±0,245[a]
CIJ (g/j)	0,317±0,012[ab]	0,310±0,007[ba]	0,283±0,001[c]
IC	1,985±0,128[a]	1,972±0,045[a]	2,042±0,276[a]
CEP	1,671±0,105[a]	1,695±0,038[a]	1,660±0,242[a]
CAP (FCFA)	699,02	666,92	696,49
MBB (FCFA)	180,88	194,47	59,76

GP= Gain de poids, CIJ= Croissance individuelle journalière, TCS= Taux de croissance spécifique ; IC=Indice de consommation, CEP= Coefficient d'Efficacité Protéique, CAP : Coût Alimentaire de Production, MBB : Marge Bénéficiaire Brute, Pmf= poids moyen final.

Les valeurs d'une même ligne ayant au moins une lettre en commun ne sont pas significativement différentes (P>0,05).

T0= traitement témoin nourris à base du régime non substitué; T1= traitement nourris à base du régime de substitution de la farine de poisson par la poudre des feuilles de Moringa à 20%; T2 = traitement nourris à base du régime de substitution de la farine de poisson par la poudre des feuilles de Moringa à 40%

sources de protéines non conventionnelles ((Pouomogne *et al.,* 1997 (2,3 à 2,5), Azaza *et al.,* 2006 (2,01±0,04 à.2,46±0.5)). Cependant, nos résultats restent moins intéressants comparativement aux données rapportées avec des régimes plus équilibrés (taux de croissance spécifique supérieur à 3 %/j, Jauncey (1982).

Quant à la croissance individuelle journalière (CIJ), les valeurs obtenues dans le cadre de cette étude vont de 0,283±0,001 à 0,317±0,012 g/j. Ces valeurs se rapprochent légèrement de celles trouvées par Azaza, 2005 : 0,428±0,022 à 0,607±0,025 g/j. Cette légère différence s'expliquerait par l'écart de température moyenne observé vis-à-vis des deux milieux de culture (29±1°C chez cet auteur et 25,91±1,52°C dans le cadre cette étude). Signalons toute fois que ces valeurs sont largement inférieures de celles obtenues avec des régimes plus équilibrés et distribués sous forme de granulé (1,5 à 1,9 g/j) (Jauncey et Ross (1982), Pauly *et al.,*(1988).

D'une manière générale, les faibles performances de croissance observées chez les poissons du traitement T2 nourris avec le régime substitué à 40% comparativement aux poissons nourris avec les régimes substitués à 0% appliqué à T0 et celui substitué à 20% appliqué à T1 pourraient s'expliquer par le fort taux de cellulose (11,59) observé lors des analyses bromatologiques des régimes et la présence des facteurs antinutritionnels signalés par plusieurs auteurs sur le Moringa. Ceci rejoint les affirmations de Richter (2003).

Au regard des valeurs obtenues pour les variables d'utilisation alimentaire, l'indice de consommation (IC) et le coefficient d'efficacité protéique (CEP), ne présentent pas de différences significatives au niveau de la consommation des trois régimes. En apparence, aucun des régimes testés n'était rejeté par les poissons (inappétence). La différence de croissance des poissons peut donc être expliquée par la différence dans l'efficacité d'utilisation des aliments (digestibilité). Comme au niveau de la consommation, la différence entre les régimes est moins apparente, la diminution des performances de croissance observées chez des poissons nourris avec le régime R40 (T2) résulteraient de la faible digestibilité des nutriments de cet aliment. En effet, la substitution de la farine de poisson par une source de protéines végétales augmenterait la teneur en fibres dans l'aliment et les facteurs antinutritionnels présents dans la majorité des légumes de la zone tropicale et subtropicale (Makkar et Becker, 1996) plus précisément les phénols totaux, les tannins, les saponines et les phytates présents dans les feuilles de Moringa oleifera. En outre, Richter *et al.,* (2003) soulignent qu'une augmentation de la farine des feuilles de Moringa dans l'aliment du tilapia du Nil diminuerait la consommation de la matière sèche, le gain moyen quotidien (GMQ) et le poids vif des poissons.

Pour ce qui est du coefficient d'efficacité protéique (CEP), l'écart entre les valeurs de T1 (1,695±0,038) et T0 (1,671±0,105) trouvées (mais différence non significative) laisse croire que la substitution de la farine de poisson par la farine des feuilles de Moringa à 20% améliore la valorisation des protéines brutes .Toutefois, la différence s'est avérée non significative entre T0 ; T1 etT2. En ce qui concerne l'indice de consommation (IC), les valeurs trouvées ici 1,972±0,045 à 2,042±0,276 bien que non significativement différentes entre les trois traitements, semblent tout de même être relativement élevées comparativement à celles obtenues avec des régimes plus équilibrés ((Jauncey et (1982). Néanmoins, ces chiffres se rapprochent des valeurs obtenues par Pouomogne *et al.,* 1997 (1,95 – 2,08) et Azaza *et al.,* 2005 (1,51 – 2,11). En outre, nous pouvons émettre certaines réserves sur la qualité de ces aliments vis-à-vis de ces valeurs si nous nous accordons que l'IC peut être influencé par plusieurs autres facteurs (température, densité, modalités de nourrissage, etc.). Pour ce qui est de notre expérimentation, la plage de température étant dans l'intervalle recommandé (22-26°C), les densités acceptables et les modalités de nourrissage reconnues, la dérive des hautes valeurs de l'IC observées ici serait la résultante d'un autre facteur à savoir : les pertes dues à la présentation des aliments sous forme pulvérulente, comme l'a fait remarquer Campbell (1978), la forme pulvérulente

augmente non seulement les possibilités de pertes quantitatives mais aussi de déséquilibres qualitatifs en raison des dissociations des ingrédients dans le mélange et du lessivage des composés hydrosolubles (vitamines, minéraux).

En outre, il serait aussi important de signaler que la quantité d'aliment prise en compte dans le calcul de l'IC peut dépasser notablement la quantité réellement consommée par le poisson. Il en est de même pour la quantité de protéines ingérées, considérées dans le calcul du CEP; car dans les deux cas, nous avons supposé que la quantité d'aliments distribuée était égale à la quantité consommée par les poissons; ce que nous n'avons pu vérifier Au regard des résultats obtenus, nous pouvons dire que nous n'avons pas enregistré de problèmes majeurs au niveau de la mortalité, le pourcentage de survie étant élevé au niveau des trois traitements (supérieur à 90%). Les quelques morts dénombrés au cours de l'expérience ne semblent pas être liés à l'aliment mais plutôt aux stress de manipulation car la majorité des décès survenaient un à deux jours après la pêche de plus ces mortalités étaient plus accentuées après la premières pêche où les poissons étaient encore bien fragiles. Ainsi, la plage de valeurs obtenues 91,11±3,85 à 93,33±6,67%, est bien dans la plage acceptable en élevage. On peut dont dire qu'aucun des régimes distribués ne s'est avéré toxique pour l'espèce *Oreochromis niloticus*.

Concernant la rentabilité économique, les valeurs obtenues laissent apparaître aisément que le régime substitué à 20% appliqué au traitement T1 est plus économiquement rentable soit 8,15 FCFA de plus que le régime témoins soit 4,89%. En outre, ce régime semble valoriser au mieux les sous-produits locaux, tout en maintenant les performances de croissance à un niveau moyen. En effet ce régime satisfait au mieux le rapport qualité/prix. Par ailleurs, la rentabilité des traitements tests peut facilement être revue à la hausse à la seule condition de promouvoir la culture du Moringa qui est d'ailleurs simple et adaptée à notre zone.

Conclusion

L'objectif principal de cette étude était de vérifier si la poudre des feuilles de *Moringa oleifera* pouvait substituer la farine du poisson dans l'alimentation du tilapia du Nil si oui à quel taux sans toutefois réduire ses performances zootechniques ni augmenter le coût de l'aliment. Ceci pourrait résoudre le problème d'accessibilité limitée de la farine de poisson aux fabricants locaux des aliments de poisson ; afin de contribuer à l'amélioration de la production de cette espèce.

Les meilleures performances de croissance ont été obtenues avec les régimes ne contenant pas la farine de Moringa et le régime substitué à 20% Pmf (28,72±0,13g et 29,33±0,18g); GPM (25,740±0,247g et 26,067±0,532g), CIJ (0,317±0,012g/J et 0,310±0,007g/J), TCS (2,583±0,245 et 2,613±0,164) respectivement. Pour le gain de poids, la différence a été non significative entre les différents traitements (P>0,05). De même, pour les performances d'utilisation alimentaire, les meilleurs indices de conversion et efficacité protéique sont aussi enregistrés au niveau des traitements T0 et T1 (IC respectifs = 1,985±0,141 et 1,972±0,045 CEP respectif =1,671±0,105 et 1,695±0,038) respectivement mais pas de différence significatives entre les trois traitements (P>0,05). Concernant le taux de survie, la substitution de la farine de poisson par la poudre de Moringa n'a pas d'effet sur la survie des poissons Ts>90% dans tous les traitements, différence non significative (P>0,05).Quant à la rentabilité économique, le régime substitué à 20% s'est avéré plus rentable soit 8,15 FCFA de bénéfice brute de plus comparativement au traitement témoins

Ces résultats viennent ainsi affirmer notre hypothèse qui stipulait que : les performances zootechniques et la rentabilité économique de la production de *O.niloticus* varient en fonction des proportions de substitution de la farine de poisson par la poudre de *M. oleifera* dans son aliment.

Au regard des caractéristiques de croissance, de l'utilisation alimentaire et du gain économique, le régime dans lequel la farine de

poisson est substituée à 20% par la poudre des feuilles de Moringa appliqué au traitement T1 retient notre attention.

En effet, le meilleur aliment est évalué par le rapport qualité/prix, le régime R20 (substitué à 20%) est une alternative au régime contenant la farine de poisson à 20% (aliment témoin). De même, la rentabilité économique du régime R20 peut encore être améliorée par la vulgarisation de la culture du Moringa tout en baissant davantage son prix.

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Impact

Mener des recherches dans le sens d'améliorer nos régimes expérimentaux en les rendant plus équilibrés en terme de vitamines, d'acides aminés essentiels qui influent aussi sur les performances des aliments; Evaluer l'effet de la substitution la qualité nutritionnelle du tilapia du Nil.

Recommandations

Parmi les contraintes qui entravent actuellement le développement de l'aquaculture au Cameroun, le manque d'aliments efficaces à un prix accessibles aux petits producteurs semble le plus crucial. La résolution de ce problème passerait bidimensionnelle: le premier revenant aux chercheurs de constituer une grande base de données à travers des expérimentations où l'on retrouvera des formules alimentaires efficaces intégrant des sous-produits agricoles moins coûteux et disponibles localement. C'est dans cette optique que s'inscrit cette étude. Le deuxième plan interpelle une volonté politique pour soutenir financièrement juridiquement ce secteur. Ainsi nous recommandons aux décideurs politiques: de mettre en place des programmes de subventions des industries de production des aliments de poissons qui intègrent les unités d'analyses bromatologiques plus complexes, promouvoir la vulgarisation de la culture du Moringa qui est une plante importante tant dans la consommation humaine qu'animale, encadrer financièrement les jeunes chercheurs ceci permettra d'approfondissement de cette étude jusqu'à l'obtention de la taille marchande des individus suivis; de la farine de poisson par la poudre des feuilles de Moringa sur la qualité nutritionnelle du tilapia du Nil

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ASSESSMENT OF *CLARIAS GARIEPINUS* BROODSTOCK QUALITY AND LARVA SURVIVAL RATES FED DIETARY DATE PALM MEAL FOR SUSTAINABLE AQUACULTURE

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Abstract

Low fry survival rate and scarcity of quality fish seed have continued to hinder the growth of aquaculture in Africa. The present study investigated inclusion of oven-dried Date palm meal (DPM) in *Clarias gariepinus* broodstock diets at 0, 2.5, 5.0, 7.5 and 10% level as diets 1 to 5 (five dietary treatments) but isonitrogenous at 40% crude protein. Five female broodstocks with average body weight of 1.10±0.06 kg were stocked into a tank of 1.5m3 and fed formulated diets for 8 weeks in triplicates. Two gravid females were selected per treatment, induced for breeding and were stripped for incubation after 11 hours latency period. Hatchlings were monitored for a week after cleaning and 500 each was transferred in batches and stocked per unit of treatment in triplicates. The larva were fed artemia diet at 50g per feeding regime 6 times daily with adjustment on weekly basis for 3 weeks. Proximate composition of experimental fish was carried out and data on weight changes in fish were recorded forthnightly. Fish carcass analysis and growth performance were significantly ($p<0.05$) affected by dietary DPM treatment since crude protein increased along with DPM inclusion levels. Specific growth rate and Feed Conversion Ratio exhibited significant increase with increase in level DPM inclusion in the broodstock diets and weight gain of fish fed diet 1 (control) showed 170g while that fed diet 5 (10% DPM) recorded 260g. Weight of eggs stripped were only marginally different among treatment. Hatchability rate was highest (88.40±0.20%) in fish fed 7.5% (diet 4) which was only marginally different from fish fed diet 5 (86.80±0.40%) while fish fed 0% DPM (control) had the least hatchability rate (76.70± 0.11%). Fry monitored for 3 weeks under intensive feeding showed progressive mean weight gain, specific growth rate, protein efficiency ratio and superior feed conversion ratio from control to treatment 5. Survival rate was lowest in control (83.60%) and no mortality was recorded in treatments 3, 4 and 5. This trend implied that dietary date palm meal promote growth in fish, enhance hatchability rate and fry survival, and ensure quality fish production. Production of fish feed with date palm at 7.5% inclusion is sufficient for quality fish production with high fry survival rate on sustainable basis.

Key words: Date palm meal, Fry survival rate, *Clarias gariepinus*, Quality fish, Sustainable Aquaculture.

ÉVALUATION DE LA QUALITÉ DES REPRODUCTEURS *CLARIAS GARIEPINUS* ET DU TAUX DE SURVIE DES LARVES NOURRIS À LA FARINE DE DATTES POUR UNE AQUACULTURE DURABLE

Resume

Le faible taux de survie d'alevins et la rareté des semences de poisson de qualité ont continué à entraver la croissance de l'aquaculture en Afrique. La présente étude a examiné l'inclusion de la farine de dattes (DPM) séchées au four dans des régimes de reproducteurs *Clarias gariepinus* à 0 ; 2,5 ; 5,0 ; 7,5 et 10% comme régimes 1 à 5 (cinq traitements diététiques) mais isonitrogènes à 40% de protéine brute. Cinq reproductrices d'un poids corporel moyen de 1,10 ± 0,06 kg ont été stockées dans un réservoir de 1, 5m3 et ont reçu des régimes pendant 8 semaines en trois répétitions. Deux femelles gravides ont été sélectionnées par traitement, induites pour la reproduction, et leurs œufs ont été recueillis pour

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incubation après une période de latence de 11 heures. Les alevins ont été suivis pendant une semaine après le nettoyage et 500 ont été transférés par lots et stockés par unité de traitement en trois répétitions. Les larves ont reçu un régime d'artémies à 50 g par régime alimentaire 6 fois par jour avec ajustement sur une base hebdomadaire pendant 3 semaines. La composition approximative des poissons expérimentaux a été effectuée et les données sur les changements de poids des poissons ont été enregistrées toutes les deux semaines. L'analyse des carcasses a révélé que la performance de croissance des poissons a été significativement ($p < 0,05$) affectée par le traitement alimentaire DPM puisque l'augmentation de protéines brutes a été parallèle à l'accroissement du taux d'inclusion de DPM. Le taux de croissance spécifique et l'indice de consommation ont augmenté de façon significative à la suite de l'augmentation de l'inclusion de DPM dans les régimes alimentaires des reproducteurs, et le gain pondéral des poissons nourris au régime 1 (témoin) a été de 170g, tandis que le régime alimentaire 5 (10% DPM) a enregistré 260g. Le poids des œufs recueillis n'était que légèrement différent entre divers traitements. Le taux d'éclosion était plus élevé (88,40 ± 0,20%) chez les poissons nourris à 7,5% (régime 4), qui n'était que légèrement différent de celui des poissons nourris au régime 5 (86,80 ± 0,40%) alors que les poissons recevant 0% DPM (témoin) avaient le plus faible taux d'éclosion 76,70 ± 0,11%). Les alevins suivis pendant 3 semaines sous alimentation intensive ont montré un gain pondéral moyen, un taux de croissance spécifique, un rapport d'efficacité protéique progressifs et un rapport de conversion alimentaire supérieur, du traitement témoin au traitement 5. Le taux de survie œuf-alevin était le plus faible chez le groupe témoin (83,60%) et aucune mortalité n'a été observée dans les poissons soumis aux traitements 3, 4 et 5. Ce résultat porte à croire que la farine de dattes favorise la croissance des poissons, augmente le taux d'éclosion et la survie des alevins, et assure une production de poissons de qualité. La production d'aliments pour poissons à base de dattes à 7,5% d'inclusion est suffisante pour une production de poissons de qualité, avec un taux élevé de survie d'alevins sur une base durable.

Mots-clés : farine de dattes, taux de survie d'alevin, *Clarias gariepinus*, poisson de qualité, aquaculture durable.

Introduction

Date palm (*Phoenix dactylifera*) is popular food crop in the tropical and subtropical regions (Northern Africa, the Middle East) and other areas around the world (Omar and Nour, 1993). All parts of the date tree yield products of economic value which include timber, handcraft, fuel, rope, and rafta in roofing houses (Omar and Nour, 1993). The date seeds (pits or stone) which represent 13-15 % of total weight of date fruits are sometimes used as livestock feed (Hussein *et al.,* 1998). Its leaves are well relished by ruminant as reported by Sotolu (2011) and the stone . Several studies on the use of dates and its by-products as feed ingredients in Nile tilapia (*Orechromis niloticus*) diets showed its importance as an alternative feed ingredient instead of the imported yellow corn or other dietary carbohydrate sources according to (Al-Asgah, 1988; Omar and Nour 1993; Belal and Al Jasser, 1997). However Yousif et al. (1996) indicated negative performances of blue tilapia (*O. aureus*) fed dietary dates-based diets and they also suggested thattilapia is capable of utilizing complex sugars as traditional energy sources more efficiently than simple sugars in dates. El-Sayed *et al.* (2006) reported that, despite the sharp retardation in the performance of Nile tilapia fed raw date pits, the expected reduction in the cost of date pits based diets may justify the use of the by-product in Nile tilapia feed. There is dearth of information on the utilization of date palm wastes by catfish therefore, the present study investigated the use of dried date palm meal in fish nutrition and seed multiplication using *Clarias gariepinus* being a widely cultured omnivorous freshwater fish species.

Materials and Methods

Preparation of experimental diets and broodstock feeding

Seventy-five catfish female broodstocks of 1.10±0.06kg average weight were evenly distributed in fifteen concrete tanks of 1.5m3 and allowed to acclimatize for two days before the commencement of the feeding at 3% body weight with experimental diets which lasted 56 days. Dates were purchased from Lafia central market and were oven dried at 35-50°C for 72 hrs and all other feed ingredients were finely ground in a hammer mill and used in the formulation of five isonitrogenous (40% crude protein). Broodstock diets were processed by a California pellet mill machine using 6 mm die and sun-dried for 48 hrs during average temperature of 31-35oC. All diets formulated were made into pellets of 6mm diameter after homogenous mixing in a Hobart mixer and were labelled in individual airtight container and stored in the cool dry place with the hatchery. Gross composition of experimental diets are shown in Table 1 while their proximate composition are shown in Table 2. Fish were fed 3% body weight daily at two feeding regimes between 08:30–09:00 hours and 16:30–17:00 hours and data on feed consumption and mean weight changes was gathered fortnightly. Water quality parameters which include dissolved oxygen, pH and ammonia were kept within the range of 6.7-6.9 (mg/l), 7.2-7.8 and 0.16-0.18 (mg/l) respectively which were considered favourable for freshwater fish culture according to Boyd (1990). All test diets and fish carcass were chemically analyzed for their proximate composition according to AOAC (2000).

Table 1: Gross ingredients of the experimental diets containing Date palm meal

Ingredient (g/100g/DM)	Dietary DPM Inclusion Levels				
	0%	2.5%	5.0%	7.5%	10%
Fishmeal	21.3	21.3	21.3	21.3	21.3
Ground nut cake	17.2	17.2	17.2	17.2	17.2
Indomie waste meal	26.4	26.4	26.4	26.4	26.4
Dried brewers' grains	29.6	27.1	24.6	22.1	19.6
Date palm meal (DPM)	0.0	2.5	5.0	7.5	10.0
D-calcium phosphate	1.5	1.5	1.5	1.5	1.5
Fish premix*	1.0	1.0	1.0	1.0	1.0
Methionine+lysine	2.0	2.0	2.0	2.0	2.0
Palm oil	1.0	1.0	1.0	1.0	1.0

**Biomix fish vitamin/mineral providing per kg of diet at 5kg per tonne inclusion: 20,000 iu, vitamin A, 200 i.u, Vit. D3, 200 mg Vit E, 8 mg Vit k3, 20mg Vit B1, 30 mg Vit B2, 12 mg Vit B6, 50 mg Pantothenic acid, 0.8 mg Biotin, 150 mg Niacin, 0.05mg Vit B12, 160mg Vit. C, 4.0mg Cobalt, 40 mg Iron, 5.0 mg Iodine, 30 mg Manganese, 4 mg Copper, 40 mg Zinc, 0.2 mg Selenium, 100 mg Lysine, 100 mg Methionine, 100 mg Anti-oxidant.*

Table 2. Proximate composition of experimental diets (g/100g/DM)

Nutrients (%)	Dietary DPM Inclusion Levels				
	0%	2.5%	5.0%	7.5%	10%
Crude protein	40.18	40.14	40.21	40.11	40.04
Crude fibre	3.91	3.66	3.83	3.41	3.02
Crude fat	7.60	7.40	7.30	8.27	7.63
Ash	6.34	6.15	6.61	5.86	6.53
Moisture	12.18	12.51	13.30	13.04	14.65
NFE	29.79	30.14	28.75	29.31	28.13
Gross energy, kcal/kg	2996.88	2991.76	3005.03	3011.12	2999.66

Table 3: Growth and nutrient utilization of *Clarias gariepinus* fed different inclusions of DPM based-diets.

Parameters	Dietary DPM Inclusion Levels					SEM
	0%	2.5%	5.0%	7.5%	10%	
Initial wt. (g) x 10^3	1.13^a	1.40^a	1.11^a	1.16^a	1.16^a	3.40
Final wt. (g) x 10^3	1.30^b	1.61^a	1.34^b	1.41^{ab}	1.42^{ab}	1.06
Wt.gain (g) x 10^3	0.17^c	0.21^b	0.23^b	0.25^a	0.26^a	2.51
SGR (%/day)	0.25^b	0.25^a	0.34^a	0.35^a	0.36^a	0.01
Feed intake (g/day)	44.8^a	45.54^a	46.07^a	45.89^a	46.43^a	1.25
T.F intake (g) x 10^3	2.51^b	2.55^b	2.58^a	2.57^a	2.60^a	3.15
FCR	1.48^a	1.21^b	1.12^c	1.03^d	1.00^d	0.02
PER	0.17^c	0.21^b	0.22^b	0.24^a	0.25^a	0.01
PPV	4.11^b	3.38^b	3.63^b	6.74^a	6.66^a	0.40
Survival Rate	83.60	88.76	100	100	100	-

Means with the same superscript in the same row are not significantly different (p>0.05)
Keys: Initial wt.-Initial weight; Final wt.-Final weight; SGR-Specific growth rate; T.F intake-Total feed intake; FCR-Feed conversion ratio; PER-Protein efficient ratio; PPV-Productive protein value.

Preparation of female brooders for breeding and determination of their performance

At the end of the feeding trials two gravid fish were selected for spwning per treatment in order to have enough eggs for fertilization. They were injected hormone (OvaprimTM) intramuscularly at the rate of 0.5ml/kg of fish at an angle of 30 – 45o on the dorsal fin to artificially induce them for spawning. Injected fish were kept in separate tanks and a latency period of about eleven hours was allowed before the eggs were stripped if the fish was ready to be stripped. Eggs were stripped into dry plastic bowls, weighed and fertilized with the mixture of milt of matured three male fish of average weight of 1.8±0.2kg. Within two to three minutes after fertilization, eggs were evenly spread on "Kakaban" (egg receiver) that was laid inside a (1.0 x 1.0 x 0.3) m square concrete tanks for incubation each for a treatment. Hatchability rates of eggs were determined based on the method of percentage in hatched eggs as described by Aluko and Ali (2001). Survival rate was determined by the methods of Jensen (1996). Normal healthy hatchlings were estimated on percentage basis of dead and deformed hatchlings and gamete quality in female *Clarias gariepinus* was determined by fecundity/gonado-somatic index ratio according to Fernandez et al. (1998). Hatchlings were fed weighted imported feed (Artemia) 3 days after hatching for 10 days followed by floating feeds of 0.3mm (Coppens) for 7 days after which 0.5mm (Coppens) for another 10 days. Average weights of fish larvae were determined per treatment at 0th day and 17th day of feeding on dry feed (that is, 11th day and 28th days of the experiment) using sensitive electronic scale (P.E Balance mx Rady 300g max).

Growth performance and nutrient utilization assessment

Average gain, specific growth rate, feed conversion ratio protein and energy utilization were determined according to Recker (1975) and Castell and Tiews (1980).

Average weight gain (g/fish) = (W2-W1)

Where: W2: Final means weight of fish in grams and W1: Initial means weight of fish in grams

Specific growth rate (SGR, % / day) = 100 × (ln W2 - ln W1) / duration period. Where: ln: Natural log and n is the duration period in days. Feed conversion ratio (FCR) = dry matter intake (g) / total weight gain (g).

Table 4: Carcass composition of *Clarias gariepinus* fed DPM based-diets for 56 days (g/100g/DM)

Parameters	Initial	Dietary DPM Inclusion Levels (%)					SEM
		0%	2.5%	5.0%	7.5%	10%	
total protein	61.74[a]	65.88[b]	65.20[b]	65.51[b]	68.69[c]	68.67[c]	3.80
Lipid	4.03[a]	4.06[b]	4.10[c]	4.05[b]	4.08[b]	4.07[b]	0.12
Ash	8.32[a]	8.73[a]	8.77[a]	8.89[a]	8.95[a]	8.97[a]	0.04
Crude fibre	ND	ND	ND	ND	ND	ND	-
NFE	13.02[a]	12.98[a]	13.46[a]	13.77[a]	13.52[a]	13.68[a]	0.43

Means with the same superscript in the same row are not significantly different (p>0.05)
ND – Not Detected.

Table 5: Hatchability rates of experimental catfish and growth rates of fry after 3 weeks

DPM Inclusion	Mean wt. of eggs (g) incubated	Hatchability rate (%)			Initial wt. of (g) of 500 fry 3 days after hatching	Mean wt. gain (g) of 500 fry after 3 weeks
		Survival	Deformed	Dead		
1 0%	215	76.7±0.04[b]	12.7±0.17[a]	11.02±0.21[a]	17.50	912.50[c]
2 2.5%	209	87.3±0.03[a]	5.05±0.06[b]	7.70±0.14[b]	17.50	927.50[c]
3 5.0%	211	87.6±0.20[a]	5.46±0.05[b]	8.12±0.20[b]	17.50	1057.50[b]
4 7.5%	225	88.4±0.20[a]	6.67±0.33[c]	8.00±0.10[b]	17.50	1122.50[a]
5 10.0%	217	86.8±0.10[a]	6.61±0.04[c]	8.31±0.24[b]	17.50	1092.50[a]

Means with the same superscript in the same column are not significantly different (p>0.05)

Protein efficiency ratio (PER) = total weight gain (g) / protein intake (g)

Protein productive value (PPV %) = (PF – PI) ×100 / protein intake (g)

Where: PF: Protein content in fish carcass at the end and PI: Protein content at the initial stage.

Statistical analysis

Data collected were subjected to one-way ANOVA using the SPSS package version 10 and significant mean differences were separated at 0.05 probability level according to Steel *et al.,* (1997).

Results

Average weight gain of brood fish were significantly ($p<0.05$) affected by dietary date palm meal. Specific growth rate and Feed Conversion Ratio exhibited significant increase with increase in the level of DPM inclusion in the broodstock diets and weight gain of fish fed diet 1 (control) showed 170g while that fed diet 5 (10% DPM) recorded 260g (Table 3).

In terms of dietary DPM utilization (PER and PPV), values in the control were lower as compared to other treatments except in treatments 2 and 3 were PPV (4.11) of the control was higher than 3.38 and 3.63 respectively. Furthermore, dietary date palm inclusion in catfish diet exhibited significant (<0.05) superior feed conversion ratio that improves with increase in DPM inclusion despite marginal difference shown in the daily feed intake among the treatments. The effects of dietary date palm meal on the carcass composition on fish for 56 days are presented in Table 4. Fish carcass protein increased throughout in all treatments. Initial carcass protein value was 61.74% while 0% DPM produced 65.88% C.P and 10% DPM produced 68.467% C.P respectively and was significantly highest (68.69% C.P) in 7.5% DPM-based diet

fed fish. Fish carcass lipid and ash increase in all DPMs fed fish. Carcass lipid was highest in fish fed 2.5% DPM but least in control fish (0% DPM) while values of ash were only marginally different across treatments.

Weight of eggs stripped were only marginally different among treatment. Hatchability rate was highest (88.40±0.20%) in fish fed 7.5% (diet 4) which was only marginally different from fish fed diet 5 (86.80±0.40%) while fish fed 0% DPM (control) had the least hatchability rate (76.70± 0.11%). Fry monitored for 3 weeks under intensive feeding showed progressive mean weight gain, specific growth rate, protein efficiency ratio and superior feed conversion ratio from control to treatment 5. Survival rate was lowest in control (83.60%) and no mortality was recorded in treatments 3, 4 and 5.

All water quality parameters tested throughout the experimental period revealed that all parameters were within the permissible levels for optimum culture of African catfish (*C. gariepinus*) as mean values of water quality parameters over the period of the experiment are: water temperature ranged from (29 to 33.5 °C), dissolved oxygen from (4.7 to 5.4 mg/ L), pH from (7.2 to 7.7), total ammonia (0.12 to 0.16 mg/ L), total alkalinity from (155 to 162 mg/ L).

Discussion

Growth and nutrient utilization by fish increased as level of DPM inclusion increases in the diets. This observed trend could probably be due to the high consumption of the diets across the treatment. Date palm has been reported to be highly relished by carp (Al-Asgah, 1988). These results seem to have direct bearing with feed intake since it increased along from control to the highest level of DPM inclusion. The importance of feed intake by fish as a determinant of fish performance has been strongly emphasized (Preston and Leng, 1987; Faturoti, 1989; Pillay 1990) while other studies (Anderson *et al.,* 1984; Keembiyehetty and De-Silva, 1993) pointed out the possibility of protein sparing effects by other nutrients in a feed, that is as more energy was supplied for metabolism through other nutrients, more protein is available for fish growth and tissue development. There appear to be that the limit to the utilization of DPM-based diets by catfish in the present study was not reached which may be reason for the overall superior performance of the experimental fish at the highest inclusion level (10%) whereas progressive depressed growth rate is an indication of unsuitability of the test diet in such study when observed according to Tangendijaja *et al.,* (1990) and Sotolu and Faturoti (2009). The higher fish growth rate recorded at graded levels of date palm meal based diets over the control indicated a positive synergetic effect between the utilization of the disaccharides in date palm and polysaccharides of brewer's grains in that the *C. gariepinus* fed was able to convert this into muscle for growth. This observation is however at variance with the reports of Wilson (1994) who earlier reported that Ictalarus punctatus utilized polysaccharides for growth better than disaccharides. All diets produced higher values of fish carcass protein and lipid than initial values, yet there existed marginal difference among them indicating different utilization levels of the diets. These relatively high values of carcass total protein on one hand could be viewed alongside the work of (Alegbeleye *et al.,* 2001) who reported that effective utilization of bambara groundnut at varying rates was responsible for variations in Heteroclarias carcass protein and lipid while on the other hand, El-Gashim *et al.,* (1995) in relation to date palm explained that the protein deposition in animal tissue may be due to the hormonal effect of date pits as a repartitioning agent (acts in a similar way as estrogen) which alters the energy deposition towards protein and away from fat. The non-detection of crude fiber in the fish carcass composition was the same in all treatments and this had been said to be associated with effective utilization of diets according to (Sotolu, 2008). The present study also revealed that dietary date palm meal is favourable to egg formation in the ovary apart from positive growth rate due to increase in the weight of eggs in brood fish fed DPM

inclusions. This observation may further be responsible for the significantly higher larval survival rate and good larval quality recorded. The importance of broodstock nutrition has been stressed earlier by Muchlisin et al. (2006) while Sotolu (2010) reported that dietary protein levels influenced fish growth rates and fish carcass composition, quantity and quality of eggs and larval viability. The earlier reports of Aiyelari et al. (2007) informed that broodstock mortality after stripping can result due to stress but no mortality was recorded during the experiment which may be due to gentle and careful handling of the brood fish and especially when culture condition is ensured favourable at all times in terms of sufficient good water quality.

Concluson and Recommendation

It is observed from the foregoing, that the use of date palm as dietary energy source at 10% inclusion in feed formulation for catfish broodstock instead of maize was without any negative effect on growth performance and feed utilization parameters. This is a positive trend and poses a viable direction towards developing broodstock diet for the African catfish having every assurances for promoting growth rate and enhancing high fry survival rates for sustainable aquaculture programme.

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DETERMINATION OF FISH VALUE ADDED PRODUCT- PREFERENCES AMONG THE RESIDENTS OF WOTE TOWN, MAKUENI COUNTY, KENYA

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Abstract

This study was conducted during a fish eating campaign to determine the preference of fish and fish value added products in Makueni County. The data is important for advising fish farmers, traders, processors and policy makers in the aquaculture value chain. The data was obtained by randomly administering questionnaires to respondents who were served with the fish products. A total of 60 questionnaires were administered. The average quantity of fish consumed by a household was 0.74±0. 6 Kg/market visit. Nile Tilapia was the most preferred fish species (74%) compared to Nile perch (10%), African catfish (5%) and other species at 3%. Farmed fish contributed 43%, fish from L .Victoria 40% while fish from other sources contributed 8% of the total fish supplied in the County. A number of the respondents (9%) were not sure of the sources of fish. Consumers who were eating fish once a week were 48.8%, bi-weekly 20.9%, monthly 18.6% and the occasional fish consumers at 7.0%. The number of consumers eating fish daily was the least at 4.7%. Fish samosa was the most preferred of the value added products (45%) compared to fingers and balls (10% respectively). About 92.7% were willing to incorporate value added products in their diet while 7.3% were not. The main reason for fish consumption was for health benefits (37%) compared to taste (32%), easy to cook (14%) and availability (12%). Age was the only factor that showed a relationship with the quantity of fish purchased. Fried form of fish was the most preferred compared to smoked and dried forms. It is recommended that consumption of African catfish to be promoted in the county since it is viable for production in the County.

Key word: Fish value added products, preference, consumers.

DÉTERMINATION DES PRÉFÉRENCES POUR LES PRODUITS À VALEUR AJOUTÉE À BASE DE POISSONS CHEZ LES RÉSIDENTS DE WOTE TOWN DANS LE COMTÉ DE MAKUENI AU KENYA

Résumé

Une etude a été menée au cours d'une campagne de consommation de poissons, dont le but était de déterminer les poissons et les produits à valeur ajoutée à base de poissons préférés par les consommateurs dans le comté de Makueni. Les données produites par l'étude sont importantes dans la mesure où elles permettent de donner des conseils aux acteurs de la chaîne de valeur aquacole, notamment les pisciculteurs, les négociants, les transformateurs et les décideurs. Les données ont été obtenues par administration aléatoire de questionnaires à des répondants auxquels des produits de pêche ont été servis. Au total, 60 questionnaires ont été administrés. La quantité moyenne de poisson consommée par un ménage était de 0,74 ± 0. 6 Kg / visite de marché. Le tilapia du Nil était l'espèce de poisson la plus préférée (74%), par rapport à la perche du Nil (10%), au poisson-chat africain (5%) et aux autres espèces (3%). Les poissons d'élevage ont contribué pour 43%, les poissons du lac Victoria 40% tandis que les poissons provenant d'autres sources constituaient 8% de l'ensemble des poissons fournis dans le comté. Un certain nombre de répondants (9%) n'était pas sûr des sources des poissons consommés. Les résultats ont révélé

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que les consommateurs qui mangeaient du poisson une fois par semaine constituaient 48,8%, deux fois la semaine 20,9%, une fois le mois 18,6% et les consommateurs de poisson occasionnels 7,0%. Le nombre de consommateurs quotidiens de poissons était le moins élevé (4,7%). Le samosa de poisson était le plus préféré de tous les produits à valeur ajoutée à base de poissons (45%) par rapport aux bâtonnets et boulettes de poissons (10% respectivement). Près de 92,7% étaient disposés à incorporer les produits à valeur ajoutée dans leur régime alimentaire, contre 7,3%. La principale raison de la consommation du poisson était ses bienfaits sanitaires (37%) qui primaient sur le goût (32%), la facilité de préparation (14%) et la disponibilité (12%). L'âge est le seul facteur qui a montré une relation avec la quantité des poissons achetés. La forme frite était la plus préférée par rapport aux formes fumées et séchées. Il est recommandé de promouvoir la consommation du poisson-chat africain dans le comté, car il y est viable pour la production.

Mots-clés : produits à valeur ajoutée à base de poissons, préférence, consommateurs.

Introduction

The world fish food supply is growing at an average of 1.5 percent higher than the 1.7 percent world population growth (FAO, 2012). The world capita apparent fish consumption has increased from an average of 9.9 kg in the 1960s to 14.4 kg in the 1990s and 19.7 kg in 2013 (FAO, 2016). In Kenya, the fisheries sector plays an important role in the national economy contributing about 0.5% to the GDP in 2011. Fish and fishery products are high in protein and essential minerals in human diet (Rashilah *et al.,* 2010) and therefore the per capita fish consumption is expected to continue increasing (FAO, 2008). Previous studies on fish source preferences have indicated a preference to capture fisheries than aquaculture products with consumers viewing farmed fish as fish of low quality and unsafe for human consumption (Meas and Hu, 2014). In view of this, the future preference of fish and fishery products especially in the developed countries would be determined by quality assurance, food safety, freshness, diversity and convenience (FAO, 2012).

The main fish preferred in North Europe and North America is dermasal fish while cephalopods are the favorites for Mediterranean and Asian countries (FAO, 2008). In Kenya, the demand for aquaculture fish products is increasing due to the rapid population growth and the declining catches from capture fisheries (Githukia *et al.,* 2014). The main freshwater species are Nile Tilapia (*Oreochromis niloticus*), African catfish (*Clarias gariepinus*) Omena (*Rastreneobola argental*), Nile perch (*Lates niloticus*) and Nile Carps. Tilapia (*Oreochromis niloticus*), African catfish are the main cultured species in the country with the supply of the other fish species coming from inland capture fisheries. Owing to its high perishability and shorter shelf life, fresh fish is of little significance at the international trade (FAO, 2012). The increasing demand for products that have longer shelf life, cater for consumer taste and diversity of products have placed pressure for fish value addition (FAO, 2012).

Fish preferences and purchasing decisions by consumers are influenced by different attributes. According to (Polanco and Luna, 2010), food purchasing decisions are directed by cultural, psychological, lifestyles, culinary trends and diet restrictions. Socio-demographic information from respondents such as age, gender, marital status, family size, income levels and household size are explanatory variables in previous fish preferences and market research. Studies have further shown that attitude affects the choice of a given product, quantity and quality (Al-Mazrooei *et al.,* 2003). Recent studies have further brought in other attributes influencing consumer purchasing decisions for fish and fishery value added products such as form of the product, package size, method of cooking, price, smell, appearance, taste, size, quality, color, nutritional value, availability and the source of fish (Githukia *et al.,* 2014; Jabbar, 2007). This study focuses on the consumers' preference for the commercially important fresh water

fish species in Kenya and value added fish products. It also investigates the effects of socio-demographic variables on the quantity of fish bought per market visit and also the preferred form of fish species.

Methodology

Study area

The study was conducted at Wote town which serves as the headquarters of Makueni County lower Eastern Kenya ((1° 47' 0" South, 37° 38' 0" East). The town has a population of 56,419, of whom 5,542 are classified as urban dwellers. The main economic activities in the area are trading, fishing and fish farming, cash crop and livestock farming. The study area was specifically selected because it's one of the counties in Kenya where aquaculture production has borne huge benefits besides the fact that the inhabitants are not historical a fish eating community. The study was conducted during a fish eating campaign held at Wote town where each constituency of the County was represented. The 60 questionnaire respondents were randomly selected from the people who ate fish in the function. Among the information collected included socio-demographic variables such as age, sex, gender, occupation, income, education level, family size and marital status since they are perceived to influence preferences for products. All socio demographic variables were categorical.

Data analysis

The data was entered and coded under spreadsheet and analyzed using SPPS version 17 for statistical analysis. Descriptive analysis was done by use of means, standard deviation, percentages and frequency distribution of responses. A chi-square test was used to test for significant differences between different classes of socio-demographic variables and products preferences. A two-way ANOVA was used to test for significant differences between different ratings of fish sizes and consumers consideration variables. All statistical tests were considered significant at 95% confidence interval.

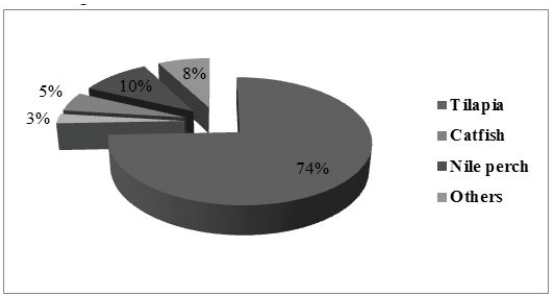

Figure 1: A pie chart illustrating fish species preferences

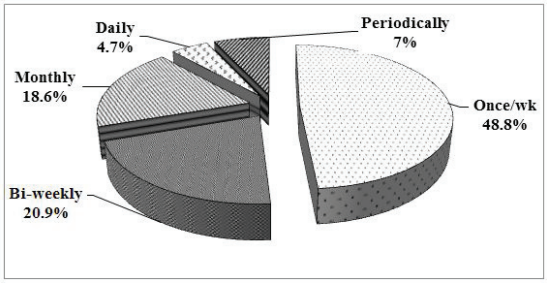

Figure 2: Frequency of fish consumption

Results

Fish preference

Observations on fish preferences are summarized in figure 1. The data indicated a statistical significance in fish preferences among the respondents. (χ2= 59.63; df= 4; p= .000). Tilapia was the most preferred species (74%), while other fish species were the least preferred (3%). Nile perch was twice more preferred (10%) to catfish (5%). Other small sized fish Omena scored higher preference (8%) compared to catfish and other types of fish but lower than Nile perch and tilapia. Aquaculture contributes 43% of the total fish consumed, 40% from L. Victoria while other sources including rivers contribute 8%. However, 9% of the respondents were not sure about the source of fish.

Frequency of fish consumption

Figure 2. represents a summary of the rate of fish consumption among the respondents. There was a significant difference between the different rates of fish consumption (χ2=26.65; df=4; p=0.000). Weekly fish consumers were the highest at (48.8%) followed by the bi-weekly

Table 1: Relationship between socio demographic variables and the mean quantity bought per market visit. ± indicates standard deviation

Variables	Mean/market visit	Df	F	p
Gender		1	0.97	0.344
Male	0.81±0.761			
Female	0.60±0.505			
Age(yrs)		4	9.126	0.000
18 to 27	0.59±0.491			
28 to 37	0.60±0.376			
38 to 47	0.48±0.335			
48 to 57	0.69±0.375			
58 to 67	2.50±0.707			
Marital status		2	0.124	0.884
Single	0.75±0 .565			
Married	0.75±0.752			
Divorced	0.50±0.27			
Education level		4	0.258	0.903
Illiterate	0.50±0.34			
Primary	0.68±0. 73			
Secondary	0.86±0.761			
Post secondary	0.58±0.411			
University	0.63±0.530			
Occupation		3	0.764	0.555
Farmer	1.11±1.019			
Business/Trader	0.64±0. 475			
Formal Employment	0.56±0. 315			
Casual Laborer	0.90±1.181			
Student	0.63±0.530			
Family size		3	1.701	0.184
1 to 3	0.66±0.553			
4 to 6	0.68±0. 610			
7 to 9	1.35±1.140			
>10	0.38±0. 177			
Monthly income		3	0.664	0.580
<5000	1.00±0.54			
5000 to 10,000	0.89±0.870			
10,000 to 20,000	0.50±0.306			
>20,000	0.75±0.354			

consumption respondents at (20.9%) then monthly consumers at 18.6% and periodically fish consumers at 7.0%. The least category was for those who consumed fish on daily basis at (4.7%).

Relationship between socio-demographic variables and fish consumption

The relationship between socio-demographic variables and the quantity bought per market visit is presented in Table 1. The average consumption per household was 0.74± 0.6kg/per market visit. There was no significant difference (F=0.917, df=1, p=0.344) between male fish consumers purchasing trend (0.8± 0.76kg/market visit) against female fish consumers (0.6±.51kg/market visit). However, the quantity of fish bought per market visit across the age categories varied significantly (F= 9.126, df= 4, p= 0.000). Respondents between 58 to 67 years bought the highest quantity per market visit (2.50± 0.707kg) followed by 48 to 57 years category (0.69± 38kg) then 28 to 37 and 18 to 27 categories at 0.60± 0.38 kg and 0.59± 0.11kg respectively. The lowest age category was 38 to 47 years at 0.48± 0.34kg/ market visit.

The results also indicated that married couples and single couples bought the highest quantity per market visit (0.75± 57kg and 0.75± 0.75kg respectively while divorcees bought the least (0.5± 0.27kg/market visit). However, there was no significant difference between the quantities purchased by people in the different marital status. Analysis of the relationship between education level and quantity of fish bought per market visit did not show any significant relationship (F=0.258, df=4, p= 0.903). That average quantity bought by secondary school leaver was (0.855±0.76kg/ market visit) followed by primary school leavers (0.67± 0.73kg/market visit) then university and post secondary at 0.63± 0.53 and 0.58± 0.42kg/market visit respectively, while illiterate people bought the least quantity(0.5± 0.34kg/ per market visit). The relationship between occupation and the quantity bought per market visit also did not show any significant difference (F=0.764, df=4, p=0.56). Farmers bought the highest quantity per market visit (1.01±1.02kg) followed by casual laborers (0.9±1.18kg) then businessmen and students (0.64±0.48kg and 0.63±0.53kg) respectively. The lowest consumers are those in formal employment at 0.56±0.32kg/market visit.

The relationship between quantity bought per market visit and family size did not show any significant relationship (F= 1.701, df= 3, p= 0.184). Families' sizes of between 7 to 9 members purchased the largest quantity per market visit (1.35±1.14kg) followed by those of 4 to 6 members (0.68±61kg) with the purchase quantity per market visit being even lower for family sizes of 1 to 3 members (0.66±0.55kg). The least were family sizes of more than10 members at 0.38± 0.18kg/market visit. The level of family income also does not affect the quantity bought per market visit (F=0.664, df= 3, p= 0.58). Small monthly income earners (<, Ksh5000) purchase the largest quantity per market visit (1.0±0.54kg) followed by Ksh5000 to Ksh10000 earners (0.89±0.87kg) then >, Ksh10000 earners at 0.79±0.72kg and the least were the, Ksh10000 to, Ksh20000 earners at 0.5±0.31kg.

Forms of fish species and their consumption

The results for the preferences of different fish forms (fresh, fried, smoked, salted and dried) are presented in Figure 3. Fried tilapia was the most preferred at (92%) compared to fresh tilapia at 5%. A few respondents (3%) preferred all tilapia forms. All the respondents who consumed other fish preferred them fried. African catfish was preferred in fried form (82%) to dried catfish (9%). Those who preferred all forms of catfish were (9%). Nile perch was preferred in fried and smoked forms. Those who preferred fried Nile perch were higher (67%) compared to 33% for those who preferred it in smoked form. The other fish consumed was Omena and was only consumed when dried.

Fish value added products consumption

Value added fish products consumption was analyzed and the results presented in figure 4. The results indicated a significant

difference between those who had consumed value added fish products, those who had not consumed value added fish products and those who the said products were not available. (χ2= 7.302; df= 2; p= 0.026).Those who had not consumed value added fish products were higher (44.2%) compared to who have consumed (41.9%) and for those who said the products were not available (14%). On the willingness to incorporate the products in their daily meal, majority of the respondents (92.7%) were willing to incorporate the products while a few of them (7.3%) had a contrary opinion on incorporating the products in their daily meal. The most preferred fish value added product was samosa at (45%) compared to fish fillet (28%), fish balls and fingers at 10 respectively. Some people had more than one product preference.Those who preferred both samosa and fish fingers were higher (5%) than those who preferred both samosa and fish fillet (3%). However, a χ2-test did not indicate any significant difference in the products preferences (p= 0.52).

Consumers' considerations when buying fish products

The ratings of factors affecting the buying of fish products are presented in table 2. More than a half of the respondents (55%) considered the health value as being an important factor while 54% deemed source of fish being not important. Processed form of fish was considered important (49%) whereas 17% of the respondents rated size of fish as being slightly important. Analysis of variance indicated significant difference between the rating levels of consumer consideration (F= 11.538; df= 3; p= 0.00705). However, there was no significant difference between the consumers consideration factors (F= 0.014; df= 8; p= 1.000).

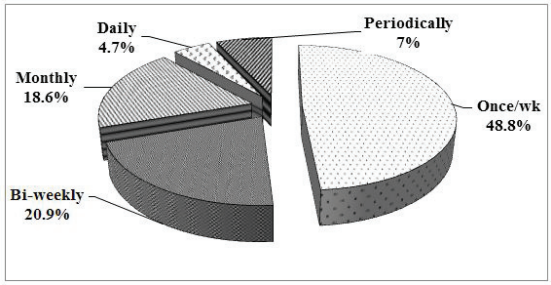

Figure 2: Frequency of fish consumption

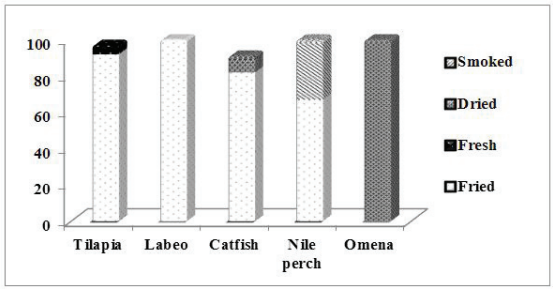

Figure 3: Fish form preferences

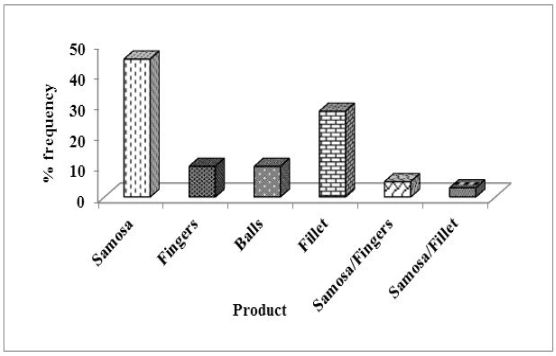

Figure 4: Comparison of value added products preferences

Table 2: Rating of fish consumers' consideration factors

	Price	Appearance	Taste	Size	Value	Health	Availability	Source	Form
Very important	48%	35%	50%	34%	49%	55%	42%	31%	33%
Important	27%	48%	45%	34%	30%	32%	35%	5%	49%
Slightly important	9%	10%	2%	17%	16%	11%	14%	10%	9%
Not important	16%	8%	2%	15%	5%	2%	9%	54%	9%

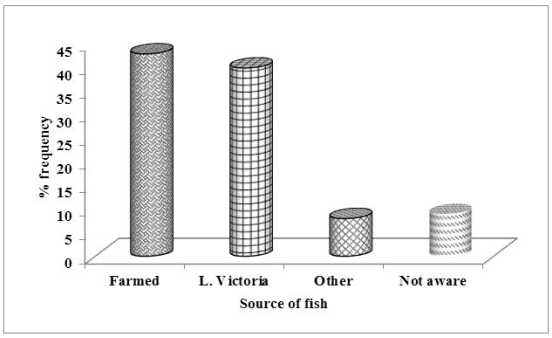

Figure 5: Comparison of fish sources in Makueni county

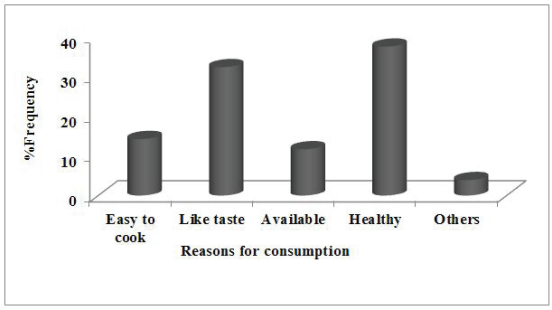

Figure 6: Comparison of reasons for fish consumption

Sources of fish in Makueni County

The sources of fish in Makueni were analyzed and presented in figure 5. There was a significant difference between the different fish sources. (χ2=24.074; df=3; p= 0.000). Majority of the respondents indicated that their fish came from fish farms (43%); another 40% confirmed that their fish came from L. Victoria while a few sited other sources (8%) including dams and rivers. Those who were not aware about the sources of fish constituted (9%) of the respondents.

Reasons for fish consumption

The reasons for fish consumption are summarised in figure 6. A significant difference existed between the various reasons given (χ2= 31.896; df= 4; p= 0.000). Majority of the respondents consumed fish because they thought it was healthy (37%) while those who said they liked the taste were 32%. Those who said fish was easy to cook were 14% while those who ate fish due to its availability were 12%.

Discussion

The results of this study have indicated a higher preference for Nile tilapia (74%) compared to 10% and 5% for Nile perch and African catfish respectively. Other fish were the least preferred at 3%. Other species also consumed by the respondents was Omena at 8%. The main cultured fish species in Kenya are Nile tilapia and the African catfish (Nyonje *et al.,* 2011). However, tilapia normally contributes a bigger share of the market supply since it accounts up to (70%) of the total aquaculture production compared to catfish which contributes 21% of the total aquaculture production in Kenya. The higher preference for tilapia from this study could be associated with its large production hence readily available at the market compared to the African catfish. (Obiero *et al.,* 2014) noted that some consumers took fish because it was readily available. The findings were in agreement with previous studies which indicated higher preference for tilapia in Kenya (Obiero *et al.,* 2014; Githukia *et al.,* 2014). (Dalhatu and Ala, 2011) also noted higher preference of tilapia from a study of fish preference in Sokoto State, Nigeria.

The fish consumption frequencies of the respondents were daily, weekly, bi-weekly, once a month and periodically. All the consumption rates were represented in the study. However, it was revealed that most of the respondents preferred consuming fish once a week (48.8%) and a few (4.7%) respondents consumed fish daily. Makueni is mainly inhabited by Akamba community who are not traditionally fish eaters. The highest fish eating regions in Kenya are the Western, Coast and Nyanza (Aloo, 2006). Thus the lower representation of daily fish consumers in this study may be associated with the cultural fish consumption habits of the Akamba community. The findings of this study agreed with (Obiero *et al.,* 2014; Githukia *et al.,* 2014) who also noted that once a week consumers were higher while daily fish consumers were the lowest. However, the findings conflicts with (Haq *et al.,* 2014) who stated that once a month fish consumers

were highest while twice a week consumers were the lowest.

Socio-demographic variables such as age, gender, occupation, family size, marital status and education level are believed to influence consumers preference for product (Quagrainie, 1998). Though education is believed to enlighten consumers about the health related benefits of fish consumption (Kinnucan *et al.,* 1993), the findings of this study have not indicated any significant difference across the different education levels. University and post secondary graduates who were expected to be more enlightened purchased less per market visit (0.63±0.53 and 0.58±0.42 respectively) compared to primary and secondary school leavers (0.67±0.73 and 0.855±0.76 respectively) who were considered to be less enlightened.

As it would be expected, the quantity purchased by a family should be determined by the family income and size. Families with higher incomes and larger number of family members are expected to purchase larger quantities of fish per market visit. However, the findings of this study have not indicated any relationship between family income and size with the quantity purchased per market visit. The average purchased for a household per market visit was very low (0.74kg/per market visit).

The study indicated higher consumption of fish among older people (58 to 67 and 48 to 57 years) and male consumers compared to female and youth consumers. According to (Darko, 2011), females usually are the main shoppers in a family while the young play an important role in future fish consumption. It's therefore necessary for fish producers to attract and retain more consumers from these two groups in future. Unlike (Githukia *et al.,* 2014), who noted that larger fish consumers were skewed towards the young people, the high fish consumers of this study were skewed towards the elderly people in Makueni County. Occupation as a factor is also thought to influence fish consumption level. Interestingly, low income earners (<Ksh5000) purchased the larger quantity per market visit compared to large income earners (Ksh10000to20000 and >Ksh20000).

Fried tilapia was the most preferred form compared to smoked form. This could be associated with the habit of people in Kenya to consume fried tilapia with ugali which is a local dish most consumed throughout the country (Quagrainie, 2010). In general, fried form is the most preferred to smoked and dried forms except Omena which is preserved by drying after being landed.

Most of the respondents consumed fish for health reasons. The respondents were aware of the health benefits of fish consumption such as reduction of risks of heart attack and good brain development for the unborn child. (Githukia *et al.,* 2014). (Nauman *et al.,* 1995) also noted that most consumers surveyed consumed fish because it was healthy. The value added products presented to respondents were fish samosas, fingers, and fillet and fish balls. Larger proportions of the respondents (59.1%) were taking fish value added products for the first time compared to 41.9%who had earlier taken the products. Fish samosas were the most preferred with a larger proportion attributing the taste to be delicious compared to the other products presented to them. Majority of the respondents also indicated interest in incorporating the products in their daily diet.

Studies by (Polanco and Luna, 2010) have shown that food purchasing decisions are directed by cultural, psychological, lifestyles, culinary trends and diet restrictions. In this study, the purchasing decision attributes considered were price, healthiness, and availability of fish, source of fish, processed form, and taste among others. Healthiness of fish was considered as the most important attribute influencing purchasing decision of fish consumers while the source of fish rated as not important in decision making. The findings were not in agreement with (Githukia *et al.,* 2014; Jabbar *et al.,* 2007) who noted that purchasing decision of fish consumers are based on prices and cooking methods respectively. Fish in Makueni County came mostly from two main sources; L. Victoria and aquaculture farms. However there were other sources such as rivers and dams

which also supplied the market but in small quantities as shown by the smaller proportion of the respondents.

Conclusion

Most of the respondents preferred consuming fish at the rate of once per week with the most preferred fish species being Nile tilapia and fish samosa as the most preferred value added fish product. The association tests conducted did not indicate any significance relationship between the quantity purchased per market visit and the socio demographic characteristic except age. It can therefore be concluded that age affect the level of fish consumption. Most of the respondents liked fish fillet while small fish was not preferred. It is clear from this study that many people were aware of the health benefits of consuming fish since majority of the respondents consumed fish for health reasons. Fried fish form was the most preferred compared to the smoked and dried fish forms.

Nile tilapia and African catfish are the main cultured fish species in Kenya. However, African cafish is not available in most places. This coud be due to its lower contribution to the total aquaculture production and lower supply at the market. The government should therefore encourage African catfish production through the aquaculture development initiatives such as supplying quality catfish fingerlings to farmers and promoting its farming. It is also necessary to diversify fish and fishery products so that consumers have a varriety of products to choose from. Fish studies in Kenya have shown high preference for fried fish compared to smoked and dried forms. According to this study, some other fish species such as Labeo and Omena should also be promoted since they are 100% consumed in fried and dried forms respectively thus reducing wastage. Value added fish products consumption campaigns should be intensified especially in rural areas since this study has indicated that most people are either not aware of the products or have never consumed fish value added products.

Acknowledgements

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Public Brief:

A policy to promote consumption of fish and fish products should be implemented in the respective counties in Kenya for health and wealth.

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EFFECT OF CONCENTRATIONS OF *ARTEMIA SALINA* ON ZOOTECHNICAL PERFORMANCES OF *FARFANTEPENAEUS NOTIALIS* IN LARVAL STAGES

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Abstract

Effect of concentrations of living food *Artemia salina* on survival and growth performances of marine shrimp *Farfantepenaeus notialis* (Pérez Farfante, 1967) from the Zoe 3 to Post larvae 1 stages, was carried out at AquaSol (Aquaculture Solidarité) structure in IRAD (Institute of Agricultural research for Development) of Kribi in Cameroon between July and August 2013. 3600 larvae (Zoe 3) born from a pregnant female (with total weight 70.6 g and 20 cm total length), collected in the natural environment by a fisherman using a bottom thread were used. The larvae were bred in an experimental device consisting of 6 treatments seeded in 3 replicates each. Treatments were randomly distributed into 18 cylinder-conical plastic bottles. Larvae were fed at different levels of concentration of imported *Artemia salina* nauplii (AN) (0 AN/ml, 1 AN/ml, 2 AN/ml, 3 AN/ml, 4 AN/ml and 5 NA/ml), Microalgae *Thalassiossira pseudonana* cultivated in the station and with a dry imported food. The best performances of survival, growth and metamorphosis were produced by 3 AN/ml concentrations of Artemia. The cost of food has increased with the concentration level of Artemia. Then, the production of viable shrimp post larvae and cheaper may be done at 3 AN/ml optimal concentrations of Artemia.

Key words: Biotic factors, *Farfantepenaeus notialis*, growth, survival, Cameroon

EFFET DES CONCENTRATIONS D'*ARTEMIA SALINA* SUR LES PERFORMANCES ZOOTECHNIQUES DE *FARFANTEPENAEUS NOTIALIS* AUX STADES LARVAIRES

Résumé

L'effet des concentrations de nourriture vivante *Artemia salina* sur la performance de survie et de croissance des crevettes marines *Farfantepenaeus notialis* (Pérez Farfante, 1967) des stades Zoe 3 à Post larves 1, a été étudié à la structure AquaSol (Aquaculture Solidarité) à l'IRAD (Institut de Recherche agricole pour le développement) de Kribi au Cameroun, entre juillet et août 2013. L'étude a utilisé trois mille six cents (3600) larves (Zoe 3) nées d'une femelle gravide (poids total 70,6 g et longueur totale 20 cm), capturée dans l'environnement naturel par un pêcheur utilisant un filet de fond. Les larves ont été élevées dans un dispositif expérimental comprenant 6 traitements, ensemencées en 3 répétitions chacun. Les traitements ont été distribués de façon aléatoire dans 18 bouteilles en plastique de forme cylindriques/coniques. Les larves ont été nourries à différents niveaux de concentration de nauplies d'*Artemia salina* (AN) (0 AN / ml, 1 AN / ml, 2 AN / ml, 3 AN / ml, 4 AN / ml et 5 NA / ml), de microalgues *Thalassiossira Pseudonana* cultivées dans la station et d'aliments secs importés. Les meilleures performances de survie, de croissance et de métamorphose ont été produites par les concentrations d'Artemia 3 AN / ml. Le coût des aliments a augmenté avec le niveau de concentration d'Artemia. On peut conclure que la production de crevettes post-larvaires viables et bon marché peut s'effectuer aux concentrations optimales d'Artemia 3 AN / ml.

Mots-clés : Facteurs biotiques, *Farfantepenaeus notialis*, croissance, survie, Cameroun

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Introduction

World production of shrimp today is growing rapidly and contributing to the expansion of aquaculture. Aquaculture farms provide 20 to 25% of the world's marine shrimp production (Avalle *et al.,* 2003 ; CSAO, 2006). Asia is the largest supplier of shrimp in the world with 88% of production, 41% from China alone (CSAO, 2006). The rest (12%) is largely provides by the Latin America (FAO, 2010). Despite the many possibilities that Africa abounds, shrimp farming is recent (ACP Fish II, 2011). In 2004, total African shrimp production amounted to 8,000 tons, or 0.3 % of total world aquaculture production (ACP Fish II, 2011). In most cases, African farms produce the shrimp Penaeus monodon, highly appreciated in the world market for its growth performances (CSAO, 2006). The major shrimp farming sites in operation in Africa are located mainly in Madagascar, Mozambique, Seychelles and Gambia (CSAO, 2006).

In Cameroon the data available on the shrimp fishery were merely within the marine capture (MINEPIA/DPA, 2009). Despite the production of freshwater shrimp; shrimp production decreased from 2000 tons in 1972 to around 250-450 tons in 2006 (MINEPIA/DPA, 2009; ACP Fish II, 2011). This drastic decline in shrimp production is the result of overexploitation, climate change, pollution and destruction of mangroves for shrimp spawning grounds; associated with rapid population increase (MINEPIA/DPA, 2009). *Farfantepenaeus notialis*, marine shrimp native to Cameroon, have been dramatically overexploited by local and foreign artisanal fishermen as well as industrial fishermen. The official captures decreased from 35,000 mt in 1999 to 11,000 mt in 2010 (Gaudin *et al.,* 2013). Consequently, the species has a high commercial value on the national market, which would help the successful development of its aquaculture (Gaudin *et al.,* 2013). Moreover, this species has a beautiful appearance that makes it attractive to consumers (Gaudin *et al.,* 2013). In this context, the need for domestication and biodiversity conservation of endogenous shrimp was imposed (Tomedi *et al.,* 2015). Thus in 2007, a collaboration agreement signed between AquaSol-SA and IRAD has allowed the establishment of a shrimp hatchery in the IRAD Station of Kribi (Southern Cameroon) (Njifonjou and Mialhe, 2009; Penkem, 2011; Kenfack, 2012, Gaudin *et al.,* 2013).

Furthermore, domestication and breeding of a species depends on the knowledge of the factors promoting its growth and survival (Fontaine *et al.,* 2009). The breeding success of all living species implies a good control of its environment and biotic factors. According to Cacot and Lazard (2009), the feeding of a species affects in its aquaculture potential and represents 35-40 % of the production cost. Knowing that the basis of the shrimp culture relies on the availability of larvae / post larvae (Alvarez *et al.,* 2004; Kenfack, 2012), control of food at different larval stages could contribute to sustainable post-larvae production and lower cost. In Cameroon, some studies have already been conducted in captivity on the effects of exogenous factors on shrimp reproduction and growth to the Mysis, post-larvae and juvenile stages (Penkem, 2011; Kenfack, 2012; Tekou; 2013; Nwamo *et al.,* 2014; Tekou *et al.,* 2014 and Tomedi *et al.,* 2015). To our knowledge no study has been done on the effects of biotic factors on the breeding of post-larval penaeid. This work is therefore devoted to determine the Artemia (*Artemia salina*) optimal concentration as feeding of marine shrimp *Farfantepenaeus notialis* (Pérez Farfante, 1967) of Zoe 3 to Post larve 1 stages in captivity.

Material and Methods

Study area

The study was carried out in the AQUASOL SA structure, IRAD Kribi, Department of Ocean in Southern Cameroon region (latitude 2°56'N et longitude 9°54'E), between July and August 2013. The climate is classic guinean type with maritime predominance. It offers two main climatic shades: maritime nuance and shade within Guinea, respectively introduced by the proximity of the sea and continentality (MEAO,

2003). In fact, the oceanian climate is warm and rainy. There are four seasons reducing in the coastal area into two main seasons: a long rainy season (March to October) and a long dry season (November to February); there are no completely dry months. Average rainfall and temperature are respectively 2970 mm and 26 °C. This Department is characterized by a particularly dense hydrographical network, with many rivers (Kienké, Lokoundjé, Lobe, Nyong and Ntem), most of which are rooted in the South Cameroon Plateau and all flow into the Atlantic Ocean (MEAO, 2003). The relief of the continental shelf of Kribi is hilly because of rocky banks and mounds of sand; soils are hydromorphic kind of ferralitic in floodplains (Letouzey, 1969). The hatchery is located in the border of the sea and far enough away from rivers joining it to prevent the influx of fresh water (greater than 25 ppt salinity) and water too loaded with suspended solids.

Animal Material and Food Used
Ethics

Just as shrimp, brine shrimp are not classified among the protected species nor in Cameroonian law either in international law. Furthermore, throughout the study, these two species not have been subject to poor handling or torture. This study was designed quite simply to improve their production in captivity, in order to no longer depend on the natural environment.

3600 larvae from a pregnant female (body weight 70.6 g and total length 20 cm), collected from a fisherman were fed with live food composed of 5 g of *Artemia salina* cysts (imported from salt lakes of Salina in the state of Utah in the USA) and microalgae of the species Thalassiosira pseudonana, cultivated in AquaSol SA- IRAD station. These living foods were supplemented by dry food to 53% crude protein, of Creve Tec brand and imported from SORGAL society in Portugal.

Experimental design

The experimental design (Table 1) consisted of 6 treatments with 3 replicates each. Treatments were randomly distributed into 18 cylinder-conical plastic bottles (recovered materials) from the brewing company SuperMont. These bottles 10 L of capacity were cut at their base and filled with 4 l of sea water each. The device was also equipped with a closed-circuit water heater at 34°C.

Assay conduct

The seawater used in this assay was pumped prior, decanted, filtered to 5 µm. and then introduced into a 100 liter tank. This water was treated with EDTA (10 mg / l), sterilized with chlorine (1 ml / l) and maintained at strong aeration for at least 5 hours before use.

The pregnant female was introduced into a spawning tank (30 ° C and 26 ppt salinity) on arrival at 9:30am. Spawning took place at 2 am next day and eggs were counted. They were then transferred to an incubation tray 2:50am (30 ° C and 26 ppt salinity). Hatching had occurred at 10 am and larvae were also counted. 48 hours post hatching; larvae (Nauplii 5) were transferred to the basins of larval rearing. They were fed on microalgae and dry food until Zoe 3 stage (after 6 days). Then 200 larvae of Zoe 3 stage were introduced into each bottle by density of 50 Zoe / l. The total length and number of metamorphosis of a sample of 10 randomly selected larvae were determined in advance.

Zoe 3 larvae were fed with Artemia 2 times a day within an interval of 12 hours (08 am and 20 pm), to dry food 3 times / day in a 8 hours interval of time (10 am, 18 pm and 2 am) and to microalgae 1 time / day (morning at 8:00am). Artemia cysts were previously hydrated, decapsulated, incubated, preserved (7 days minimum to 4°C) and calculated volumetric before distribution using a micro pipette (10-100 µl) MICROLIT brand. The dry foods were weighed using an electronic balance 10-3 g accuracy brand Sartorius Competence and distributed using a Pasteur pipette (5 ml) and a graduated plastic test tube (50 ml). Living microalgae were distributed to the graduated plastic test tube (50 ml).

Each day from 8pm, 05 larvae were taken at random from each replicate, then introduced into 50 ml plastic test tubes and

03 drops of Betadine were added thereto. Their total lengths and their larval stages were then identified. Salinity, temperature and pH of the water were sampled 02 times per day to 5am and 8pm, during the study using respectively a brand salinometer HANNA, a thermometer and a JBL pH-paper. The average values of temperature, salinity and pH were; 30.50 ± 0.04 ‰, 31.00 ± 0.53 ° C and 7.80 ± 0.01 ppt respectively. The different replicates were siphoned daily from 5 pm 30 and the water was then renewed at 50%. Siphoned water was evacuated through a screen of 180 µm mesh, which allowed to retain larvae in experimentation.

Data collected

The total length was determined by optical microscope brand ZEIZZ (magnification × 5 cm and precision 10-1 cm). 05 larvae per replicate were randomly selected and measured each of the front edge of the carapace at the end of the telson (Gaxiola *et al.,* 2010).

The larval stage of each larva was determined using the morphological description key of Dobkin (1961). The number of larval Zoe 3 and post-larvae 1 stages was determined by a visual count. Quantity distributed of Artemia by treatment was assessed using a micro pipette (10-100 µll) of MICROLIT brand. The cost of feed per kilogram was also determined (Price in Kilogram converted to milligram).

Studied parameters

The following parameters were studied:

- Survival rate (SR) was calculated using the formula: SR (%) = (Nf/Ni) X 100, with Ni and Nf : number of shrimp at the beginning and at the end of experiment respectively)
- Metamorphosis rates also called development index (ID), was calculated using Villegas & Kanazawa (1980) formula: ID=(∑□A)/N With A = absolute value X no. Where no = number of larvae in each considered stage; N = total number of larvae in each sample. Absolute values assigned to each sub stage are: Zoe 3 = 3; Mysis 1 = 4; Mysis 2 = 5, Mysis 3 = 6; Post-larve1 = 7.
- Length gain (LG) between the beginning and end of the study was calculated according to the formula used by Gaxiola et al. (2010): LG (mm) = TLf -TLi , where imTL (mm) = initial mean total length and fmTL (mm) = final mean total length
- Mean daily length gain (mDLG) was calculated using the formula: mDLG = (fmTL – imTL) / t, With t : time in day.
- Specific growth rates (SGR) was calculated according to (Ricker, 1975) formula : (SGR (%) = 100 X [Ln fmTL – Ln imTL)] / t, where Ln : logarithm Neperian) .
- Food cost: The quantity and cost of imported dry food as well as those living microalgae are fixed for all treatments, only the concentration of Artemia varies. The cost of dry food (FC) is calculated using the formula: FC (f CFA) = Quantity of dry food distributed × Price of food by Kilogram

Statistical analysis

Data were subjected to analysis of variance (ANOVA I), and when the differences were significant, means were separated using the Duncan test at 5% probability level. SPSS 20.0 software was used for this analysis.

Results

Survival rates of *F. notialis* larvae from Zoe 3 to post-larvae 1 stages depending on Artemia concentrations in captivity Figure 1 shows the survival rate of *F. notialis* larvae at different concentrations of Artemia. It appears that survival rates between treatments were low (= 55%) and significantly different (p = 0.05). However, the T3 et T4 concentrations showed similar results (P = 0.05) and they were significantly higher (P = 0.05) than others. 2- Growth performances of *F. notialis* from Zoe 3 to Post-larves stages 1 depending on

Artémia concentrations in captivity

From Table 1 shows growth performances of *F. notialis* larvae depending on concentrations of Artemia, it appears that shrimp fed at 3 AN/ml recorded higher growth

Table 1: Different treatment depending on the concentrations of Artemia in AN/ml distributed in replicates per daily ration per meal.

Traitements	Concentrations of Artémia (AN/ml)	
	per daily	Per meal
T0	0	0,0
T1	1	0,5
T2	2	1,0
T3	3	1,5
T4	4	2,0
T5	5	2,5

AN: Artemia Nauplii

Table 2: Growth performances of *F. notialis* in captivity depending on Artemia concentrations

Treatments	Growth performances				
	iTL (mm)	fTL (mm)	TLG (mm)	mDGL (mm)	SGR (%)
T0	2,56	2,99 ± 0,09^{c}	0,43 ± 0,10^{c}	0,09 ± 0,02^{c}	1,35 ± 0,26^{c}
T1	2,56	3,18 ± 0,08^{bc}	0,62 ± 0,09^{bc}	0,12 ± 0,02^{bc}	1,89 ± 0,21^{bc}
T2	2,56	3,16 ± 0,19^{bc}	0,60 ± 0,23^{bc}	0,12 ± 0,04^{bc}	1,81 ± 0,53^{bc}
T3	2,56	3,63 ± 0,18^{a}	1,07 ± 0,22^{a}	0,21 ± 0,04^{a}	3,03 ± 0,43^{a}
T4	2,56	3,57 ± 0,05^{a}	1,01 ± 0,06^{a}	0,20 ± 0,01^{a}	2,88 ± 0,11^{a}
T5	2,56	3,39 ± 0,04^{ab}	0,83 ± 0,05^{ab}	0,17 ± 0,01^{ab}	2,44 ± 0,11^{ab}
Means	2,56	3,32 ± 0,26	0,76 ± 0,26	0,15 ± 0,05	2,23 ± 0,68

Mean ± standard deviation is based on three replicates, (a, b, c) : each column with same superscript were not significantly different (P = 0.05) ,T0 : 0 AN/ml,T1 : 1 AN/ml,T2 : 2 AN/ml,T3 : 3 AN/ml,T4 : 4 AN/ml,T5 : 5 AN/ml, AN :Artemia Nauplii , iTL : initial total length, fTL : final total length, LGT : total gain length, mDLG : mean daily gain and SGR : spécific growth rate.

performances. However, these performances were comparable (P = 0.05) to those shrimp fed on 4 AN / ml concentrations of Artemia. Furthermore; these performances are significantly higher than those of other batches. The witness treatment T0 recorded the weakest growth performances (P = 0.05).

Effect of Artemia concentrations on metamorphosis rates of *F. notialis* from Zoe 3 to Post-larves 1 stages Table 3 shows that regardless the treatments, the highest transformation rates (p = 0, 05) were observed on days 3 and 4 which corresponded to the Mysis 3 and Post-larva 1 stages. Depending on the treatment and independently of periods, the highest metamorphosis rates (p = 0, 05) were recorded from T3. The lowest metamorphosis rate from Mysis 3 to Post-larva 1 (day 4) corresponds to 0 AN / ml.

Food cost (FC) depending on concentrations of Artemia

The cost of feed (dry feed and Artemia) depending on the concentration of Artemia as presented in Table 4 shows that, the unit cost of feed increases with Artemia concentrations (p < 0, 05). However, the T3 and T4 treatments recorded comparable unit costs (P = 0.05).

Discussion

The lowest survival rate recorded by the witness treatment T0 showing the influence of Artemia on larval survival. Registered survival rates were low (= 55%) and the highest was 52.17%, corresponding to 3 AN / ml. These results do not corroborate with those of Gaxiola et al. (2010) who reported from *F. brasilensis* the highest survival rate of 98.3 ± 2.9% to 4AN/ml. This superiority could be due to

Table 3: Daily evolution of metamorphosis rate of *F. notialis* depending on different artemia concentrations in captivity

	Treatments					
Days	**T0**	**T1**	**T2**	**T3**	**T4**	**T5**
J0	3,00 ± 0,00^{a}	3,00 ± 0,00^{a}	3,00 ± 0,00^{a}	3,00 ± 0,00^{a}	3,00 ± 0,00^{a}	3,00 ± 0,00^{a}
J1	1,87 ± 0,92^{b}	1,60 ± 0,00^{b}	1,87 ± 0,46^{b}	3,20 ± 0,00^{a}	1,87 ± 0,46^{b}	2,13 ± 0,92^{b}
J2	2,40 ± 0,00^{b}	1,67 ± 0,58^{b}	1,67 ± 1,15^{b}	3,67 ± 0,58^{a}	2,33 ± 0,58^{b}	2,33 ± 0,57^{b}
J3	2,4 ± 0,00^{b}	1,6 ± 0,70^{b}	2,00 ± 0,70^{b}	4,40 ± 0,70^{a}	2,80 ± 0,07^{b}	2,80 ± 0,70^{b}
J4	0,93 ± 0,80^{b}	1,40 ± 1,40^{b}	1,87 ± 0,81^{ab}	3,73 ± 0,81^{a}	3,73 ± 1,62^{a}	3,73 ± 0,81^{a}

Mean ± standard deviation is based on three replicates, (a, b, c) : each column with same superscript were not significantly different (P = 0.05) ,T0 : 0 AN/ml,T1 : 1 AN/ml,T2 : 2 AN/ml,T3 : 3 AN/ml,T4 : 4 AN/ml,T5 : 5 AN/ml,AN :Artemia Nauplii ; J0 : day 0 (Zoea 3), J1 : day 1 (Mysis 1), J2 : day 2 (Mysis 2), J3 : day 3 (Mysis 3) and J4 : day 4 (Post-larvae 1).

Table 4: Food cost depending to Artemia concentrations and quantities of food distributed for rearing *F. notialis* from Zoea 3 to Post-larvae 1 stages in captivity

	Treatments					
Food cost and quantities	**T0**	**T1**	**T2**	**T3**	**T4**	**T5**
Food cost (FCFA)	22,57	49,41	76,25	103,09	129,92	156,77
Quantity (mg)	668,30	896,40	1124,60	1352,70	1580,80	1809,00
Unit cost (FCFA/mg)	0,03^{c}	0,06^{b}	0,07^{b}	0,08^{ab}	0,08^{ab}	0,09^{a}
Unit cost (FCFA/g)	30,00^{c}	60,00^{b}	70,00^{b}	80,00^{ab}	80,00^{ab}	90,00^{a}

(a, b, c): each line with same superscript were not significantly different (P = 0.05),T0: 0 AN/ml,T1 : 1 AN/ml,T2 : 2 AN/ml,T3 : 3 AN/ml,T4 : 4 AN/ml,T5 : 5 AN/ml,AN :Artemia Nauplii

differences in experimental conditions (Alvarez *et al.,* 2004). Indeed, these authors worked at a water temperature of 28 ° C and a salinity of 35 ppt, while in this study, these parameters were 30.5° C and 31 ppt respectively. However, our study only respected the optimal conditions of salinity (between 20 and 38 ‰) as indicated in technical sheet (2014).

Growth performances of the control treatment (0 AN/ml) are lowest. This shows the positive impact of live food on linear growth in larval rearing. Indeed, Barros and Valenti (2003) show that in hatchery, due to the higher demand of larvae for their growth, it is necessary to supplement commercial food with Artemia. Treatment with the highest growth performances corresponds to 3 AN/ml. These results are different from those of Gaxiola *et al.* (2010) who found no significant difference between treatments. Furthermore, these authors obtained 4 AN/ml concentration as having highest growth performances. These differences could be explained by factors relating to the species used. In fact, Gaxiola *et al.* (2010) experimented on species *Farfantepenaeus brasiliensis* and *Artemia franciscana* contrary to this essay which was carried out on *Farfantepenaeus notialis* and *Artemia salina*.

The metamorphosis rate from Mysis 3 to Post-larva 1 (day 4) was the lowest (0.93 ± 0.81) to 0AN / ml.This result could be explained through the work of Barros and Valenti (2003) which showed that during the preparation of larval to their metamorphosis for Post-larva 1, energy demand is high. Hence the need for the use of Artemia for energy intake. In 4 days, the concentration of 3 AN/ml gave the highest metamorphosis rate from Mysis 1 to Post-larva 1 stages (3,20 ± 0,00 ; 3,67 ± 0,58 ; 4,40 ± 0,70 et 3,73 ± 0,81 respectively). These results are different from those of Gaxiola et al. (2010), who found no significant difference between treatments. Furthermore in four days they have registered the highest metamorphosis rate (4 ± 0 ; 5 ± 0 ; 5,7 ± 0,33 et 7 ± 0) with 4 AN/ml.This divergence could be explained by the fact that these authors have combined the Artemia and

diatoms (*Chaetoceros gracilis*: 80 × 103 cells/ml) and flagellates (*Tetraselmis chuii*: 2 × 103 cells/ml). While in this study, they are combined with the commercial feed (formulated to 53% protein) and diatoms (*Thalassiossira pseudonana*).

Treatments T3, T4 and T5 cost respectively 3 and 2.7 times more expensive than the treatment T0. These results are similar to those of Banag (2012) which showed that the living food cost relatively more expensive than artificial foods. Robinson et al. (2005) in the same direction show that the use of artificial feed for the production of shrimp larvae would represent a significant reduction in production costs. This insofar as the use of artificial food reduces or eliminates the costs associated with microalgae or Artemia cultures.

Conclusion

On completion of this study, it appears that supplementation of *Artemia nauplii* in shrimp feeding from Zoe 3 to Post larvae stages has a positive influence on their survival, growth performance and metamorphosis rates. It also reveals that the concentration of 3 AN/ml of *Artemia salina* is optimum for larval culture of *Farfantepenaeus notialis*, since it gives the best performances for survival, growth, metamorphosis and minimizes the cost of production, compared to other concentrations.

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PARTICIPATORY APPRAISAL OF THE IMPACT OF FISHERIES POLICY AND GOVERNANCE REFORM: THE CASE OF THE YAWRI BAY MARINE PROTECTED AREA ALONG THE COAST OF SIERRA LEONE

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Abstract

The potential of the Fisheries of Sierra Leone to make significant contributions to societal wellbeing has been firmly acknowledged. Nevertheless, the sector has failed to play its optimum possible role in the country's economic development. Having examined the opportunities the sector have to offer and the challenges holding it back from achieving developmental goals, the Government of Sierra Leone recently commissioned targeted projects to seize sectoral opportunities and address challenges. Chief among these projects are the West African Regional Fisheries Programme in Sierra Leone (WARFP-SL) and West African Pilot Project in Sierra Leone (WAPP-SL). WARFP-SL focused on Resource Governance, Reduction of Illegal Fishing and Official Quality Control & Value Addition. WAPP-SL on the other hand, realises that a pre-condition for successful fisheries development is the establishment and operationalisation of appropriate fisheries policy/legal frameworks, and the design/implementation of fisheries management plans.

The aforesaid resource stewardship interventions require policy and governance reforms which could generate losers and or winners. Understanding the impact on those that fail to benefit from such reforms particularly from the lens of those charged with implementation in the field; is decisive for compliance during and after the transition to reformed fisheries management systems. For example, change management is crucial for achieving resource-wealth benefits without sacrificing other benefits. This paper gauges the likely impacts of instituted reforms on practitioners (focusing on CMA executives in the clustered fisheries communities) in the Yawri Bay Marine Protected Areas - one of the most productive, yet vulnerable fisheries ecosystems along the coast of Sierra Leone.

Analysis evaluated the philosophy underpinning the reforms sought by the projects which formed the basis for identifying strategies as to how wealth realised from fisheries as a result of reforms can be redistributed to facilitate livelihood adjustment for would-be losers. Juxtaposing reform activities/ counter activities with the possible environmental / socio-economic impacts and the emanating winners/ losers; enabled the discernment and isolation of the mitigating actions recommended. Participatory impact appraisal indicated a desirable environmental impact score of 72% and no adverse environmental impact was recorded. However, whilst a desirable socio-economic impacts score of 66% for possible winners was observed; an even higher adverse socio-economic impact score of 68% was recorded for would-be losers. This is indicative of hard trade-offs between environmental gains and the accompanying difficult socio-economic effects on the wellbeing of vulnerable stakeholders.

Keywords: Fisheries Reforms, Impact, Stakeholders, Compliance

ÉVALUATION PARTICIPATIVE DE L'IMPACT DE LA RÉFORME DES POLITIQUES ET DE LA GOUVERNANCE : LE CAS DE LA ZONE MARINE PROTÉGÉE DE LA BAIE DE YAWRI LE LONG DE LA CÔTE SIERRA-LÉONAISE

Résumé

En Sierra Leone, le potentiel de la pêche à apporter des contributions significatives au bien-être de la société est bien reconnu. Néanmoins, le secteur n'a pu jouer de manière optimale son rôle potentiel dans le développement économique du pays. Après avoir examiné les possibilités offertes par le secteur et les défis qui l'empêchent d'atteindre les objectifs de développement, le gouvernement de la Sierra Leone

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a récemment mis en route des projets ciblés destinés à exploiter ces possibilités et à relever les défis qui entravent le développement du secteur. Parmi les projets du secteur figurent le Programme régional de la pêche en Afrique de l'Ouest / Sierra Leone (WARFP-SL) et le Projet pilote ouest-africain en Sierra Leone (WAPP-SL). WARFP-SL s'est concentré sur la gouvernance des ressources, la réduction de la pêche illicite, le contrôle officiel de la qualité et la production de valeur ajoutée. WAPP-SL, par contre, est convaincu que la condition préalable au développement réussi de la pêche est la mise en place et l'opérationnalisation des cadres politiques / juridiques appropriés pour la pêche et la conception / mise en œuvre de plans de gestion de la pêche.

Les interventions en matière de gestion des ressources exigent des réformes au niveau des politiques et de la gouvernance, et ces réformes sont susceptibles de produire des perdants et /ou des gagnants. La compréhension de l'impact de ces réformes sur les populations qui n'arrivent pas à bénéficier de telles réformes, en particulier par les responsables de l'exécution sur le terrain, est décisive pour la conformité pendant et après la transition vers des systèmes réformés de gestion des pêches. Par exemple, la gestion du changement est cruciale car elle permet d'atteindre des bénéfices en termes de richesses tirées des ressources sans sacrifier les autres avantages. Ce document mesure les répercussions possibles des réformes instituées sur les praticiens (avec focalisation sur les cadres de CMA dans les communautés de pêches groupées) dans les aires marines protégées de la Baie de Yawri - l'un des écosystèmes de pêche les plus productifs mais très vulnérables le long de la côte sierra-léonaise.

L'analyse a évalué la philosophie sous-tendant les réformes recherchées par les projets, qui ont servi de base à l'identification des stratégies sur la façon dont les richesses découlant de la pêche et engendrées par les réformes peuvent être redistribuées pour faciliter l'ajustement des moyens d'existence pour les perdants éventuels. La juxtaposition des activités de réforme / activités contraires avec les impacts environnementaux / socio-économiques possibles et les gagnants / perdants potentiels, a permis le discernement et l'isolement des mesures d'atténuation recommandées. L'évaluation participative des impacts a indiqué une note d'impact environnemental souhaitable de 72%, et aucun impact environnemental négatif n'a été enregistré. Cependant, bien que l'on ait observé un score d'impact socio-économique souhaitable de 66% pour les gagnants potentiels, un score d'impact socio-économique négatif plus élevé de 68% a été enregistré pour les perdants potentiels. Ceci est révélateur de compromis durs entre les gains environnementaux et les effets socio-économiques difficiles qui en découlent sur le bien-être des parties prenantes vulnérables.

Mots-clés : réforme de la pêche, impact, parties prenantes, conformité

Introduction

An Overview of the Fisheries of Sierra Leone

Historically, the aquatic environment to which Sierra Leone lays claim could support robust fisheries. As part of the upwelling system of the northern section of the Guinea shelf, Sierra Leone benefits from high marine biological productivity over the whole area (McGlade *et al,* 2002). Moreover, runoff water and a rich network of river inflows also enhance inshore productivity (cf. Baio, 2009). It has also been noted (e.g. Sherman and Hempel, 2008) that the country's marine ecosystem area is influenced by the Guinea Current Large Marine Ecosystem (GCLME) and the Canary Current Large Marine Ecosystem (CCLME) that flows with nutrient rich waters supporting large quantities of pelagic and demersal fish stocks. Thence, it may be well founded that scoping study (cf. Neiland *et al,* 2007) revealed a marine fish stocks estimated to be worth over US $735 million (economic capital value) and capable of generating economic rent of US $59 million per year under effective fisheries management and a well-functioning economy. The capture marine fisheries sub-sector with an annual production of some 150,000 tons, also produces a wide range of benefits such as employment and a source of livelihoods for over 500,000 people mainly in coastal communities (e.g. MFMR, 2008). Fish is also the most important source of animal protein for the majority of the population. It is therefore not surprising that the importance of fisheries in the economic development of Sierra Leone

Table 1: Fisheries of Sierra Leone: SWOT Analysis

Strengths	**Weaknesses**
1. Abundant and diverse fisheries and aquatic resources; 2. Workforce skilled in traditional practices; 3. Strong local and international market for fish, and livelihood opportunities; 4. Support for investment in sector (private, donors); 5. Long-established fisheries administration and research; 6. New fisheries policy; 7. Initiatives to improve governance 8. High consumer preference for Sierra Leone fishery products 9. Adequate political mandate for regulation and governance	1. Some fish stocks threatened by high fishing pressure; 2. Conflict between sub-sectors and at maritime boundary with Guinea; 3. Inadequate landing site infrastructure; 4. Low level of organisation and business skills; 5. No access to EU markets for fish trade; 6. Fisheries policy has been revised, but implementation approach requires attention 7. MFMR is under-resourced to perform its role; 8. Foreign IUU fishing and illegal exports; 9. Weak capacity for the middle level staff 10. Lack of fish harbour complex hinders value addition and fisheries investments 11. Focus on production-oriented management framework. 12. Sierra Leonean ownership and participation in industrial fisheries sector is weak. Benefits accrue to vessel owners and capital repatriated 13. Low licenses fess which does not reflect resource scarcity
Opportunities	**Threats**
1. Some fish stocks are underexploited; 2. Possibility of enhancing existing fishing activities through effective management, technology transfer and onshore processing; 3. Expansion of inland fisheries and aquaculture for improved food security and employment 4. Access to EU markets and fish trade; 5. Government and donor support for sector development; willingness of stakeholders and CBOs; 6. Role of artisanal fisheries in rural economy; 7. Inland water bodies and valley swamps supporting Aquaculture growth 8. Positive development in regional cooperation in sector development and management 9. Private sector investment in industrial fish processing and storage facilities exist 10. 4 fish landing, processing and storage facilities have been constructed - will enhance value addition and expand fish trade 11. Fast fisheries patrol vessel for MCS. 12. Sector GDP contribution to the economy > 10%	1. Overexploitation if fisheries expansion overrides fisheries management system development, including MCS; 2. Inadequate status of MFMR is not addressed; 3. Change in policy/ management may adversely affect employment and food security for the population of Sierra Leone; 4. Uncertainty/risks of investment; 5. Infrastructure is underdeveloped (electricity, roads and water supply); 6. Lack of donor coordination; 7. Threats to biodiversity conservation (illegal methods of fishing and by-catch problem) 8. Limited capital investment for the industrial fisheries sector and limited loan facilities for the artisanal fishery sector 9. The absence of fish reception centres and storage facilities at the port, airport and border areas hinder the export of fishery products 10. Coastal erosion and disaster prone Islands 11. Vulnerability to climate change 12. Political economy issues

Source: Neiland and Baio, (2013)

has been resolutely recognised (Baio, 2010; MFMR, 2016a; MFMR, 2016b; Neiland *et al,* 2007).

Notwithstanding, the aforementioned strengths and opportunities, Table 1 suggests real outstanding challenges undermining the potential of the fisheries sector. For example, only US$ 6 million accrued to the government of Sierra Leone in 2014 against a possible US$59 (Accounts Department, MFMR, Freetown, Sierra Leone). The country also loses about US$ 29million to IUU fishing per year (ODI, 2016) equivalent to about a tenth of the Education budget (MRAG, 2005: 6). With more than 50% of the fisheries resources in the stretch of coast ranging from Senegal to Nigeria already overfished (ibid.: 11p), this so-called "Sunken Millions" (e.g. World Bank 2008) is an important source of development funding. Moreover, sectoral challenges may have been reinforced by the crippling impact of the recent Ebola Virus Disease (EVD) epidemic on the economy (cf. Neiland *et al,* 2016).

The Basis of Recent Interventions

The forgoing analysis suggests that a significant policy and governance reform should be undertaken if the fishery of Sierra Leone is to realise its full potential. It is against this background that the Government Sierra Leone (GoSL) is implementing the WARFP-SL and WAPP-SL projects geared towards addressing these challenges and indeed seizing the opportunities.

West African Regional Fisheries Programme in Sierra Leone (WARFP-SL)

WARFP-SL focuses on Resource Governance, Reduction of Illegal Fishing and Official Quality Control & Value Addition. The resource governance aspect set outputs such as establishing clear principles and policies to increase the wealth from fisheries through strengthened rights and equitable allocation of these rights which balances economic efficiency and social benefits; allocation of fishing rights to communities; reduction of number of vessels in targeted fisheries that are overexploited. On the reduction of illegal fishing front, the aim is to increase number of total patrol days at sea per year in targeted fisheries; set up a functioning satellite-based fishing vessel monitoring system (VMS). The official quality control and value-addition feature of the programme is to establish pilot integrated fish landing site clusters; accredit a sanitary authority for certification of fish quality for consumer health and exports to the European Union and the rest of the international market.

West African Pilot Project in Sierra Leone (WAPP-SL)

WAPP-SL realises that a pre-condition for successful fisheries development in Sierra Leone is the establishment and operation of an appropriate fisheries policy and legal framework, and the design and implementation of fisheries management systems. Thus, in order to provide long term policy advice for the management of the fisheries of Sierra Leone, the Partnership for African Fisheries (PAF) of the NEPAD Planning and Coordinating Agency (NPCA) is implementing WAPP within the framework of the WARFP. Working groups of experts were established and authorized under this grant to provide technical backstopping for a long term policy support. The policy and development strategy of fisheries and aquaculture developed under this programme have been aligned to important regional and international guidelines (see MFMR, 2016a; MFMR, 2016b) - advocating for sustainable derivation of wealth from fisheries resources in a manner that is sensitive to safeguards and equitable wealth redistribution. Thus, strategic actions amongst other important considerations include; the introduction of user rights, reduction of effort, human capacity development and a governance framework upholding the human rights and dignity of interested parties.

Rationale

The aforementioned projects are implementing fisheries policy and governance reforms in order to strengthen institutional arrangements for the improvement in fisheries and aquaculture productivity. Consequently, losers and or winners will emerge – a process

Table 2. Acronyms and Abbreviations

CMAs	Community Management Associations
ESHIA	Environmental Social and Health Impact Assessment
EEZ	Economic Exclusion Zone
FBC	Fourah Bay College
GoSL	Government of Sierra Leone
IDRC	International Development Research Centre
IEZ	Inshore Exclusion Zone
IMBO	Institute of Marine Biology and Oceanography
IUU Fishing	Illegal Unregulated and Unreported Fishing
MCS	Monitoring Control and Surveillance
MEY	Maximum Economic Yield
MFMR	Ministry of Fisheries and Marine Resources
MFR	Management and Functional Review
MPAs	Marine Protected Areas
MRAG	Marine Resource Assessment Group
MSY	Maximum Sustainable Yield
NPCA	NEPAD Planning and Coordinating Agency
OAE	Open Access Equilibrium
ODI	Overseas Development Institute
RBFM	Right-Based Fisheries Management
SoFIA	State of the World Fisheries and Aquaculture
TACs	Total Allowable Catches
TURFs	Territorial Use Rights in Fisheries
USL	University of Sierra Leone
VMS	Vessel Monitoring System
WAPP-SL	West African Pilot Project in Sierra Leone
WARFP-SL	West African Regional Fisheries Programme in Sierra Leone
WBFM	Wealth-Based Fisheries Management

which should be well understood and managed for a successful transition to a reformed fisheries stewardship system. The management of changes brought about by reforms is important for achieving resource-wealth benefits without sacrificing other benefits. Thus, the realisation of the possible consequences of policy and governance reform on diverse resource user groups necessitated and indeed justifies this study. The objective is to gauge the likely effects of reforms on fisheries from the perspective of local artisanal fisheries resource managers in The Yawri Bay Marine Protected Areas (MPAs) in Sierra Leone. This should form the basis for identifying strategies for wealth redistribution to facilitate livelihood adjustment for the losers.

Scope of Study

The investigation involves a participatory policy/governance and institutional analysis involving local fisheries resource managers following revised policy/ fisheries resources governance in Sierra Leone under the auspices of WARFP-SL and WAPP-SL. Two key variables germane to the acceptance and compliance with policy and governance reform have been considered - namely:

i. Nature and impact of policy and governance reform sought
ii. Possible mitigation actions

Layout

The introductory Section 1 of this paper gives an overview of the fisheries of Sierra Leone including the basis, justification/ objective and scope of the study. Section 2 examines the philosophy underpinning the policy reforms sought by WARFP-SL and WAPP-SL whereas Section 3 presents the methods followed in data collection and

analysis including the procedures followed in the elicitation of the environmental and socio-economic impacts and their mitigation from stakeholders. In Section 4, the results are presented and discussed whereas conclusions and recommendations are given in the final Section 5 (See acronyms in Table 2).

Philosophy Underpinning Policy and Governance Reforms

The proposed policies and governance reforms are conceived to sustainably generate wealth from the fisheries via efficient exploitation mechanisms. This would demand the provision of incentives for positive investment in resource stock rebuilding and human wellbeing while curbing avenues of losses such as IUU fishing.

Policy and Governance Reform Activities in the Fisheries of Sierra Leone

This sub-section outlines ten reform activities being implemented in the fisheries of Sierra Leone as they relate to reasoning outline in Table 3.

Wealth-Based Fisheries Management (WBFM)

Both the WARFP-SL and WAPP-SL have advocated capacity development to accommodate the wealth-based approach to fisheries management which as portrayed in the fisheries policy and development strategy (MFMR, 2016a; 2016b). WBFM is deemed as a flexible management system that taps from other management systems e.g. right-based and incentive-based management systems, value addition ventures etc. - in the process of maximizing resource rent while ensuring optimal capital stock formation. The approach also seeks to tame rent because it can act as a motivation to drive overexploitation. For example, without proper allocation of fisheries resources, the motivation for overfishing could be induced by price and cost interaction (see 6 in Table 3). As Seijo, *et al,* (1998) demonstrated, rent from low cost of fishing and the high price of fish product will serve as an impetus for overexploitation in open access fisheries. But, on the other hand (e.g. Sumaila, 2012) if properly addressed in well allocated fisheries, rent derived from cost and price reflective of the scarcity of fish products would optimally contribute to societal wellbeing and uphold resource sustainability (see 1, 2, 3, 4, 5, 7 and 13 in Table 3). However, serious concerns have been raised about the applicability of the concept of MEY. For example, Béné et al; (2010) predicts potentially dreadful impacts from universal implementation of the rent-maximisation model in developing countries owing to severe lack of capacity, resources, poor governance and a weak public and private institutional context which makes it very difficult to ensure the creation, or subsequently, the equitable redistribution of rent. Dichmont, *et al.,* (2010) are also concern that unconstrained optimisation may result in effort trajectories that would be unacceptable to industry or managers because the approach does not account for the costs associated with effort reduction or fishery closure especially if vessels do not have viable alternative use. But, as Cunningham *et al,* (2009) showed, WBFM ensures that wealth from fisheries is maximised and contributes to improving social conditions because, it establishes the actual accruable rent and develops systems to obtain and equitably allocates such wealth. Such sentiments have been endorsed (e.g. Norman-López and Pascoe, 2011) - arguing that achieving MEY will result in a net economic benefit to society in the longer term particularly for local fisheries communities. Furthermore, it has been demonstrated (e.g. Brønjdal and Munro, 2012; Whitmarsh, 2011), that bio-economic models are the only means of deriving the true economic value of a fishery integrating economic and ecological functions.

Right Based Fisheries Management (RBFM)

RBMF is positioned as a tool to introduce ownership in a de facto open access fisheries of Sierra Leone in order to address challenges brought about by the so-called imperative of the commons (cf. Keen, 1988). Under such circumstances, first, the resource is harvested before someone else does and the

lack of catch limit is a motivation for resource overexploitation. This social trap means that micro-motive of one fisher in the short run (i.e. catch as much fish as possible to increase marginal benefits) is at variance with the long-term macro-motive of the fishery (i.e. achieving a designated reference point e.g. MEY). Also, there is no incentive for investment to improve productivity of the resource because everybody's business tends to be nobody's business. Third, the most desired stock is harvested first with a rush that generates considerable wastage during harvest. As Wilen (2006) argued, measures to deal with these imperatives have typically been unsuccessful and have tended to treat the symptoms rather than the causes. The author contrasts two perspectives on the fisheries overexploitation problem arguing that fisheries science has got the wrong diagnosis because it sees overexploitation as caused by bad behaviour by resource users (i.e. greed, short sightedness, prospect of wealth). Thus, attempts to restrain this bad behaviour by direct controls on fishing (e.g. time and area closures, gear restrictions, etc.) have been unsuccessfully. Fisheries economics on the other hand (cf. Op. Cit.), sees overfishing and depletion of resources as caused by insecure user rights to the resource leading to such perverse but individually rational behaviour (see 9 in Table 3). Fixing this anomaly requires the creation of secure access privileges via rights to generate incentives for investing in the resource.

Marine Protected Areas (Evolving into Territorialising the Sea in Artisanal Fisheries)

MPA is appreciated as a positive investment into the marine resources - recognising that wealth generation from marine resources requires capital formation from which the stream of services would flow into the future. This standpoint invokes the application of the economic theory of capital and investment in fisheries (see Scott, 1983). Thus, MPAs have a clear socio-economic purpose to maintain or enhance the marine resource base for human use. The cost of this investment in stock protection, conservation and rebuilding, is the value of the catch that would have been harvested (See 8 in Table 3). Crucially, MPAs presupposes exclusion from sources of livelihoods - posing a threat to acceptability and compliance with stewardship arrangements that require livelihood adjustment for losers (See 11 in Table 3). Such a management strategy also demands high cooperation, collaboration and information sharing between co-managed interest groups pursued via CMAs in Sierra Leone (See 10 in Table 3). The MPAs are planned to evolve in TURFs in Sierra Leone seeking optimal allocation of resources (See 9 in Table 3).

Effort and Catch Regulation (Effort Capping)

Post-World War II observation of increased abundance of fisheries resources and the connection between growth in the fishery resources and the sharp decline in fishing activities due to wartime conditions (cf. Brønjdal and Munro, 2012); witnessed the curtailment in fishing effort as the main strategy employed for stock recovery. This is so because as Flaaten (2010) noted, the unit cost of harvest decreases with an increase in stock size which has a cost saving effect (also See 5 in Table 3). Large stock size could be maintained by effective effort and catch control in a healthy environment which suggests limited entry from rights based fisheries management. Reforms are therefore, geared towards effort and catch controls to maintain a healthy stock level – an action that will mean exclusion of some actors.

Net Exchange Programme

The rationale of using appropriate gears during fishing operations is to guarantee that only the fishable part of the stock is taken (cf. Pope et al; 1975). For example juveniles of a stock should not be targeted in order to avoid growth and recruitment overfishing to support resource sustainability. As Hannesson (1993) argued, fishing from matured year classes ensures increased catch value with a positive influence on revenue. Accordingly, illegal fishing nets in the artisanal fisheries such as monofilaments are exchanged for legal environmentally friendly fishing nets in a net

exchange programme (See 14 in Table 3).

Management and Functional Review (MFR) of the Ministry of Fisheries and Marine Resources

It has been acknowledged (cf. Baio, 2009; World Bank, 2009; Baio, 2010; MFMR, 2016a; MFMR, 2016b; Neiland *et al,* 2016) that the human capacity requirement for contemporary fisheries management is quite demanding - breeding the need for human capacity development of staff at the MFMR (See Table 1 and 12 in Table 3). A MFR is proposed to both train and attract qualified practitioners to perform the various order functions of interactive fisheries governance (see Kooiman *et al,* 2005) and satisfy the cognitive dimension of institutions (cf. Scott, 1995). MFR may result in retrenchment or demotion of officers who may not have much to offer in a reformed system but who maybe senior officers with long term experiences.

Co-Management via Community Management Associations (CMAs)

Co-management mechanisms conceive and shares images for fisheries resource stewardship with the involvement of the multiplicity of interest groups. It establishes a clear line of communication between interested parties so that the interaction process is both complimentary and supplementary with respect to mapping out the required desired state of affairs; formulating the rules of the game in pursuing such goals and implementing management/governance strategies or tactics (cf. Pemoroy and Rivera-Guieb, 2006). In this way, co-management institutions provide support to other institutions such as research, MCS, and MPAs. The interactive governance arrangement advocated by co-management potentially confers legitimacy on the resource governance arrangements owing to the involvements of stakeholders because when rule system enjoys legitimacy, breaking them is considered unethical (See 10 in Table 3).

Table 3. Reasoning Informing Policy and Governance Reform in the Fisheries of Sierra Leone

1.	Profit is maximised where the marginal cost is equal to the marginal revenue at the Maximum Economic Yield (MEY). Thus, the MEY should be pursued with equity ensured in rent distribution (e.g. Brønjdal and Munro, 2012; Cunningham, *et al.,* 2009; Hannesson, 1993).
2.	Effort required for harvesting at Maximum Sustainable Yield (MSY) - where yield is maximised and at Open Access Equilibrium (OAE) - where profit is dissipated to zero; is significantly larger than that required at MEY – where the largest possible profit is obtainable. This reinforces MEY as a more sustainable reference point (e.g. Flaaten, 2010; Whitmarsh, 2011; Seijo, *et al.,* 1998).
3.	Stock level at MEY is larger and more conservative than MSY and OAE - reinforcing MEY as a more sustainable reference point (e.g. Norman-López and Pascoe, 2011; Seijo, *et al.,* 1998).
4.	Change from MSY or OAE to MEY requires effort reduction to allow for rebuilding stock (e.g. Scott, 1983; Whitmarsh, 2011; BrØnjdal and Munro, 2012).
5.	The unit cost of harvest decreases with an increase in stock size. Large stock is cost saving (e.g. Hannesson, 1993; Dichmont, et al; 2010; Flaaten, 2010).
6.	Stock level will reduce if fish is expensive and easy to catch at low cost suggesting that the price of fish and the cost of effort are very influential factors in sustainable fishing (e.g. Brønjdal and Munro, 2012; Sumaila, 2012; Norman-López and Pascoe, 2011; Seijo, *et al.,* 1998).
7.	Value addition increases revenue from unit output, creates jobs and a potential effort and thus, harvest reduction mechanism (e.g. Beddington and Rettig, 1984; Scott, 1983, Brønjdal and Munro, 2012).
8.	Rebuilding stock is a positive investment of forgone harvest which reduces revenue in the short run for larger revenue in the future (e.g. Scott, 1983; Pitcher and Hart, 1994; Brønjdal and Munro, 2012; Whitmarsh, 2011; Wilen, 2006).

9. Establishment of full ownership over fisheries resources in the form of rights, serves as incentive to harvest rationally, invest in stock building, avoid overfishing, eliminate wastage and curb illegal fishing by instituting rights enforced with MCS using VMS and systems that deters offenders by increasing their cost and reducing their benefits (e.g. Keen, 1988; Wilen, 2006; Flaaten, 2010; Whitmarsh, 2011; Sumaila, 2012).
10. Acceptance of and compliance with resource stewardship strategies and tactics, requires value reconciliation across bio-physical, social-cultural and economic values held and brought to the table by the multiplicity of stakeholders in a non-discriminatory or non-domineering interactive governance environment (e.g. Kooiman et al; 2005; Pomeroy and Rivera-Guieb, 2006; Jentoft, 2007; Baio, 2010).
11. Wealth sustainably generated should be redistributed for supporting societal wellbeing; livelihood adjustments for less successful actors and for the maintenance of the resource governance system such as, meeting management transaction cost and addressing cross-cutting issues such as natural disaster and climate change (e.g. Béné et al; 2010; Dichmont, et al; 2010; Cunningham, *et al.,* 2009).
12. Human resource requirement at MFMR be reviewed (Management and Functional Review) to address the paucity of professional staff. This will involve both the development of existing human capacities and recruitment of new professionals in the diverse specialties in fisheries in order to accommodate the responsibilities emanating from the policy and governance reform (e.g. Baio, 2009; MFMR, 2016a; MFMR, 2016b; Neiland *et al.,*2016).
13. Fish is a scarce resource thus; its price must reflect its scarcity to ensure sustainable and rational exploitation (e.g. Evans, 1981; Scott 1983; Thorpe and Bennett, 2001; BrØnjdal and Munro, 2012).
14. Fishing with appropriate mesh size controls growth and recruitment overfishing with a positive influence on catch value, and thus, increased revenue derived while promoting resource sustainability (e.g. Hannesson, 1993; Pitcher and Hart, 1994; Pope *et al.,* 1975).

MCS with VMS to Curb IUU Fishing and Enforce IEZ

An important reason why so much effort/resources are spent on MCS is because as Keen (1988) rightly stressed, ensuring ownership over environmental resources is fundamental to wealth creation from such resources (See 9 in Table 3). The institution of MCS is not only imperative in enforcing rights over the IEZ and EEZ, but also in supporting conservation and data gathering for sound fisheries management planning. The strategy in support of the MCS institution should fulfill the three tier functions of establishing ownership over resources by enforcing regulations on the capture process; collecting data for management planning; and ensuring that all illegal operators/operations are curbed to recoup lost resources from IUU fishing.

Influencing Marketing to Maximise Value, Regulate Effort/Catch and Reduce Post Harvest Losses

Getting value added quality fish and fish products on the local and international markets increases income in both local and foreign currencies. Value addition has been shown (e.g. Beddington and Rettig, 1984), to be a potential and viable mechanism to regulate the reduction of both catch and effort in fisheries exploitation. This is so because, increased income from low volume but high value added products is more beneficial than comparatively low income from high volume unsustainable catches (See 7 in Table 3).

Review of Licenses Fines & Fees

Although fish is one of the most traded commodities in the world (cf. Thorpe and Bennett, 2001), it is at the same time, one of the scarcest resources as reinforce by the overfished (31.4%), and fully fished (58.1%) state of global fisheries (FAO, 2015: p38). Hannesson (1993) insist that for the optimisation of rent

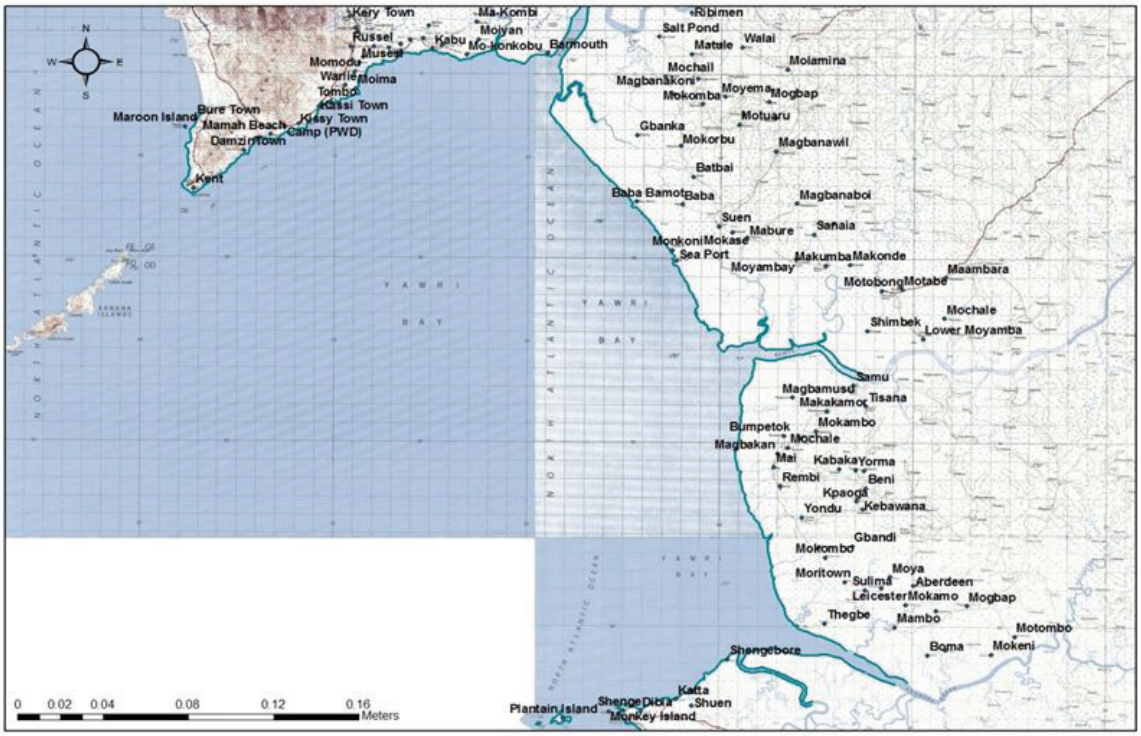

Figure 1: The Yawri Bay Depicting Settlements

Table 4: Clustered CMAs along the Shenge and Tombo Flanks of the Yawri Bay MPA

Flank	Clustered CMA	Villages
Shenge	Cluster 1 (Malachika)	Bendu, Mosangra, Mano, Baosma Bumpetoke, Makayla, Masam, Sonway, Grendema, Thumba
	Cluster 2 (Tassor)	Shenge , Bandokoh, Tissana point, Debia, One Ose, Katha, Tissana Wharf Plantain Island, Patti and Shengebul
	Cluster 3 (Lower Kagboro)	Marthyn, French, Thegbe, Mai, Mambo, Dami Town, Kitheni, Taintary
	Cluster 4 (Bumpeh Lumpthibul)	Moyeamar, Mamu, Kabengo, Tissana, England, Magbongbonto, Konolar, Mabari, Samu, Belenti
	Cluster 5 (Tawopaneh)	Makumba, Jamaica, Seaport, Barba, Mohkeni, Gbanka, Fison, Swen
Tombo	Cluster 6 (Tombo)	Tombo, Kassie Wharf, Gbankoh, Tissana, New Town Moseh, Sherbro Town, Banga ground
	Cluster 7 (Kissy Town)	Kissy Town, Mama beach, Compound, Bonga Wharf
	Cluster 8 (Fogbo)	Fagbo, Magbampo, Punyeah, Waterloo
	Cluster 9 (Rogbangba)	Rogbangba, Yams farm, John Thorpe, Marout
	Cluster 10 (Kent)	Kent, John Obay, Bureh Town, Banana Island, Ricket

from fisheries, it is important that the price reflects the scarcity of the resource. But as Baio (2009) observed, this is not the case in the fisheries of Sierra Leone because, access arrangements are managed via arbitrary licenses, royalties, landing obligations, and violation fines without any scientific rationale for the scale of the fees levied. There is no consideration for the cost of management of the fisheries sector, the profitability of the fishing fleets or the nature and value of other benefits accruing to the economy from fisheries. Under such circumstances, Evans (1981) submission remains relevant - that fisheries management is best served and scarcity of fisheries resources better reflected in it price; if a percentage of the value of the catch is taken as access fees. In addition, fines for violators should be of an adequate deterrent (See Table 1 and 9 & 13 in Table 3).

Methods

Study Area

The study was carried out along the Yawri Bay Marine Protected area. The Bay is at the southern side of the Western Area Peninsula of Sierra Leone; about 60km south east of the Capital -Freetown located around 7°52', 8°20'N 12° 45', 13° 10'W. It is a shallow coastal wetland, with 9,100ha expanse of intertidal mudflats that extend along 60km of foreshore backed primarily by mangrove swamps covering 24,505ha (14% of total area of mangrove swamp in Sierra Leone); - interlaced with a network of creeks (Birdlife International, 2005). Rivers, i.e. Ribbi, Bumpe and Kagboro rivers, each forming an estuarine ecosystem, flow into the Yawri Bay. The waters are sheltered with a gentle topography and continental shelf providing protection from strong currents - thus providing very suitable spawning and nursery for fish and other marine life (ibid.). This has led to the development of fishing communities and the establishment of commercial fisheries along its shores (see Figure 1); the most important ones being Tombo and Katta/Shenge.

Data Collection

Questionnaire Development and Field Study

The social science perspective of conducting research in conservation (see Newing *et al.,* 2011) was adopted; involving questionnaire administration, focus group discussions and observational research designed to ensure full participation of local artisanal fisheries managers. Considering that the communities in the clustered Yawri Bay MPA area have multi-stakeholders with different views captured on conceptual variables specified in Section 1.4., interviewees were asked to express a position on 10 questions (see Appendix 1) developed to elicit stakeholder standpoints in two stages.

The questions were couched around the impact and possible mitigation action for policy and governance reform activities being implemented in the fisheries of Sierra Leone. Field observational research and focus group discussions (see Robson, 2002) were also employed and field notes recorded have been useful information for the discussions herein. Once the questionnaires were finalised, stage one involved administration to the selected study sample (as defined in sub-section 3.2.2) to provide answers to the possible reform impacts, winners & losers from reforms and possible mitigation mechanisms. A follow-up workshop organised by IMBO on the socio-economic study of MPAs (stage 2), brought in the study sample elements during which participants further discussed the impacts from reform activities and indicated percentage impact scores to give a reform/impact matrix. Workshop proceedings provided insights into the inclination of scores allocated.

Sampling

One of the processes during the formation of CMAs in clustered communities involved the election of executives from a wide range of stakeholders. Jentoft (2007) added an interesting dimension to the concept of stakeholder when he noted that one is a stakeholder because of "who you are, what you have and what you represent and not necessarily what you do that determines whether or not

Table 5: Range of Possible Policy & Governance Reform Impact

Environmental Impact		**Socio-economic Impact**	
Positive	**Adverse**	**Positive**	**Adverse**
• Sea bed rejuvenated • Evidence of fish stocks recovery • Biodiversity enhanced	• Sea bed degraded • Evidence of reduced fish stocks • Biodiversity reduced	• Increased harvest (catch volume) • Increased catch value • Reduced costs of inputs • Increased profit • Enhanced livelihoods • Increased job opportunities • Increased Community cohesion • Improved compliance with regulations	• Reduced harvest (catch volume) • Reduced catch value • Increased costs of inputs • Reduced profit • Reduced livelihoods • Reduced job opportunities • Increased Community conflicts • Reduced compliance with regulations

Table 6: List of Policy/Governance Reform Activities in the Fisheries of Sierra Leone and Nature of Win/Loss

	Reform Activities	**Impact**	**Description**
1.	Shrimp/Industrial fisheries streamlined and catch per vessel increases	Winners	Individual companies, trained skippers/crews maintaining licenses from increased catch/revenue
		Losers	Displaced companies/labour losing licenses
2.	Industrial fishing excluded from inshore water	Winners	Coastal artisanal fisheries realise stock recovery/increased catch/revenue
		Losers	Excluded industrial operations losing catch/revenue
3.	Regulation of catch e.g. fishing for selected species/reducing juvenile/by-catch to improve catch value	Winners	Entire fishery from improved resource health
		Losers	Inefficient industrial operators leaving fisheries
4.	Stabilisation of fleet capacity at sustainable levels	Winners	Boat owners and crew maintaining licenses from increased catch and revenue
		Losers	Displaced boats/new entrants
5.	Preparation and implementation of management plans that sets levels of sustainable exploitation with TACs	Winners	Fisheries sector/communities from allocated harvesting ensuring goo resource health
		Losers	Excluded operators
6.	Introduction of MPA/TURFs via co-management system/CMAs	Winners	Fisheries sector/communities from allocated harvesting ensuring good resource health
		Losers	Excluded operators

	Reform Activities	Impact	Description
7.	Value addition to maximise commodity value and reduce post-harvest losses	Winners	Entrepreneurs, investors, corporate marketing associations increased revenue
		Losers	Tendency of displacing small-scale processors
8.	Improving fish processing to meet market demands	Winners	Efficient processors and their costumers from increased revenue and quality products respectively
		Losers	Tendency to displace small-scale operators
9.	Net Exchange Programme	Winners	Compliant fishers with legal gears with catch from matured year classes attracting higher prices
		Losers	Illegal fishers fishing with destructive gears
10.	Adoption of Wealth Based Fisheries Management guided by the MEY reference point	Winners	Fisheries sector/efficient operators from increased rent and healthy stock
		Losers	Inefficient operators leaving fisheries
11.	Robust MCS to ensure fishing operations is done according to law and regulations and to collect and transmit management information	Winners	Fisheries sector/legitimate operators increased revenue
		Losers	Illegal operators risk arrest with heavy fines etc.forced to leave fisheries
12.	Management Functional Review of MFMR	Winners	Fisheries sector, young qualified resource managers and other specialist with attractive wages
		Losers	Officers at or near retirement age and lazy low output workers laid off
13.	Review of licenses and fees to reflect the scarcity of fisheries resources	Winners	Fisheries sector from increased revenue
		Losers	Inefficient operators opting out

you are a stakeholder" (362p). For example one could be working in a different occupation but if you come from a region where fisheries is a cultural heritage, you would be interested and sensitive to the survival of the fishery which makes you a stakeholder. This conforms to the much wider perspective on the concept which is important in subjecting the fisheries governing system to the collective oversight of the broader civil society in order to curb the politicisation of resource stewardship at all levels (cf. Andrew et al. 2007). Such arguments influenced the deliberations on the nature of stakeholders who should constitute CMA executives. Accordingly, stakeholders were elected from societal segments as varied as Fishermen, Community Leaders, Local Government Councilors, NGOs, Representatives of MFMR, Civil Society (Mainly fisher organization) and Law Enforcement Agency. The 5 executive positions per cluster elected comprised of Chairman, Secretary General, Public Relations Officer, Financial Secretary and Treasurer. Hence, the entire population of executives for the 10 clustered CMAs amounted to 50 executives of CMAs in the Yawri Bay MPA which formed the sample size that was the subject of the field study.

Data Analysis

The responses from the sample elements with respect to the 10 field questions in Appendix 1 were pooled and analysed to indicate the range of possible impact (Table 5) and discern winners/losers (including nature of gains/losses) from reform activities (Table 6). The

Table 7: Mean % Scores for Socio-economic Impacts of Governance and Policy Reform Activities in the Fisheries of Sierra Leone

		Favourable Socio-economic Impacts								
	Governance and Policy Reform Activities	*Harvest Increased*	*Catch Value Increased*	*Reduced cost of Input*	*Increased Profit*	*Enhanced Livelihoods*	*Increased Jobs Opportunities*	*Increased Cohesion*	*Improved Compliance*	**Mean**
1	Shrimp/Industrial fisheries streamlined and catch per vessel increases	85	90	0	95	85	0	75	75	63
2	Industrial fishing excluded from inshore water	95	87	0	90	85	88	85	80	76
3	Regulation of catch e.g. fishing for selected species/reducing juvenile/by-catch to improve catch value	90	88	0	92	85	0	70	72	62
4	Stabilisation of fleet capacity at sustainable levels	91	93	0	85	80	0	75	75	62
5	Preparation and implementation of management plans that sets levels of sustainable exploitation with TACs	85	82	0	80	80	0	78	75	60
6	Introduction of MPA/TURFs via co-management system/CMAs	90	85	0	88	80	0	88	86	65
7	Value addition to maximise commodity value and reduce post-harvest losses	0	95	0	95	92	95	70	70	65
8	Improving fish processing to meet market demands	0	93	0	90	80	90	70	70	62
9	Net Exchange Programme	75	85	0	90	85	0	80	85	52
10	Adoption of Wealth Based Fisheries Management guided by the MEY reference point	78	85	0	87	80	75	85	85	72
11	Robust MCS to ensure fishing operations is done according to law and regulations and to collect and transmit management information	90	85	0	95	83	85	86	82	76
12	Management Functional Review of MFMR	75	80	0	75	70	80	70	70	65
13	Review of licenses and fees to reflect the scarcity of fisheries resources	70	70	0	70	85	80	70	70	64
	Mean	71	86	0	87	82	46	77	77	66

		Favourable Socio-economic Impacts								
	Governance and Policy Reform Activities	*Harvest Increased*	*Catch Value Decreased*	*Increased cost of Input*	*Decreased Profit Hinder Livelihoods*	*Increased Jobs Opportunities*	*Reduced Cohesion*	*Hinder*		**Mean**
1	Shrimp/Industrial fisheries streamlined and catch per vessel increases	90	87	0	88	92	85	75	70	73
2	Industrial fishing excluded from inshore water	92	90	0	89	93	80	77	75	75
3	Regulation of catch e.g. fishing for selected species/reducing juvenile/by-catch to improve catch value	80	78	0	80	76	75	70	70	66
4	Stabilisation of fleet capacity at sustainable levels	95	92	0	88	90	90	85	87	78
5	Preparation and implementation of management plans that sets levels of sustainable exploitation with TACs	90	88	0	85	88	85	75	77	74
6	Introduction of MPA/TURFs via co-management system/CMAs	86	88	0	91	88	78	75	71	72
7	Value addition to maximise commodity value and reduce post-harvest losses	65	60	0	50	75	80	75	78	60
8	Improving fish processing to meet market demands	63	56	0	55	80	85	80	80	62
9	Net Exchange Programme	80	78	0	85	85	75	80	85	71
10	Adoption of Wealth Based Fisheries Management guided by the MEY reference point	75	78	0	80	85	77	76	75	68
11	Robust MCS to ensure fishing operations is done according to law and regulations and to collect and transmit management information	80	85	0	88	85	85	75	75	72
12	Management Functional Review of MFMR	0	0	0	0	85	90	75	70	40
13	Review of licenses and fees to reflect the scarcity of fisheries resources	88	85	0	85	88	85	80	80	74
	Mean	76	74	0	74	85	82	76	75	68

Table 8: Mean % Scores for Environmental Impacts of Governance and Policy Reform Activities in the Fisheries of Sierra Leone

		Favourable Environmental Impacts				Adverse Environmental Impacts			
	Governance and Policy Reform Activities	**Sea bed rejuvenation**	**Evidence of fish stocks recovery**	**Biodiversity enhanced**	**Mean**	**Sea bed degraded**	**Evidence of reduced fish stocks**	**Biodiversity reduced**	**Mean**
1	Shrimp/Industrial fisheries streamlined and catch per vessel increases	78	73	77	76	0	0	0	0
2	Industrial fishing excluded from inshore water	85	82	80	82	0	0	0	0
3	Regulation of catch e.g. fishing for selected species/reducing juvenile/by-catch to improve catch value	82	85	80	82	0	0	0	0
4	Stabilisation of fleet capacity at sustainable levels	75	78	70	74	0	0	0	0
5	Preparation and implementation of management plans that sets levels of sustainable exploitation with TACs	75	75	70	73	0	0	0	0
6	Introduction of MPA/TURFs via co-management system/ CMAs	86	85	90	87	0	0	0	0
7	Value addition to maximise commodity value and reduce post-harvest losses	65	60	60	62	0	0	0	0
8	Improving fish processing to meet market demands	60	55	60	58	0	0	0	0
9	Net Exchange Programme	0	75	75	50	0	0	0	0
10	Adoption of Wealth Based Fisheries Management guided by the MEY reference point	86	85	82	84	0	0	0	0

		Favourable Environmental Impacts				Adverse Environmental Impacts			
	Governance and Policy Reform Activities	**Sea bed rejuvenation**	**Evidence of fish stocks recovery**	**Biodiversity enhanced**	**Mean**	**Sea bed degraded**	**Evidence of reduced fish stocks**	**Biodiversity reduced**	**Mean**
11	Robust MCS to ensure fishing operations is done according to law and regulations and to collect and transmit management information	80	82	80	81	0	0	0	0
12	Management Functional Review of MFMR	65	60	60	62	0	0	0	0
13	Review of licenses and fees to reflect the scarcity of fisheries resources	60	65	65	63	0	0	0	0
	Mean	73	72	71	72	0	0	0	0

Table 9: Adverse Socio-economic Impact from Key Reform Activities and Potential Mitigation Mechanisms

	Key Reform Activities	Adverse Impact	Potential Mitigation
1.	Instituting right-based fisheries/fisheries management planning	Displace inefficient operators would be out-competed, lose-out	Compensation packages for Sierra Leonean crew members, retraining for other job opportunities
2.	Effort and catch regulation	Fishers and fish processors will feel the adverse temporary effect of reduced catches.	Assistance provided to help foster alternative livelihoods.
3.	Instituting Marine Protected Areas	Some sort of exclusion either permanently or temporarily from harvesting fish.	Alternative livelihoods are crucial for the acceptance of MPA management strategies.
4.	Stabilise fleet capacity at sustainable levels in artisanal fisheries (Capacity capping)	Fisheries dependent communities will incur income loss. threaten community security from livelihood insecurities	Buy-back schemes to control overcapacity and viable alternative livelihoods.
5.	Value addition, reduction of post-harvest losses and institution of official control measures	Generates interest in export in traditional fisheries which would have supplied the local market. Artisanal fish processors would be displaced in an export oriented production.	Policy that ensures space for artisanal processors supplying local market
6.	Exclusion of industrial fishing from IEZ	Industrial operators would experience lower catch/output value, reduced profit	Assist genuinely deserving cases where crew need to transfer to other sectors of the economy. Training to engage in other economic activities
7.	Management decentralisation with co-management via CMAs	The real fear is for capture of the CMAs by local elites as a way of reinforcing their private interest - a recipe for political patronage in the artisanal fisheries	It is important to foster the collective security of a well organised community of actors, and broader civil society should be empowered to participate fully
8.	Management and Functional Review (MFR)/Capacity Building Drive	Those whose services will not be required would be retrenched.	Retirement packages would help retirees to adjust to this reality.
9.	MCS and IUU reduction/ role of the JMC	Once IUU fishing is controlled, traditional illegal operator will lose catch/ job	Artisan using illegal net will benefit from net exchange programme. Incentive for change programmes
10.	Review of licenses, royalty fees and fines and the role of Fishing Port Infrastructural development	Access rights gravitates towards the more efficient operators with loss of job by less efficient operators and their crew members	Buy-back programmes and promotion of viable alternatives

calculated % impact score (to the nearest whole number) formed the basis of constructing the reform/ impact matrix in Tables 7 and 8. Focus group discussions solicited and elicited insights into mitigation mechanisms from participant's viewpoint. Proceedings were recorded which informed the discussion in Section 4.1.

Results

Sample elements offered a list of possible policy and governance impacts categorised into environmental and socio-economic issues, distinguishing between beneficial and adverse effects as depicted in Table 5.

The nature of winners and losers from reform activities were also described by the study sample which has been given in Table 6.

The mean % reform activity/impact score as indicated by the local resource management executives with respect to the environmental and socio-economic impacts are given in Tables 7 and 8. The scores in the matrix cells represent the mean reform activity/impact score of the sample elements. It is important to note that matrix scores are influenced by whether one is a winner or loser and respondent took that into account.

Adverse socio-economic impacts emanating from policy and governance reforms could be very corrosive to acceptance and or compliance with resource stewardship strategies and tactics. The elicited interaction between key reform activities, adverse impacts and the accompanying possible mitigation actions have been tabulated in Table 9.

Discussions

Review of the full range of policy, governance and development activities that could be prompted under the WARFP and WAPP suggests that there are no risks to the marine or littoral environment (Table 8). Instead, successful implementation of the policy, and governance reform activities should result in very significant environmental gains. Therefore, it is therefore not surprising that a 72% favourable environmental gain was recorded. Over a time, e.g. a decade, interlinked reform activities have been found (Pitcher and Hart, 1994) to result into significant improvements in the condition of the sea bed in coastal waters such as re-establishment of benthic flora and niche habitats, increased fish stock and enriched biodiversity. These interlinked activities include: the exclusion of industrial vessels and trawling within coastal waters; regulation of fish catches through quotas, seasonal control of fishing and standards for vessels/gear; stabilisation of the fishing fleet within sustainable harvesting yields; the adoption of management plans, formulated and agreed with full cooperation of local communities; the introduction of MPAs and fishing rights (TURFs) through co-management agreements; well-planned consultation and information dissemination throughout the fisheries sector and the MFR of MFMR. Introduction of MPAs and TURFs is the most influential reform activity positively impacting most on the environment whereas; seabed rejuvenation is the most favourable environmental impact obtained (Table 7). But, field observational research suggests that developmental proposals such as, construction of landing clusters or jetties and other harbour facilities, or any major infrastructure development for fishing ports would have localized effects on the physical environment. These risks are capable of being fully managed by ESHIA procedures that are well-established in Sierra Leone. The practice (by former industrial fisheries operatives) of employing artisanal operators to harvest inshore Pseudotolithus spp (Gwangwan), as a counteracting ploy to MCS agency's robust IEZ policing, risks overexploiting the species. Stock rebuilding strategies should now be invoked to prevent the over-exploitation of the species.

A 68% adverse socio-economic score from the reform activities is considered quite high. Accordingly, discussion focuses on reconciliation of the environmental gains and socio-economic losses with the object of facilitating livelihood adjustment for would-be losers for the enhancement of reform acceptability and compliance. It is easily

discernable from Table 7 that it's possible to record high % from both the favourable and adverse socio-economic impacts emanating from the same reform activity. For example, whilst the intensity of impact (91%) on increased harvest was recorded as favourable impact from fleet stabilisation (Table 7), 95% reduced harvest was recorded as adverse impact from the same reform activity. This is reminiscent of the saying "he who feels it knows it" - underscoring the basis of contextual assessment of social interactions. Thus, respondents considered whether actor is a winner or loser from the reform impact. Increased profit is the highest overall impact variable whereas; exclusion of industrial fishing from IEZ and robust MCS are the most influential reform activities (Table 7) for a would-be winner experiencing favourable socio-economic impacts. Conversely, the hindrance of livelihoods is the greatest adverse impact whereas; fleet stabilisation is the most influential reform activity for a would-be loser generating the highest impact score. Although reform activities e.g. fleet stabilisation can bring about substantial environmental and socio-economic benefits, they could be counterproductive and are a source of misery for losers. For example, observational research suggests that operators rush to build boat in anticipation of capacity capping to the extent that irreversible damage could be done to the health of the stocks due to excess capitalisation. Again, with the industrial operator's support in the Gwangwan fishery, a significant spike in capacity before the capping is in force. It is therefore not surprising that mitigation mechanisms suggested (Table 9) include; alternative livelihoods, compensation packages, buy back schemes and incentive for change programmes amongst others. Apparently reform activities did not have any influence on input cost. A monopoly is observed on the import of fishing gears which the fisheries sector should address to have competitive prices to improve on profitability across the value chain.

Assessment of policy options exercises during the workshop, examined "do nothing", "haphazard attempt" and "take full action" options. With respect to the first option, the signs are ominous that current levels of exploitation are leading to progressive decreases in annual catches for most species in marine waters (cf. MFMR, 2008; Baio, 2009). If collective failure to recognise the seriousness of the current position and lack of commitment to taking hard decisions continues, the omens for the future are not good. If any reform action (no matter how haphazard) is to bear fruits, national fisheries management effort at government level should be fully equipped; there must be political resolve to implement unpopular measures; adequate technical and financial resources should be made available; and the internal resistance and inertia towards change should be broken by major awareness building and communications strategy targeting in particular the traditional leaders of the fishing industry. The full action option would need measures in place to offer encouragement and practical assistance to fishers to convert to more sustainable practices while at the same time introducing effective enforcement. Moreover, those displaced from the industry should find gainful employment and livelihoods in other sectors of the economy.

Conclusion and Recommendation

The study provides the inkling of local artisanal fisheries resource managers on the impact of fisheries policy and governance reforms being implemented in one of the major fishing ecosystems/settlements in Sierra Leone. This would serve as a guide to the design of future legitimate developmental interventions because, as mentioned earlier, when rule systems enjoy legitimacy, breaking them becomes unethical. Fisheries policy and governance reforms activities being implemented could potentially result into substantial environmental gains (72%) with minimal adverse environmental impact. The reforms will also bring about increased revenue, reduction of post-harvest losses and added value to fish products will bring major economic returns. At the same time, there will be some individuals who do not participate in

direct gains and whose livelihoods could be adversely affected if appropriate safeguarding measures are not put in place. Mindful of the influence socio-economic impacts from reforms would have on the acceptance and compliance with the strategies and tactics for the implementation of such reforms; the indication that the adverse socio-economic impact (68%) outweighs the favourable impact (66%) is noteworthy. The level and extent of these socio-economic risks will be governed by the level of commitment that the Government enters with its development partners to deliver incentives to vulnerable and disadvantaged groups. With such a level of adverse socio-economic impact, the speed with which the sector is transformed becomes pivotal. Rapid change could cause significant displacement of less-efficient operators, especially within the artisanal sector which would have serious ramifications for resource dependent communities. However, these effects can be marginalised if the development programme is carefully phased to ensure that alternative livelihood and employment incentives are available. The main risks to local livelihoods relate to the potential for: loss of employment for crews of unseaworthy/obsolete vessels (from all sectors including industrial and artisanal) that are withdrawn from the fishing fleet because they no longer comply with license regulations; and the inability of vulnerable and disadvantaged groups, including artisanal fishers, vendors and individual fish processors in small fishing villages to adjust to new market conditions.

List of Field Study Questions

1. What are the possible socio-economic impacts of policy and governance reform from the list of activities being implemented in the Fisheries of Sierra Leone? (Categorise in adverse and positive and give % score)
2. Who are the winners and what are they wining?
3. Who are the losers what are they losing?
4. What are the possible environmental impacts of policy and governance reform from the list of activities being implemented in the Fisheries of Sierra Leone? (Categorise in adverse and positive and give % score)
5. Who are the winners and what are they wining?
6. Who are the losers what are they losing?
7. What are the mitigating strategies would you employ to address the adverse socio-economic impacts?
8. What are the mitigating strategies would you employ to address the adverse environmental impacts?
9. What strategies would you employ to improve on the positive socio-economic impacts?
10. What strategies would you employ to improve on the positive environmental impacts?

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INFLUENCE DES MACROPHYTES ET DE QUELQUES PARAMÈTRES PHYSICO-CHIMIQUES SUR LA DIVERSITÉ ICHTYOLOGIQUE DE LA PARTIE HAUTE DU FLEUVE NYONG AU CAMEROUN

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Résume

L'étude sur l'influence des macrophytes, et de quelques paramètres physico-chimiques sur la diversité ichtyologique de la partie haute du Fleuve Nyong effectuée de Mars à Novembre 2014, avait pour objectifs de voir l'état d'avancement du phénomène de pullulement des espèces invasives végétales (macrophytes). D'autre part dire si ces macrophytes étaient également repartis tout au long du cours amont du fleuve dans les sites d'Abong-mbang; Akonolinga et Endom. Enfin conclure si en fonction de la répartition de ces macrophytes, la distribution de l'ichtyofaune y dépendait. Cela a été possible grâce aux inventaires ichtyologiques (le suivi des débarquements des pêcheurs, et les pêches expérimentales), et des inventaires des macrophytes et des paramètres physico-chimiques sur ce fleuve. Le taux de couverture en macrophytes (Echinochloa stagnina, Nymphae amaculata etc.) du fleuve Nyong tel que observé dans cette étude a été : (Abong-Mbang 40% ; Akonolinga 38% ; Endom 25%), le site d'Endom s'est avéré le moins couvert en macrophytes, et celui d'Abong-Mbang le plus couvert. Sur un échantillon de 3689 poissons inventoriés l'on a dénombré une richesse taxonomique de 16 espèces reparties en 10 familles allant des Alestidea au Cichlidea en passant par les Claridea et autres. Le calcule de l'Indice de shannon-weaver a donné pour le site d'Endom (3,48 bits/individus) plus diversifié, tandis que le site d'Abong-Mbang (2,24 bits/individus) moins diversifié. Ensuite en corrélant les paramètres physico-chimiques, les macrophytes et l'ictyofaune du fleuve, l'on a obtenu: pour la corrélation linéaire entre la turbidité et la diversité ichtyologique r= 0,64; La corrélation entre l'oxygène dissous et la diversité ichtyologique a donné r =0,99; En fin La corrélation linéaire entre les macrophytes et la diversité ichtyologique a donné une valeur de r = -0,94. Notre étude a révélé une influence significative des macrophytes sur la diversité ichtyologique du fleuve Nyong.

Mots clés : Fleuve Nyong, Macrophytes, Ichtyofaune, influence, Corrélation.

INFLUENCE OF MACROPHYTES AND SOME PHYSICO-CHEMICAL PARAMETERS ON THE ICHTHYOLOGICAL DIVERSITY OF THE TOP OF THE NYONG RIVER, CAMEROON

Abtract

The study on the influence of macrophytes, and some physicochemical parameters on the ichthyological diversity of the top of the Nyong River was conducted from March to November 2015. The study aimed to seethe progress of the phenomenon of swarm plant invasive species (macrophytes). Also say if these macrophytes were also distributed throughout the course of the river upstream in sites: Abong-mbang; Akonolinga and Endom. A conclusion can be made that distribution of fish fauna dependent on the distribution of macrophytes. This was possible thanks to the fish surveys by monitoring fishing landings, experimental fishing, and inventories of macrophytes and physicochemical parameters by sampling on the river. The coverage rate in macrophytes (Echinochloa stagnina, Nymphae amaculata etc..) Nyong River as observed in this study was: (Abong-Mbang 40%; 38% Akonolinga; Endom 25%), the Endom s website 'was the least covered by macrophytes, and that of Abong-Mbang most covered (40%). In a sample of 3689 fish inventoried the taxonomic richness there were 16 species divided into 10 families ranging from

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the Alestidea Cichlidea through the Claridea and others. The calculation of the Index Shannon-Weaver returned to the site of Endom (3.48 bits / individual) more diversified, while the site of Abong-Mbang (2.24 bits/individual) less diversified. Then correlating the physicochemical parameters, macrophytes and ictyofaune the river, we obtained for the linear correlation between turbidity and fish diversity r = 0.64; The correlation between the dissolved oxygen and ichthyological diversity gave r = 0.99; In the end the linear correlation between macrophyte diversity and ichtyologique gave a value of r = -0,94. Our study revealed an influence of macrophyte in dichtyological diversity of Nyong River.

Keywords: River Nyong, Macrophytes, Fish fauna, influence, Correlation

Contexte et justificatif de l'étude

La biodiversité d'eau douce contient 40% des ressources ichtyologiques mondiales (Harvey, 2001), ce chiffre expriment l'importance de la biodiversité ichtyologique des eaux douces mondiales. Le Cameroun, dont les eaux océaniques s'avèrent pauvres en produits halieutiques, tente à y remédier par l'exploitation de ses multiples cours d'eau. En effet le pays est parcouru par plus d'une vingtaine de cours d'eau avec des richesses en espèces halieutiques considérables et d'une extrême importance, dont le fleuve Nyong. Ce cours d'eau a un potentiel halieutique remarquable, par le fait qu'il possède l'une des ichtyofaunes les plus originales de la basse guinée (Teguels et Brummet,, 2007), grâce aux activités de pêches dans ce fleuve la production en poissons était de 2500 tonnes /an (FAO, 2007), contribuant ainsi à l'alimentation, la réduction du chômage, et le développement des communautés de pêcheurs locaux. Enfin la partie haute du fleuve Nyong a connu des introductions réussies de certaines espèces ichtyologiques comme *Heterotis niloticus* (Vivien, 1977). Or Malgré l'importance de la biodiversité des eaux douces, 84% des espèces figurant dans la liste rouge des espèces menacées d'extinction sont les écosystèmes d'eau douce (Harvey, 2001). Au Cameroun cette menace sur la biodiversité ichtyologique des eaux douces se fait aussi ressentir, comme le révèle les études d'Ulrich en 2006 en ce qui concerne le fleuve Nyong ce qui peut conduire à sa perte.

La diversité ichtyologique du fleuve Nyong participe au développement socio-économique des communautés locales (lutte contre la pauvreté, le chômage, et apport au PIB national), sert à l'alimentation des populations locales (plus d'un million de personne y dépendent directement) comme source en protéines et à la collecte de la semence pour des besoins aquacoles. Cependant ce fleuve subit des menaces qui, entre autres, sont : la dégradation et la déforestation de ses berges, la pollution anthropique de l'eau, et l'irrégularité des pluies qui, depuis des années, a fait baisser le débit en eau de ce fleuve. Tous ceci pouvant conduire à la perte de l'ichtyofaune de cet écosystème et avoir des conséquences majeurs sur la vie des communautés locales. Face à cette situation il sera important de mener des études sur la qualité du milieu et son influence sur les espèces qui y vivent pour sauvegarder la diversité ichtyologique. Il ya eu certes des études qui ont été menées sur la diversité ichtyologique du Nyong (Ulrich, 2006), et sur les activités socio-économiques de la pêche dans ce fleuve (Mbida, 2012), mais aucune, à notre connaissance, n'a mis en relation la diversité ichtyologique de ce fleuve avec son écologie. Il est donc important de mettre en évidence l'influence de la qualité du milieu du fleuve Nyong sur sa diversité ichtyologique. C'est dans ce sens que l'influence des macrophytes et de quelques paramètres physico-chimiques sur la diversité ichtyologique a été observée sur le cours amont du fleuve Nyong, ceci dans le but de contribuer à la lutte contre la dégradation de l'ichtyofaune de ce fleuve.

Matériels et méthodes

Cette étude a été réalisée dans la partie amont du fleuve Nyong, trois sites d'études : S1 (Abong-Mbang), S2 (Akonolinga), et S3 (Endom) ont été sélectionnés en fonction de l'intensité de couverture des macrophytes sur le lit du fleuve, l'accessibilité

et la répartition des débarcadères.A l`intérieur de chaque site une station a été choisie pour la pêche expérimentale, l'échantillonnage des macrophytes, et des paramètres physico-chimiques de l'eau. Ainsi on avait la station 1 (Sokamalam) à Abong-Mbang, la station 2 (Ndibi) à Akonolinga et la station 3 (Bikomam) à Endom. Le choix de ces stations a été fait selon la couverture du lit en macrophytes, l'intensification des activités de pêche et le degré d`anthropisation du fleuve. Le GPS de marque Garmin a permis de faire une bonne circonscription de notre zone d'étude, avec une carte détaillée des sites et stations d'études (figure1).

Grace au suivi des débarquements et des prises effectuées lors des pêches expérimentales, les données ichtyologiques ont été collectées. En effet pour le suivi des débarquements il était questions pour nous d`aller dans chaque débarcadère de nos trois sites très tôt le matin et tard dans la soirée suivant une fréquence de 6 jours / semaine, pour inventorier et identifier les poissons avant l'arrivée des acheteurs. Les pêches expérimentales, dans nos trois sites, ont été faites ainsi qu'il suit : trois campagnes de pêche expérimentale par site ont été réalisées durant la période d'étude à raison d'une campagne (6 jours pour la semaine choisie) de pêche par mois à bord des pirogues locales et avec l'aide des pêcheurs locaux. Techniquement, chaque matin et soir des 6 premiers jours de la semaine on se rendait dans nos différentes stations, on posait des nasses, on jetait des filets (2, 3, 4, 5, et 6 doigts) et des lignes de pêche sur différents faciès d'écoulement (zone pélagique, demersales, benthique, rivage, etc.) des eaux intérieures du fleuve. Les mêmes techniques et méthodes de pêche que celles utilisées par les pêcheurs locaux ont donc été prises en compte et considérées.

Les espèces récoltées lors du suivi des débarquements des pêcheurs et des pêches expérimentales ont été identifiées sur la base de leurs traits morphologiques majeurs présence ou non des écailles, formes et positions des nageoires, taches particulières sur le corps. Les noms locaux ont été obtenus avec l'aide des pêcheurs, des revendeurs, et de nos guides locaux. Tout cela s'appuyait sur les clés d'identifications du CLOFFA (Teguels et Gueggan, 2007), on procédait ainsi à une détermination et 'identification première des espèces sur le terrain. Après des prises photographiques pour illustrations,

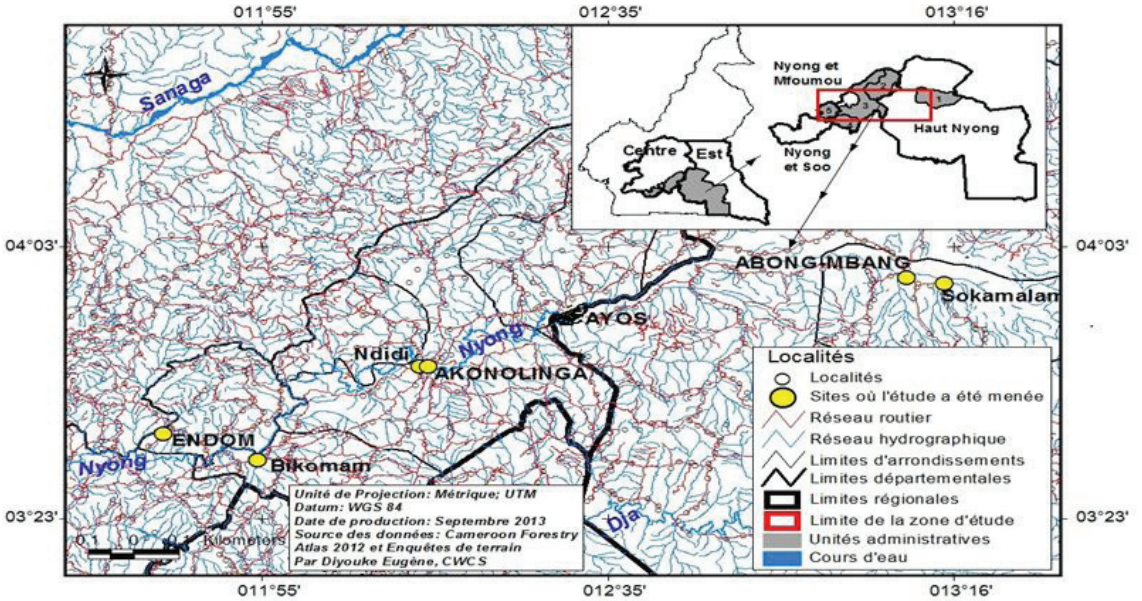

Figure 1 : carte de la zone, des sites, et des stations d'étude (source CWCS, 2013 adaptée par l'auteur)

quelques espèces étaient introduites dans des boites transparentes contenant du formol et étiquetées avant de les apporter au Laboratoire d'Aquaculture et d'Ichtyologie de l'Institut des Sciences Halieutique de l'Université de Douala pour l'identification approfondie.

L'inventaire des macrophytes a été réalisé par la méthode des transects (Lauret et, Jocelyne 2011). On plaçait dans le sens parallèle à l'écoulement de l'eau au niveau de chaque station, un transect de 100 m de long et 1m de large délimité sur les berges du fleuve grâce à des jalons et des cordes. Ensuite, suivant un sens perpendiculaire à l'écoulement de l'eau, un deuxième transect de 100 m de long et 1m de large était placé et délimité sur le lit mineur du fleuve. Le long de chaque transect, des carrés en bois de 1m×1m ont été délimités suivant un pas régulier de 1m. Dans chaque carré, une fraction des tiges et feuilles des macrophytes présentes a été prélevées, puis placée dans des sacs en plastique codifiés. Toutes les feuilles obtenues par tige et par espèce ont été décomptées, les formes ont été notées et rapprochées à des figures géométriques standards pour le calcul du taux de couverture foliaire. Les mensurations de chacune des feuilles ont été prises au cm près grâce à une règle graduée. Pour chaque spécimen de macrophyte recensé, 2 à 3 échantillons de feuilles ont été prélevés, imbibés d'une solution d'alcool à 90°C et conservés dans des papiers journaux codifiés, puis conduits à l'Institut National de l'Herbier du Cameroun pour identification et détermination des espèces, par des botanistes et à l'aide de clés d'identifications des adventices d'Afrique (Okezie et Agyakwa, 1989).

Au cours de l'échantillonnage des paramètres physico-chimique, cinq paramètres ont été mesurés (température, turbidité, oxygène dissous, PH, conductivité,). Quatre de ces cinq paramètres ont été mesurés in situ (température, oxygène dissous, PH, conductivité). Seule la turbidité a été collectée et mesurée en laboratoire. L'échantillonnage de l'eau a été effectué dans chaque station, suivant une fréquence mensuelle durant trois mois (juin, juillet, août 2014). Les échantillons d'eau destinés à l'analyse de quelques paramètres physico-chimiques ont été prélevés dans des flacons en polyéthylène de 500 et 1000 ml à double bouchage et à contre-courant, en prenant soin de ne pas faire de bulles. Ces échantillons ont été conservés dans une enceinte réfrigérée et conduit au laboratoire.

La mesure de la température a été effectuée in-situ, à l'aide d'un thermomètre à colonne de mercure gradué au 1/10°C. Les résultats sont exprimés en degré Celsius (°C).

Le pH a été mesuré in-situ grâce à un pH-mètre digital modèle SCHÖTT GERÄTE CG 818. Les résultats sont exprimés en Unités Conventionnelles (U.C).

Les mesures de la conductivité ont été réalisées in-situ à l'aide d'un conductimètre HANNA série HI 8733. Les valeurs obtenues sont exprimées en micro siemens par centimètre (µS/cm).

Les teneurs en oxygène dissous ont été mesurées in-situ au moyen d'un oxymétrie de marque HACH. Les résultats sont exprimés mg /l.

La turbidité a été mesurée en laboratoire à l'aide d'un spectrophotomètre HACH DR/2000 à la longueur d'onde 450nm. Les valeurs obtenues sont exprimées en NTU (NephlometricTurbidity Unit).

Pour l'analyse statistique, on a utilisé dans le cadre de cette etude deux types d'analyse : une dite descriptive et l'autre dite inférentielle. Pour l'analyse descriptive le tableur Excel a été utilisé. Certains indices comme celui de recouvrement foliaire des macrophytes (%F) , et celui de Shanon et Weaver (H') (calculer du dégré de variété et de variabilité des écosystèmes) ont été determinés.

$H' = - (\sum^{n}_{i=1} Ni/N \log_{(2)} Ni/N)$ ou $Ni/N = Pi$□
$H' = - \sum Pi \log(2) Pi$. Avec $0<H'<8$

Ni: Nombre d'individu d'une espèce ; N: Nombre d'individu total ; log(2) : Logarithme en base 2 ; n : nombre d'espèces. Lorsque $H' \geq 4,5$ cela signifie que le milieu est suffisamment riche et on calcule l'équitabilité.

$$\% F = \sum ni \times Si$$

%F = pourcentage de couverture foliaire
ni = nombre de feuille moyen par carré de l'espèce i

Si : superficie moyenne occupé par une feuille moyenne de l'espèce i ; i : espèce

L'analyse inférentielle a été réalisée grâce au logiciel SPSS.12.0. Cette analyse a essentiellement porté sur la recherche des corrélations entre les paramètres physico-chimiques de l'eau du cours amont du fleuve Nyong et la diversité ichtyologique.

Selon Chen et Popovich (2002), le coefficient de corrélation de Spearman a été utilisé pour évaluer les différentes corrélations.

$$r\_s = 1 - \frac{6 \times \sum (y_{i1} - y_{i2})}{(n\text{^}3 - n)}$$

r_s:coefficient de corrélation de Spearman
Y_{i1} rang de Y1
y_{i2} rang de Y2

n: nombre de valeurs de yi

Le coefficient de corrélation R2 a été utilisé pour déterminer l'interaction entre quelques paramètres physico-chimiques de l'eau et la diversité ichtyologique.

$$R^2 = (r)^2$$

Lorsque $R2 \geq 0,5$, La corrélation du paramètre considéré est jugée significative sur la diversité ichtyologique.

Résultats

Caractéristiques de l'abondance spécifique, de variété et de la variabilité de la biodiersité ichtyologique du fleuve Nyong

Du calcul des abondances relatives, il ressort que l'inventaire ichtyologique réalisé sur un échantillon de 3689 poissons inventoriés on a une richesse taxonomique de 16 espèces reparties en 10 familles. La famille des Alestidea avec 3 espèces (Phenocogrammus major, Brycinus macrolepidotus, Brycinus kingsleyae) est la plus représentée, suivie de quatre autres familles (Moryridea, Bagridea, Cichlidea,et Claridea) représentées chacune par 2 espèces. Les cinq dernières familles quant à elles sont représentées chacune par une seule espèce, il s'agit de la famille des Arapamidea, Shilbeidea, Hepsetidea, Cyprinidea et des Channidea. L'analyse du graphe de la composition spécifique par site donne comme espèces les plus abondantes pour les trois sites:*Clarias gariepinus* suivie de *Parachanna Obscura*. Les résultats de l'inventaire ichtyologique sur le cours supérieur du fleuve Nyong sont marqués par une forte présence d'espèces introduites (*Parachanna obscura*, *Oreochromis niloticus*, et *Heterotis niloticus*) au détriment des espèces endémiques (*Oreochromis margaritacea* et *Shilbe nyongesis*) (figure 2).

Le calcul de l'Indice de Shannon-Weaver a donné pour le site d'Endom (3,48 bits/individus) plus diversifié, tandis que le site d'Abong-Mbang (2,24 bits/individus) moins diversifié (figure3). En outre le site d'Endom, a un nombre total de 15 espèces (Brycinuskingsleyae, Brycinus macrolepidotus, Chrisichthys longidorsalis, Cyprinuscarpio, *Clarias gariepinus*, Hemichromis elongatus, *Heterobranchus longifilis*, Heterotisniloticus, *Parachanna obscura*, Petrocephalus microphtalmus, Phenogrammus major Shilbe multitaeniatus) sur 16 espèces recensées au total dans toute la zone. Le site d'Akonolinga 9 espèces (*Heterotis niloticus*, Hepsetusodoe, *Clarias gariepinus*, Chrysichthys longidorsalis, *Oreochromis niloticus*, Bricynu smacrolepidotus, *Heterobranchus longifilis*, *Clarias gariepinus*). Enfin, le site d'Abong-mbang 6 espèces recensées (*Heterotis niloticus*, *Parachanna obscura*, Hepsetus odoe, *Clarias gariepinus*, *Oreochromis niloticus*).

Analyse des macrophytes

L'inventaire des macrophytes dans les trois sites d'étude, a conduit au recensement de 10 espèces de macrophytes (Echinochloa stagnina, Cyperus iri, Nymphae amaculata, Hydrolea glabra, Dissotis erecta, Ipomoea aquatic, Diplazium sammatii, Acroceras zizanioides, Pistia stratiotes, Celosia sp etc.) appartenant à 9 familles (Poaceae, Araceae, Cyperaceae,

Convolvullaceae, Athyriaceae, Araceae, Hydrophyllaceae, Melastomataceae). Le taux de couverture foliaire en macrophytes indique une importante présence des macrophytes dans les trois sites d'études (figure4). Le taux de couverture le plus élevé en macrophyte est observé dans les sites d'Abong-Mbang et Akonolinga (40%), le site d'Endom en est le moins couvert, à un taux de couverture en macrophyte le plus bas soit (25%).

Analyse des paramètres physico-chimiques

La température moyenne de l'eau dans la zone est de 22,8°C ± 1,6. Elle oscille entre 20 °C et 25 °C et s'élève dans les stations d'Abong-Mbang et d'Akonolinga, en juin puis baisse progressivement dans les stations d'Endom (Figure 5A).

Les valeurs de la turbidité oscillent entre 25 NTU et 55 NTU (Figure5B). Contrairement à la température, ce paramètre a des valeurs minimales dans les stations d'Abong-Mbang et d'Akonolinga en juin et maximales dans la station d'Endom en juillet. Les valeurs du pH ont très peu varié au cours de l'étude, oscillant entre 5,14 et 6,18 (Figure 5C). Pour une moyenne de 5,72 ± 0,15. Ces valeurs, à tendance générale acide, sont globalement minimales dans les stations d'Abong-Mbang et d'Akonolinga et maximales dans la station d'Endom.

Les valeurs de conductivité sont comprises entre 13 µS/cm et 28 µS/cm (Figure 5D), pour une moyenne de 22,19 µS/cm ± 1,1. Le taux de saturation en O2 dissous oscille entre 5,2 % et 5,4 % (Figure 5E) pour une moyenne de 5,5 ± 0,2%

Corrélation entre les macrophytes et les paramètres physico-chimiques par rapport à la diversité ichtyologique en amont du fleuve Nyong.

L'analyse des corrélations linéaires entre 5 des paramètres physico- chimiques mesurés et la diversité ichtyologique (figure 6) donne, pour la corrélation linéaire entre la température et la diversité ichtyologique, une valeur significative où r = -0,55. Cette valeur négative de r montre une évolution en sens inverse de ce paramètre et la diversité ichtyologique. Plus la température augmente plus la diversité ichtyologique diminue par site. Ensuite vient la corrélation linéaire entre la turbidité et la diversité ichtyologique ou r= 0,64. On constate au fait une évolution de la turbidité dans le même sens de l'augmentation de la diversité. En effet, la diversité croît avec la turbidité. La corrélation linéaire entre l'oxygène dissous et la diversité ichtyologique donne r =0,99. Cette valeur montre la forte corrélation linéaire entre ce paramètre et la diversité ichtyologique. En effet l'oxygène dissous par site varie dans le même sens de la diversité ichtyologique, plus l'oxygène dissous croit plus la diversité ichtyologique par site augmente. Le site d'Endom illustre bien cette forte liaison. La liaison linéaire entre le pH et la diversité ichtyologique donne une valeur de r = 0,72, indiquant une forte corrélation entre le paramètre pH et la diversité ichtyologique. En effet, plus le pH tend vers la neutralité (7U.C),

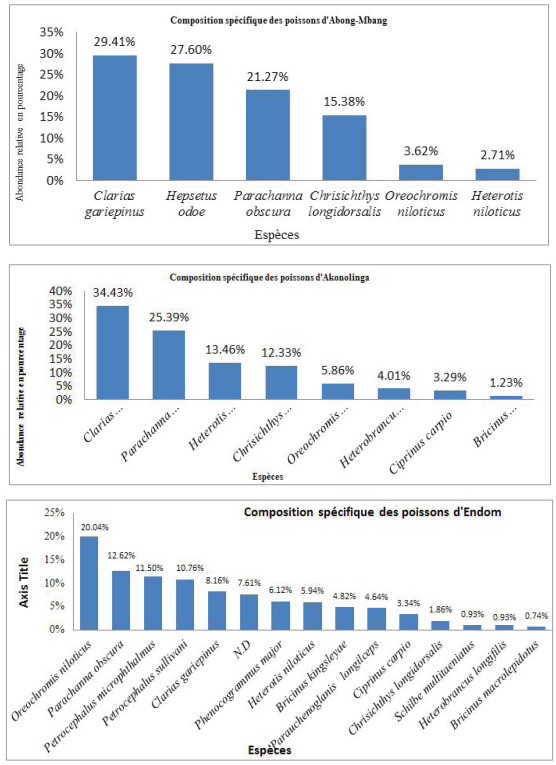

Figure 2: Graphes de la composition spécifique et abondance relative des poissons des trosites (Abong-Mbang(A), Akonolinga(B), Endom(C) dans le cours amont du fleuve (Juin-Aout 2014)

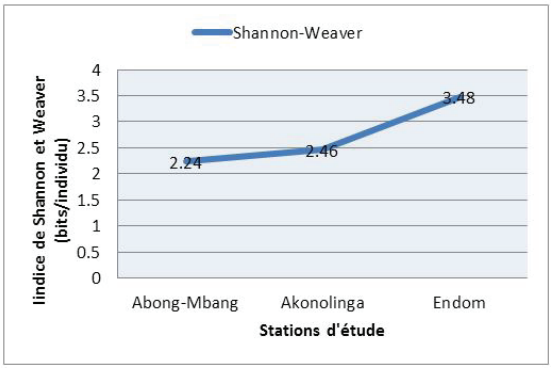

Figure3 : Graphe de la variété et de la variabilité spécifique (indice de shannon-weaver) des trois sites (Abong- Mbang,Akonolinga,Endom) dans le cours amont du fleuve Nyong

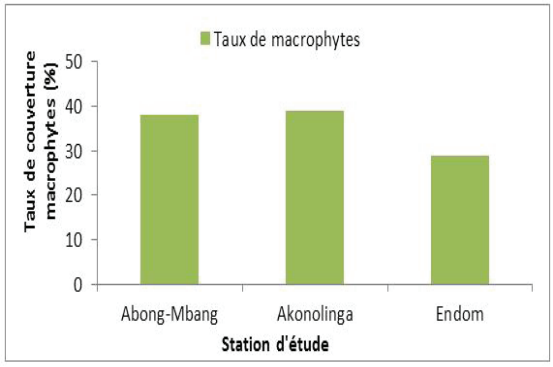

Figure 4: Taux de couverture en macrophytes par stations d'étude.

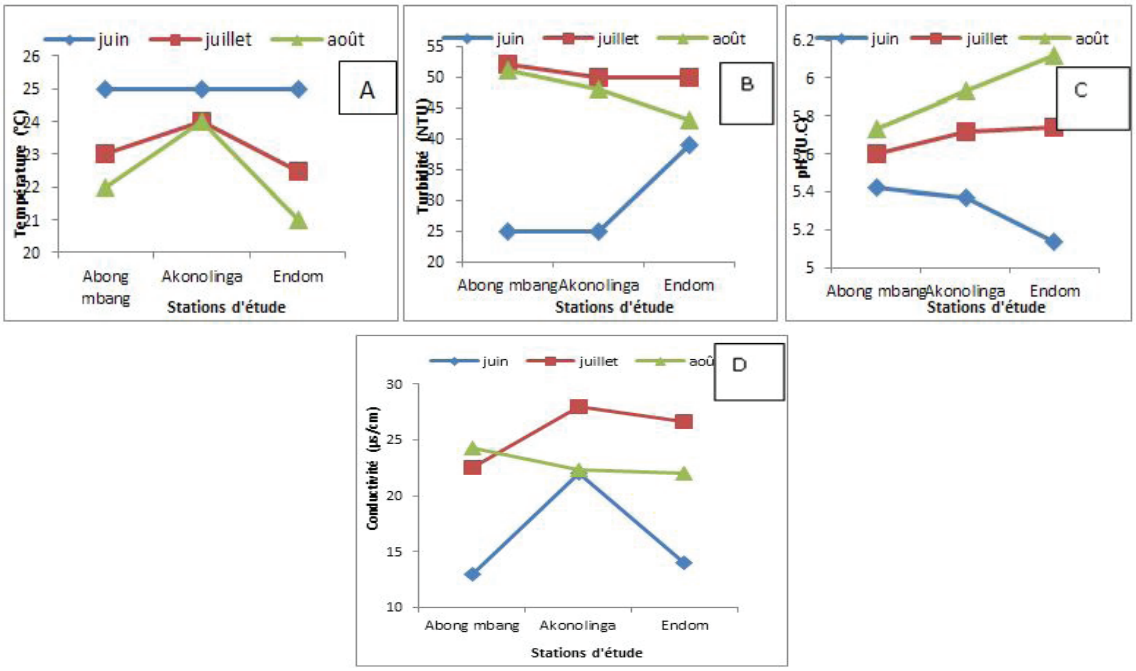

Figure 5 : Variation spatio-temporelle de la température(A), et de la turbidité(B), pH(C), conductivité(D), oxygène dissous(E) de l'eau du cours amont du fleuve Nyong

plus la diversité augmente par site .Ce pendant la corrélation linéaire entre la conductivité (figure 6) avec la valeur de r = 0,02 ne signifient pas que ce paramètre n'influence pas la diversité ichtyologique mais plutôt que cette influence, comparativement à l'influence des autres paramètres, est très faible et négligeable. La corrélation linéaire entre les macrophytes et la diversité ichtyologique où r = -0,94 (figure 6), est une valeur qui indique une corrélation significative et négative entre ce paramètre et la diversité ichtyologique. En effet, plus le site a un taux élevé en macrophyte moins sa diversité ichtyologique est importante, le site d'Abong-Mbang et d'Akonolinga, aux diversités ichtyologique les plus basses (2.24 et 2.46), illustrent bien cela par leur indice de Shanon comparativement faible par rapport à celui d'Endom (3.48)

Discussion

Ces résultats sur l'abondance spécifique dans le cours amont du fleuve Nyong montrant une dominance des espèces introduites (*Parachanna obscura*, *Oreochromis niloticus*, et *Heterotis niloticus*) et une rareté des espèces endémiques (*Oreochromis margaritacea* et *Shilbe nyongesis*), semblent aller dans le même sens que ceux d'Ulrich (2006) qui, dans ses études portant sur l'évaluation de la biodiversité ichtyologique de la partie amont du fleuve Nyong, a montré qu'il y avait une disparition probable des espèces endémiques de ce fleuve. En outre Vivien (1977) dans son étude sur les introductions postcoloniales de certaines espèces dans le fleuve Nyong a indiqué que *parachanna obscura* et *Heterotis niloticus* avaient connu des introductions à succès dans ce fleuve rejoignant ainsi nos résultats qui révèlent la présence abondante de ces espèces dans cette partie du fleuve Nyong.

Les résultats indiquant la faible variabilité et la variété (2.24 et 2.46) de la biodiversité ichtyologique (figure3) dans certains sites seraient peut être dues aux différences écologiques entre sites ou encore au degré d'anthropisation du cours amont du fleuve dans ces différents sites d'études. En effet, Harvey (2001) dans ses études sur les conditions favorisant la stabilisation, l'abondance et la diversification des espèces ichtyologiques a démontré que dans un même fleuve il était possible de trouver des espèces différentes selon les sites d'étude. Notre étude corrobore ainsi celle de Harvey. Toutefois, on pourrait aussi envisager l'effet des pressions exercées sur la ressource qui peuvent faire varier cette dernière selon les sites.

Dans cette étude les cinq paramètres physico-chimique analysés montrent une variation significative de certains de ces paramètres (turbidité et température) par site, tandis que d'autres ne varient pas de façon significative (pH). Ces différences observées sur la variation des concentrations de certains paramètres par site sont certainement la conséquence des apports en nutriment d'origines diverses et pourquoi pas, celle de la pollution qui sévit dans certains de ces sites. Lauret (2007) dans une étude similaire sur les lagunes du Laguedoc a trouvé des tendances différentes dans l'évolution des paramètres physico-chimiques suivant ses sites d'étude. Cette différence est due peut être au fait que Lauret a travaillé dans les lagunes et nous dans un cours d'eau. Par ailleurs la présence de plusieurs familles de macrophytes et d'une dizaine d'espèce de ceux-ci en abondance dans le fleuve indique déjà sans doute l'envahissement du fleuve par cette flore invasive et nuisible. En outre la présence d'un taux abondant de cette flore, qui croit de l'amont (Abong-Mbant) vers l'aval (Endom), indiquerait déjà la source et le sens d'envahissement du fleuve par ces macrophytes qui, à l'heure actuelle, sont présents dans tout le cours amont du fleuve Nyong même si c'est à des échelles différentes par sites. En effet selon FOMETE (1998), sur son étude qui portait sur l'évaluation forestière du bassin du Nyong, l'auteur a annoncé une déforestation et dégradation des berges du fleuve Nyong avec comme conséquence la prolifération de plusieurs espèces de macrophytes dans le lit du cours d'eau. Les résultats de notre étude illustrant une présence forte de plusieurs espèces de macrophytes dans ce cours d'eau s'ajoutent ainsi à ceux trouvés par FOMETE.

Les résultats sur l'analyse des corrélations entre les paramètres physico-chimiques, les macrophytes et la diversité ichtyologique nous montrent, pour ce qui est du paramètre turbidité, que ce dernier évolue dans le même sens de la diversité et influencerai positivement. Cette influence positive de la turbidité sur la ressource ichtyologique est la même que celle de l'oxygène dissous sur la diversité ichtyologique du cours amont du Nyong (figure6), Villanueva en 2004 dans ses études sur les facteurs favorisant la productivité dans l'estuaire du Saloum et de la Gambie ayant montré que les paramètres tels que la turbidité, le taux d'oxygène dissous, le potentiel d'hydrogène peuvent influencer positivement la productivité de l'ichtyofaune de certains estuaires et cours d'eau. Les résultats de notre étude rapprochent ainsi ceux de Villanueva. La

Corrélations	température	turbidité	pH	conductivite	oxygene	macrophytes
Indice de shanon	-,637	,728	,637	-,140	,992	-,969

Figure 6 : Tableau des matrices des corrélations entre macrophytes, paramètres physico-chimiques de l'eau et diversité ichtyologique dans le cours amont du fleuve Nyong

corrélation linéaire entre les macrophytes et la diversité ichtyologique où r = -0,94 (figure 6), est une valeur qui indique une corrélation significative et négative entre ce paramètre et la diversité ichtyologique. En effet, plus le site a un taux élevé en macrophyte moins sa diversité ichtyologique est importante. Le site d'Abong-Mbang et d'Akonolinga aux diversités ichtyologique les plus basses illustrent bien cela.

Notre étude rejoint celles d'avec celles d'Ulrich (2006) qui, a signalé une probable dégradation de la ressource ichtyologique du fleuve et celle de Fometé (1998), qui a signalé déjà une prolifération des espèces invasives de macrophytes sur le cours amont du Nyong, pour montrer que la richesse ichtyologique par site serait fonction du taux de macrophytes. En effet ces macrophytes peuvent dans certains cas, augmenter les compétitions au niveau de l'acquisition des ressources dans le milieu aquatique et influencer négativement la biodiversité. Les sites d'Abong-Mbang et d'Akonolinga le confirment (figure6).

Bref public de l'étude au benefice des pouvoirs publics

L'étude sur l'influence des macrophytes et de quelques paramètres physico-chimiques sur la diversité ichtyologique de la partie haute du fleuve Nyong a révélé que le fleuve Nyong était encli n à la disparition et à la perte de sa prestigieuse diversité ichtyologique. Tout ceci étant la cause de la déforestation, de la dégradation et de la pollution dont est victime ce système depuis plus de deux décennies. C'est pourquoi il important de promouvoir une gestion durable et écosystmique des zones humides du Nyong pour les sauver. Concrètement il pourra être question pour les autorités publiques et politiques d'encourager tous projets de reboisement des berges du Nyong, d'éducation environnementale, et de la promotion d'autres activités génératrices de revenu (agriculture, commerce, et élevage) autres que la pêche. Enfin de se dire qu'il est grand temps d'agir pour sauver le Nyong.

Conclusion

L'étude qui a porté sur l'analyse de l'influence des macrophytes et de quelques paramètres physico-chimique sur la diversité ichtyologique de la partie amont du fleuve Nyong a ressortit que l'Indice de Shannon-Weaver pour le site d'Endom (3,48 bits/individus) est plus diversifié, tandis que le site d'Abong-Mbang (2,24 bits/individus) l'est moins diversifié.

Sur 16 espèces de poissons recensées, l'étude signale en outre une prédominance des espèces introduites (*Parachanna obscura*, *Oreochromis niloticus*, et *Heterotis niloticus*) et une raréfaction des espèces endémiques. L'analyse des paramètres physico-chimique et des macrophytes donne des taux de ces paramètres différents dans les trois sites. En effet, l'envahissement important et accéléré en macrophytes dans les sites d'Abong-Mbang et d'Akonolinga serait du à la forte déforestation et dégradation qu'a subit et que continue à subir les berges de cette partie du fleuve. En établissant des corrélations entre quelques paramètres physico-chimiques, les macrophytes et la diversité ichtyologique en amont du fleuve on a constaté dans cette étude qu'il existe de fortes corrélations

linéaires significatives entre 5 des 6 paramètres analysés et la diversité ichtyologique en amont de ce fleuve. Par exemple la corrélation entre l'oxygène dissous, la turbidité, le pH et diversité ichtyologiques avec des valeurs de coefficient de corrélation r égale respectivement à 0,99 ; 0,72 et 0,64 qui indiquent que ces paramètres sont des facteurs limitant importants pour le développement des poissons car évoluant dans le même sens. Cependant les corrélations entre les macrophytes, et la température avec les valeurs de r égale respectivement à -0, 94; -0,55, indiqueraient que ces paramètres influencent négativement sur la biodiversité avec comme conséquence directe la dégradation de l'ichtyofaune et sa raréfaction. En somme le fleuve Nyong, qui se caractérise par le fait qu'il contient l'une des ichtyofaunes les plus originales de la Basse Guinée (Teguels et Brummet, 2007), est parmi les 200 écorégions les plus importantes du monde et l'un des 11 landscapes du programme de conservation des forêts du bassin du Congo (WWF, 2003). La deuxième zone inondée du Cameroun après le bassin du Lac Tchad, connait à l'heure actuelle de nombreux problèmes (déforestation ; pollution ; dégradation des berges ; exploitation abusive de la ressource ichtyologique ; rétrécissement et diminution de la profondeur du lit et des eaux).

Cette étude signale la forte dégradation et déforestation des berges de ce fleuve et les divers types de pollutions dont il est victime avec, comme conséquence directe, son envahissement par les macrophytes et la dégradation de la prestigieuse ichtyofaune, d'où l'impact direct sur la vie des communautés de pêcheurs, et autres utilisateurs locaux de la ressource faunique et floristique du Nyong. D'où les recommandations suivantes:

A la communauté scientifique:

- Réaliser des inventaires réguliers de la ressource ichtyologique du cours amont du fleuve Nyong pour en déterminer la diversité ichtyologique et les stocks exploitables pour une gestion durable.
- Analyser les interactions entre un nombre plus élevé de paramètres et la diversité ichtyologique en amont du fleuve Nyong, en associant des interactions synergiques des paramètres.
- Analyser les impacts des différentes pressions exercées sur la ressource le long du fleuve Nyong et voir son évolution dans l'espace et le temps.
- Mettre en place, le long du fleuve, des zones de surveillance écologique de l'évolution des macrophytes et de l'envahissement du fleuve par cette flore nuisible.

Aux organismes privés nationaux et internationaux:

- l'assistance technique et financière des projets de reboisement des berges du fleuve Nyong ;
- l'assistance technique et financière des projets de lutte contre l'envahissement du fleuve Nyong par les macrophytes ;
- la promotion de la pisciculture autour du fleuve Nyong pour les communautés de pêcheurs afin qu'ils ne soient plus trop dépendants de la ressource du fleuve ;
- Appuyer les populations locales dans la pratique d'autres activités génératrice de revenus (commerce, pisciculture, et agriculture) pour la lutte contre la vie chère, le chômage, la pauvreté et la faim.

Remerciements

L'aboutissement de ce modeste travail a été rendu possible grâce à l'apport de plusieurs personnes sans lesquelles ce travail n'aurait pu être accomplit. Que ces dernières trouvent ici l'expression de toute ma gratitude pour leur générosité. Avant toute chose permettez-moi de dire merci au Seigneur Tout Puissant qui durant toute cette étude nous a accordé santé, intelligence, courage ; sagesse et protection pour mener cette étude à son terme.

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LES AIRES MARINES AMÉNAGÉES PAR LES RÉCIFS ARTIFICIELS : OUTILS DE PROTECTION ET DE GESTION DES RESSOURCES DE LA PÊCHE ARTISANALE EN TUNISIE.

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Résumé

La région du Golfe de Gabès, représentant 33% des côtes tunisiennes, est l'une des régions les plus touchées par la pollution et par surpêche à travers les arts trainants. Ce Golfe, jouit de conditions maritimes très favorables pour le développement de l'activité de pêche. En effet, il dispose d'une large plate-forme continentale, sans présence de relief et ayant une pente très douce qui fait que l'isobathe de 200 m n'est atteinte qu'au-delà des 250 Km de la côte. Ces particularités, avec la présence d'herbiers vastes de phanérogames ont permis le développement abondant d'espèces de grande valeur commerciale (poissons, crustacés et céphalopodes). La pollution et la surpêche ont provoqué une diminution des stocks de nombreuses espèces et à d'autres part, fragilisé les biocénoses qui les abritent. Ainsi un conflit direct s'est installé entre la pêche artisanale et les chalutiers qui ne respectent plus la réglementation et trainent leurs chaluts dans la bande côtière ayant des profondeurs inférieurs à 20 m, zone réservée à la pêche artisanale. Devant l'aggravation de la pêche illicite, les pêcheurs artisans se sont organisés pour immerger des blocs de béton pour contrer la pêche à la traine dans les faibles profondeurs. Ces expériences ce sont consolidé par un projet de coopération avec le Japon et aussi par la mobilisation des fonds pour un vrai aménagement récifal au Golfe de Gabés. Ainsi depuis 2007, de multitudes zones dans le Golfe de Gabés ont été aménagées à vocation halieutique sans aucune gestion n'est réellement mise en place. Il est recommandé de mettre en place, d'une manière participative, des protocoles de gestion, se résument essentiellement à interdire les activités autres que la pêche artisanale sur ces zones aménagées.

Mots clés : récifs artificiels, outils de gestion, aménagement récifal, pêche, Gabés, immersion

MARINE AREAS CREATED BY ARTIFICIAL REEFS: TOOLS FOR SMALL-SCALE FISHERY RESOURCE PROTECTION AND MANAGEMENT IN TUNISIA.

Abstract

The region of the Gulf of Gabes, which represents 33% of the Tunisian coast, is one of the areas that are mostly affected by pollution and overfishing through trawler fishing. The Gulf enjoys very favorable maritime conditions for fishing industry development. Indeed, it has a large continental shelf, which is flat, with a very gentle slope, meaning that the isobath of 200 m is reached only beyond 250 km off the coast. These features, combined with the presence of vast phanerogam seagrass beds, allowed the abundant development of high value commercial species (fishes, crustaceans and cephalopods). Pollution and overfishing have resulted in a decrease in many species on the one hand, and undermined the biocenosis that shelters them on the other hand. Thus a direct conflict has arisen between small-scale fishing and trawlers that no longer comply with the regulations and drag their trawls in the coastal strip with depths of less than 20 m, an area reserved for small-scale fishing. Faced with worsening illegal fishing, small-scale fishermen have organized themselves to immerse concrete blocks to counter trolling in the shallows. These experiences were consolidated by a project of cooperation with Japan and also by the mobilization of funds for a proper reef development in the Gulf of Gabes. Thus, since 2007, multitudes of areas in the Gulf of Gabes have been developed for fishing purposes, without any management actually put in place.

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It is recommended to put in place, in a participatory manner, management protocols that would essentially prohibit activities other than small-scale fishing on these developed areas.

Keywords: Artificial reefs, Management Tools, Reef Development, Fishing, Gabés,

Introduction

La pêche en Tunisie est exclusivement méditerranéenne, par une façade sur cette mer sur environ 1300 km avec une importante zone néritique concentrant les 2/3 environ des ressources vivantes, s'étendant sur une superficie d'environ de 77000 km².

L'étendu du plateau continental varie du nord au sud. Très étroit et rocheux au nord, le plateau continental gagne en superficie à l'est et surtout au sud dans le golfe de Gabes (de Ras Kapoudia au 35éme parallèle jusqu'à la frontière tuniso-libyenne).

Le golfe de Gabès a une position stratégique dans le secteur de la pêche en Tunisie. En effet in contribue à 65 % de la production halieutique nationale ; et concentre presque les 2/3 de la flottille de pêche tunisienne, et le 62% de la population maritime.

La très faible déclivité de son plateau continental et l'absence de relief sous-marin (sauf quelques bancs immergés), avec une richesse faunistique et floristique de ses fonds sont des critères qui ont développés une pêche artisanale utilisant des engins ancestraux sélectifs et non destructifs des habitats.

Le golfe de Gabès, comme toute les zones de la pêche artisanale exerçant sur la bande littorale (golfes, baies, lagunes…) abrite des habitats clés pour le cycle biologique de nombreuses espèces marines. Or elles sont soumises à une forte pression anthropique à travers de nombreux usages qui ont profondément évolué ces dernières décennies (Bretagnolle *et al.,* 2000 ; Rogers, 2001) et les écosystèmes côtiers s'en trouvent profondément affectés. La plupart des ressources marines sont maintenant surexploitées ou en passe de l'être (Lauck *et al.,* 1998 ; Castilla, 2000) et la pérennité des pêcheries n'est pas assurée (Murray *et al.,* 1999 ; Pauly *et al.,* 2002).

Cette région est victime des importantes pressions anthropique rendant ses écosystèmes fragilisés et moins productifs. En effet elle a reçu pendant plus que 30 ans d'importante quantité de phosphogypse déversés dans la partie nord de la mer du Golfe de Gabés. Ce polluant, provenant du grand complexe chimique implanté sur le littoral de Ghannouch, laissent des séquelles parfois sérieuses sur la faune et la flore. Ainsi les rendements de la pêche des navires ont énormément régressé. Ce qui a obligé les chalutiers à exploiter des zones maritimes réservées à la pêche artisanale.

Devant cette situation, les pêcheurs artisans ont réagi et ont souhaité que leurs zones de pêche soient aménagées et réservées à certaines catégories de pêcheurs, travaillant avec les engins passifs et sélectifs, afin de redonner aux pêcheurs artisans quelque espoir dans l'avenir de leur activité.

Il apparaît donc nécessaire de mettre en œuvre des outils de gestion de la bande littorale et de préciser les modalités d'usage de cet espace fragile, afin de minimiser les conflits entre activités et d'assurer la pérennité de celles qui s'appuient sur les ressources naturelles.

Parmi ces outils, les Récifs Artificiels (RA) ont été utilisés pour gérer la disponibilité et l'accessibilité aux ressources marines tout en protégeant et restaurant les communautés.

Après des actions de sensibilisation de l'intérêt des RA, maintenant tous les acteurs de la pêche se lancent dans la création de nouvelles aires marines aménagées en récifs artificiels pour être approprié par les pêcheurs artisans.

Les Critères pris en considération pour les aménagements récifal

Définition, fonctions et typologie des RA

Les directives pour l'implantation de récifs artificiels (Convention et Protocole de Londres / PNUE, 2009) ont adopté la définition

suivante : «Un récif artificiel est une structure immergée, construite ou placée délibérément sur le fond marin dans le but d'imiter certaines fonctions d'un récif naturel destinées à protéger, régénérer, concentrer et/ou valoriser les peuplements de ressources marines vivantes. Le terme n'englobe pas les structures immergées, délibérément placées pour remplir des fonctions qui ne sont pas liées à celles d'un récif naturel, comme par exemple les brise-lames, les corps-morts, les câbles, les pipelines, les appareils de recherche marine ou les plates-formes, même si elles imitent accessoirement certaines fonctions d'un récif naturel.»

On distingue six fonctions de RA : nutrition, protection, repos, aire de ponte et nurserie, création et protection de zones de pêche

- *Nutrition:* L'immersion d'un substrat dur en milieu aquatique s'accompagne de sa colonisation par une grande quantité d'organismes benthiques sessiles végétaux et animaux qui vont constituer la production primaire du récif. Ainsi une chaine alimentaire s'installe aux abords d'un RA.
- *Lieu d'abri:* Pour fuir les prédateurs les espèces proies et juvéniles de poisson se protègent en se cachant dans les nombreuses anfractuosités que présente un RA. Il a été mis en évidence que leur taux de survie est meilleur que dans des zones sans récifs artificiels.
- *Aire de ponte et nurseries:* Les récifs artificiels sont le lieu de ponte de nombreuses espèces marines, et l'on peut considérer qu'il remplit la fonction de lieu de frai et nurseries.
- *Repos:* Il a été observé au Japon que la croissance des poissons est meilleure dans le bassin avec des récifs artificiels. L'étude du comportement des poissons montre que les récifs sont utilisés comme lieux de repos en se groupant devant la face à faible courant.
- *Création de zones de pêche:* Les récifs artificiels peuvent augmenter la productivité en biomasse d'un site pauvre, et le rendre propice à la pêche, on peut alors parler de création de zones de pêche.
- *Protection de zones de pêche existantes:* Les récifs artificiels peuvent jouer le rôle de protection en faisant obstacle aux chaluts et dissuader les armateurs de pratiquer la pêche dans les zones interdites.

Les récifs artificiels sont constitués de matériaux inertes qui n'engendrent aucune pollution par lessivage, désagrégation physique ou chimique par les intempéries et/ou activité biologique (Convention et Protocole de Londres / PNUE, 2009).

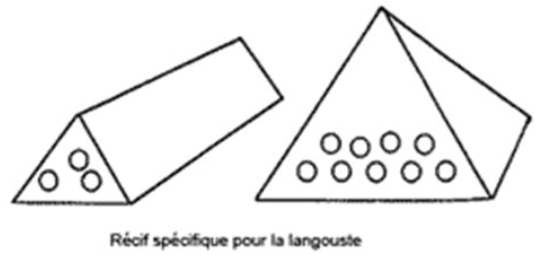


Fig2. Récifs artificiels de production

Le choix des formes et des matériaux employés pour la construction des récifs artificiels permettent de distinguer 4 types de RA :

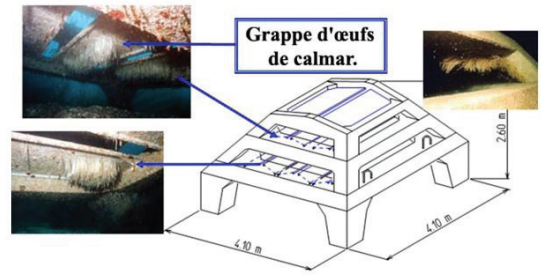
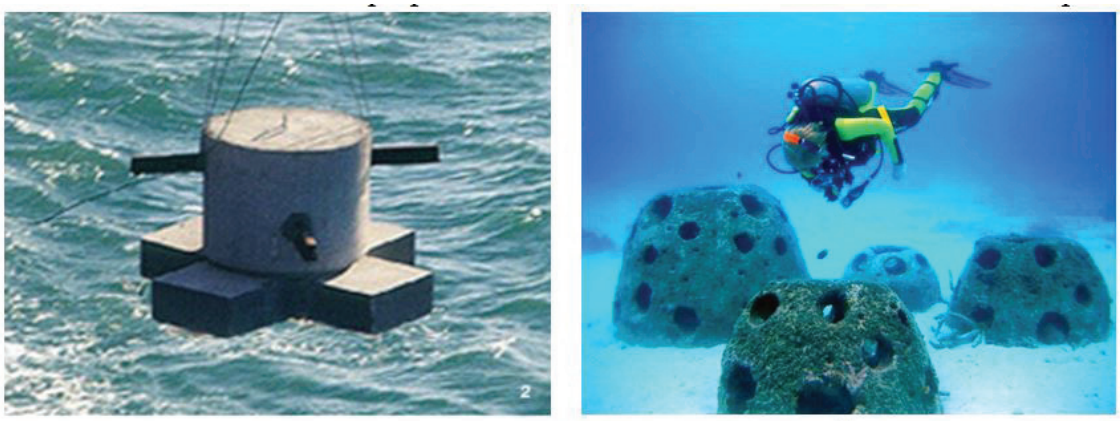


Fig 3. Des grappes d'œufs de Calamar dans un récif artificiel (Source www.okabe-marine.com/)

- *Les récifs de production:* L'usage de ce type de récif vise un accroissement des ressources en vue d'une exploitation par la pêche, en créant un nouvel habitat, de type substrat dur.
- *Les récifs de ponte et nurseries:* on peut construire des RA ayant des cavités de dimension et de géométrie adaptées pour la ponte d'une espèce bien déterminée.



a b

Fig 4. Récifs de protection «sea-rock» Source : Catalunya arrecife (a) Les sites Reefball Source : internet (b)

- *Les récifs de protection:* Ce type de récif est utilisé en tant qu'obstacles physiques au chalutage illégal, permet la gestion des usages et des conflits entre pêcheurs, ainsi que le partage de l'espace de pêche et des ressources vivantes.
- *Les récifs paysagers:* Ce sont des récifs mis en œuvre à des fins de loisirs ou aux activités récréatives. Ce qui permettrait de délester certains sites naturels trop fréquentés.

Objectifs d'un aménagement récifal

Les objectifs de l'immersion de RA sont le plus souvent liés à la protection des habitats (Polovina, 1991; Guillén *et al.,* 1994 ; Pickering *et al.,* 1998 ; Ramos-Esplà *et al.,* 2000), au développement des pêcheries (Nakamura, 1985; Samples & Sproul, 1985 ; Polovina, 1991; Bohnsack *et al.,* 1994), à la profitabilité économique (Whitmarsh & Pickering, 1995, 1997), à la conservation de la biodiversité ou la connaissance écologique, en particulier des processus de colonisation d'un habitat vierge (Bohnsack & Sutherland, 1985; Ardizzone *et al.,* 1996b; Barnabé *et al.,* 2000).

Les objectifs retenus pour les immersions réalisées dans le golfe de Gabès sont :

- réduction des impacts néfastes sur les habitats existants à travers l'exclusion des chaluts et restauration des habitats dégradés
- réduction de conflits entre usagers, en particulier entre la pêche artisanale et celle pratiquant la pêche aux arts trainants,
- augmentation de la diversité faunistique, en fournissant de nouveaux habitats,
- augmentation des profits économiques indirects, par les activités de pêche ou de plaisance.
- Promouvoir la pêche artisanale responsable.

Ces objectifs ont permis d'établir un plan d'action pour l'aménagement de plusieurs zones de la pêche artisanale situées dans le golfe de Gabés.

Cadre réglementaire d'immersion des RA

Bien que la Convention des Nations Unies sur le droit de la mer établisse un cadre global pour la réglementation des activités en mer, il n'existe actuellement aucun instrument international qui traite spécifiquement des récifs artificiels (Convention et Protocole de Londres / PNUE, 2009). Mais il existe des directives en vue d'indiquer la voie à suivre pour établir au niveau national un cadre de contrôle ou de réglementation des récifs artificiels: Directives pour l'implantation de récifs artificiel.

En Tunisie l'octroi d'une autorisation d'immersion de RA est subordonné à la présentation d'une étude décrivant l'état initiale de la zone d'immersion, les modules à immerger et les impacts attendus. Une commission interministériel examine les demandes d'autorisation et formule son avis sur la base, notamment :

- de la conformité de la demande aux objectifs ;
- des risques sur la sécurité maritime que peuvent engendrer les immersions dans les canaux de navigation ou proche des pipelines.

Choix de la zone à aménager

Le choix du site doit être réalisé en concertation avec tous les acteurs socio-économique de la région (tourisme, activités de prospection et d'exploitation du pétrole, navigation…). En premier lieu, le choix doit prendre en considération:

- La proximité du site d'un port de pêche,
- Le site doit être en pente douce,
- Le site n'est pas utilisé à d'autres fins (navigation, mouillage, zone désignée pour les éliminations en mer, puits de pétrole, câbles, oléoducs et gazoducs),
- La proximité du site des zones naturelles riches (herbiers, roches), favorisant une colonisation plus rapide des futurs récifs et les échanges d'espèces.

Analyse des conditions du milieu:

L'analyse des conditions du milieu est importante, elle permet de définir l'état initial (point zéro) du site avant l'immersion des RA. C'est cet état qui nous renseignera sur les lieux propices à l'implantation de récifs et sur leurs effets lors du suivi scientifiques et socio-économique.

L'analyse doit toucher les aspects suivant :

- Les conditions hydrodynamiques sont déterminantes par rapport à des soucis de stabilité des structures immergées (effet des houles). Les courants sont déterminants par rapport à l'efficacité biologique attendu du récif (apports nutritifs, colonisation par les larves, lessivage des sédiments fins) ;
- La bathymétrie, la nature des fonds et des sédiments (proximité des habitats riches et prioritaires tels que les herbiers de Posidonies, les fonds coralligène, substrats durs naturels, granulométrie, état d'envasement, etc) ;
- La qualité des eaux (turbidité, apports temporaires fleuves) et les apports nutritifs telluriques (bassin versant);
- Les peuplements environnants (biodiversité, abondance des espèces, répartition).

L'analyse comprend aussi une autre zone proche du site choisi et ayant des caractéristiques similaires. Cette zone appelée témoin fera l'objet d'un suivi scientifique parallèlement à celui de la zone avec récifs artificiels.

Il est important d'obtenir des données de l'état actuel de la production de la pêche dans la zone afin de comparer avec les résultats obtenus après les aménagements récifaux pour dégager l'impact socio-économique. Une enquête doit être menée pour recueillir les données suivantes :

- Principales Espèces ciblées
- Evolution de la production du port de la zone
- Engins de pêche utilisés
- Zones de pêches fréquentées
- Périodes de pêche
- zone de pêche illégale

La mise en place

Pour la mise en place des Pour la mise en place des récifs artificiels, il convient de tenir dûment compte de toute activité légitime en cours ou prévue dans la zone en cause, telle que navigation, tourisme, récréation, pêche, aquaculture, conservation de la nature ou aménagement de la zone côtière.

Avant qu'un récif artificiel ne soit mis en place, tous les groupes et toutes les personnes susceptibles d'en être affectés ou d'y être intéressés, seront informés des caractéristiques

du récif artificiel, de son emplacement et de la profondeur de son implantation. Il leur sera donné l'occasion de faire connaître leurs points de vue en temps voulu avant la mise en place.

Modalités de gestion

La gestion d'un aménagement récifal regroupe normalement cinq axes : la concertation avec les acteurs locaux, l'encadrement des usages sur le site, la surveillance in situ et la prévention des situations à risques, la communication et sensibilisation des acteurs, et enfin l'évaluation des impacts environnementaux et socio-économiques du récif.

L'encadrement d'un usage particulier peut-il intervenir sous différentes formes :

- une interdiction de l'usage lui-même,
- une restriction des conditions d'accès au site pour certains usagers,
- une limitation de l' « intensité » de l'usage concerné,
- une mise en avant de comportements à promouvoir, ou au contraire de comportements à résorber.

En général, l'implantation d'un nouveau site de récifs artificiels devra ainsi faire l'objet d'une interdiction de l'ensemble des usages extractifs pendant une période minimale de 3 ans suivant la date de l'immersion. Cette période dite de "jachère" a pour objectif d'optimiser la colonisation du récif par les espèces animales et végétales marines.

Il est souhaitable de mettre en place des structures capables d'élaborer, animer et mettre en œuvre les mesures de gestion.

Sur les sites de récifs artificiels du golfe de Gabès aucune réglementation des usages n'a été promulgué ni un balisage des zones aménagées. Une réglementation concernant à la fois les usages extractifs (pêche de loisir et professionnelle), le mouillage ou la plongée doit etre élaborée pour une bonne gestion sur les sites d'implantation.

Par contre, des modalités d'encadrement ont été discutées avec les acteurs dont la création d'un comité de pêcheurs et la mise en place d'une période de jachère interdisant toutes activités extractives dans une partie de chaque site aménagé.

L'évaluation de la performance des RA

Un aménagement récifal nécessite d'être suivi pour évaluer s'il satisfait les attentes des gestionnaires. Mais avant tout, il est important de remarquer que la performance d'un RA dépend entièrement de l'objectif pour lequel il a été mis en place et dans le meilleur des cas, conçu. Ces objectifs déterminent les critères de succès et le type de suivi à mettre en place pour les évaluer.

Le suivi d'un récif artificiel recouvre toutes les actions qui visent à mesurer, analyser puis rendre compte des interactions qui se développent sur le site d'immersion et dans l'aire d'influence du récif entre :

- la structure immergée,
- la colonne d'eau et le substrat,
- la faune et la flore marines,
- les activités humaines.

De façon plus générale, le suivi d'un récif artificiel consiste à :

- Décrire la colonisation des récifs artificiels par la macroflore et la macrofaune sessile et vagile depuis leur immersion jusqu'à la première phase de stabilisation des peuplements en privilégiant les espèces d'intérêt commercial.
- Comparer les caractéristiques des zones d'immersion de récifs avec les zones non aménagées.
- Evaluer le « comportement » des ouvrages par rapport aux contraintes naturelles (enfouissement, envasement …).
- Mesurer l'impact de ces immersions sur la pêche professionnelle locale et formuler des propositions pour de futurs aménagements au moyen de RA.

État des lieux des implantations de récifs artificiels en Tunisie

Distribution des RA

Les premières immersions se sont déroulées en 1993, sur le site de Sidi Jmour à Djerba (golfe de Gabès, Tunisie). Le volume immergé lors de cette première implantation

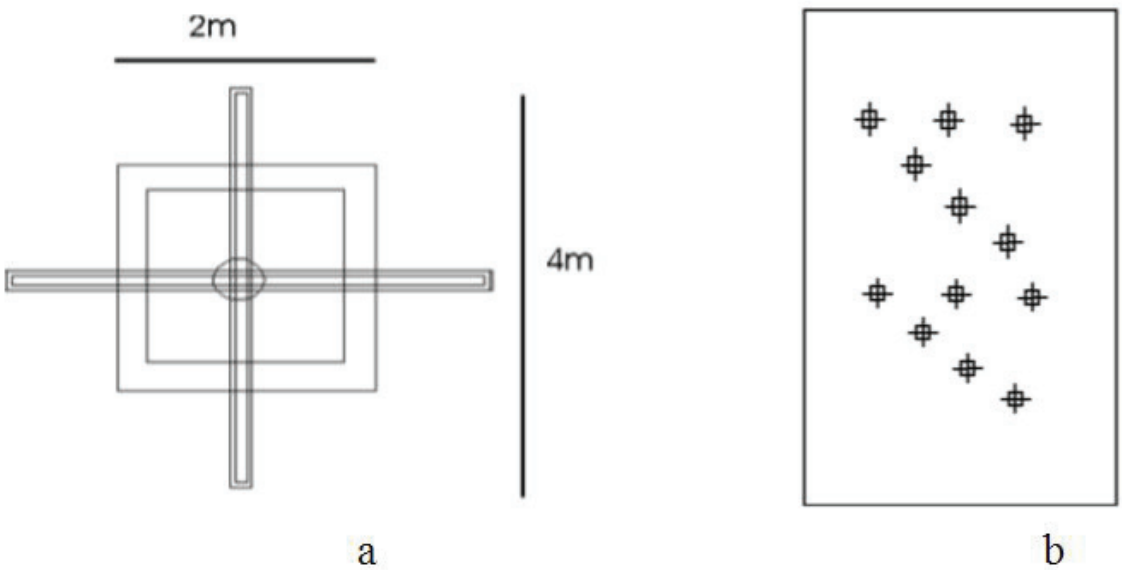


Fig 5. Schéma de conception des blocs(a) et Plan d'implantation(b) (Ben Mustapha , 1993).

est toutefois resté modeste (12 blocs anti-chalutage en béton de volume total de 768 mètres cube). L'étude de suivi, réalisée cinq ans plus tard, a montré une bonne reconstitution des communautés benthiques dans la zone d'influence des récifs et un meilleur rendement de la pêche, par rapport aux zones chalutées (Meliane, 1999).

Les modules ont été arrangés selon la disposition illustrée par la figure 6 b couvrant ainsi une surface de 0,5 km²

L'état a participé dans la lutte contre la pêche au chalut dans les faibles profondeurs en immergeant huit carcasses de navires de pêche pour être utilisés comme des récifs au large de Skhira (2003) et des Iles de Kerkennah (2005) (N. Haddad 2013). Les missions effectuées par l'INSTM en 2004 à Skhira et en 2006 à Kerkennah, ont montré la présence de diverses espèces de poissons pélagiques, ainsi qu'une colonisation de la coque des bateaux par les algues, les annélides, les bryozoaires, les spongiaires, les ascidies etc. (Anonyme 2004, 2006).

Avec l'enrôlement des petites barques aux efforts de chalutage destructif des habitats et des juvéniles, les pêcheurs artisans ont fabriqué des récifs artificiels rudimentaires en utilisant des fûts et des barres de fer (fig. 7 a), matériaux améliorés par l'appui du Programme de Microfinancement du Fond pour l'Environnement Mondial (PMF/FEM, 2005 ; PMF/FEM-LCST, 2006) des nouveaux blocs (fig. 7 b) ont été immergés à Kerkennah et à Djerba.

Le projet Tuniso-Japonais « gestion durable des ressources de la pêche côtière en

Fig 6. Les fûts utilisés comme RA (a) et les RA construits par les pêcheurs à Ajim et Zarrat (golfe de Gabès, Tunisie).

Fig 7. Les sites d'immersion des RA dans le cadre du projet tuniso-japonais au golfe de Gabès, Tunisie.

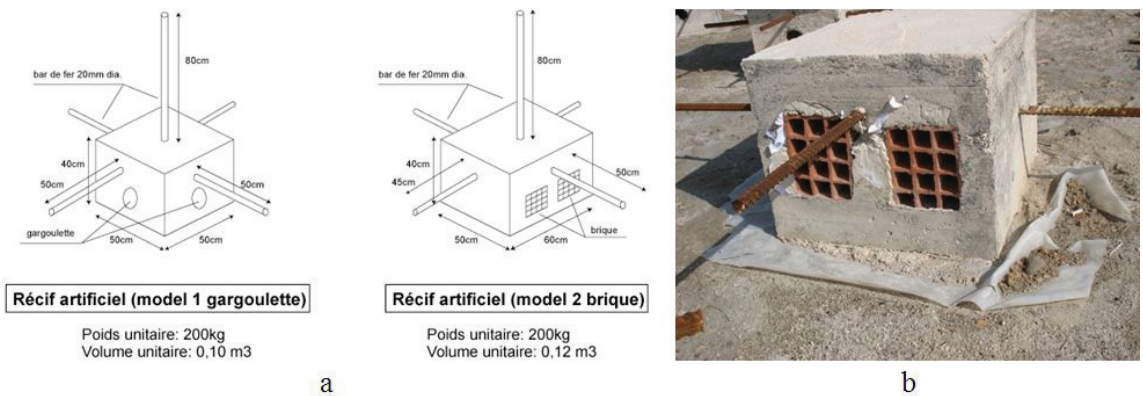


Fig 8. Les modules de RA utilisées dans le cadre du projet tuniso-japonais.

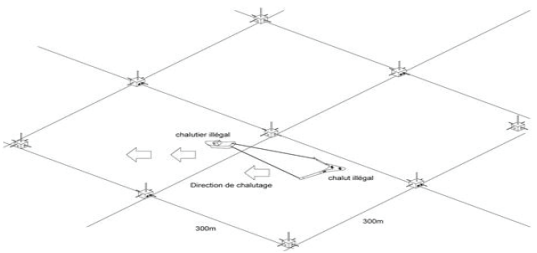


Fig 9. Plan de disposition des RA en grille et espacés de 300m environs

Tunisie » a trouvé que ces modules de RA sont efficace contre les petits chalutiers opérant dans les profondeurs inferieurs à 20 m. Lancé en Juin 2005 pour une durée de 5ans, le projet a immergé 2000 modules RA dans 4 sites situés dans le Golfe de Gabés : les iles de Kerkennah (Ataya et Kraten), Mahres, Zarat et Ile de Djerba (Ajim).

Les modules de RA utilisées dans le

cadre du projet de coopération tuniso-japonais sont conçus dans l'objectif de faire participer les pêcheurs dans la fabrication et l'immersion. Les 4 types de module sont simples à fabriquer en utilisant du béton et n'ayant pas un poids important. Ces modules ont pour objectif principale l'anti-chalutage et secondairement la production, en mettant des gargoulettes et des briques creuses à l'intérieur de chaque bloc (Fig. 9).

Les Ra ont été implantés dans des profondeurs variant entre 5 et 15 m et avec un maillage de 300 m (Fig. 9).

D'autres immersions sont financées par les pêcheurs eux même en cotisant lors du débarquement de leurs productions. Une partie de leurs recettes de vente de produits de la pêche a servi à l'achat du sable, gravier, ciment et barres en fer ainsi que la fabrication, le transport et l'installation des blocs.A Zarat, le transport terrestre des blocs depuis le chantier de construction jusqu'au port de pêche a été effectué par les engins de la municipalité.

Ainsi d'autres sites ont été protégé contre la pêche illicite dont : Zarat (2006-2008), Ouled Ezzeddine (2008-2010), Mellita (2009) et Ajim (2009-2010).

Les modules choisis sont en béton ayant les caractéristiques suivantes :

- Modules utilisés à Kerkennah par les groupements de développement de la pêche de Ouled Ezzeddine et Mellita sont identique à ceux utilisés par le Projet JICA (Fig 10 a).
- Modules utilisés par les pêcheurs de Zarat : sont de forme cubique ayant un poids plus important de 2 à 3 tonnes pour résister parfaitement au grand chalutier, c'est la seule vocation de ces récifs (Fig 10 b).
- Module utilisé par le groupement de développement de la pêche d'Ajim : est de forme cubique ayant un poids d'une tonne.

Il a été constaté plus tard que les modules du projet tuniso-japonais ont des inconvénients dont :

- Ils sont très légers et facilement déplaçable en mer,
- le module construit avec gargoulettes est meilleur que les briques dont les trous sont facilement ensevelies par les particules suspendues dans l'eau.
- Les barres de fer ont causés des dégâts aux files des pécheurs.
- Les morceaux de filet accrochés aux barres de fer des RA continue à capturer les poissons causant une pêche fantôme (Fig 11).

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- le module construit avec gargoulettes est meilleur que les briques dont les trous sont facilement ensevelies par les particules suspendues dans l'eau.

a b

Figure 10: Construction des RA réalisé par les pêcheurs artisans à Ouled Ezzedine (Kerkennah en 2008) (a) à Zarat (en 2008) ayant un poids de 1 à 2 T.(b).

Fig 11. Pêche fantôme provoqué par un morceau de filet abandonné dans un RA

Fig 12. Récifs artificiels de repeuplement implantés au large de Zarat (golfe de Gabès, Tunisie 2009)

Figure 14: Des modules de RA adaptés par N. Haddad pour jouer le rôle de protection et de production, immergés en 2011-2012.

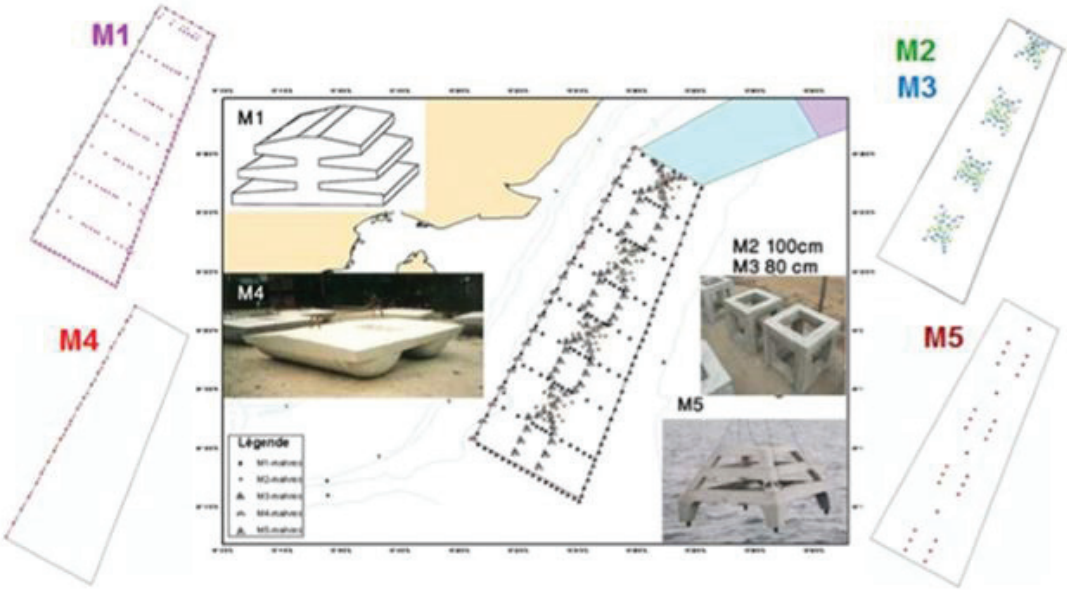

Figure 15. Plan d'implantation des modules de RA à Mahrés (golfe de Gabès, Tunisie) réalisé par N. Haddad.

- Les barres de fer ont causés des dégâts aux files des pécheurs.
- Les morceaux de filet accrochés aux barres de fer des RA continue à capturer les poissons causant une pêche fantôme (Fig 11).

Pour cela le projet a expérimenté des modules de RA de production au large de Zarat . Trente RA ont été immergés dans un seul endroit ont donné de bon résultat de repeuplement.

A partir de 2009 l'Etat a approuvé l'exécution d'un programme d'immersion de RA sur une période de 10 ans. Ce programme envisage la protection et la réhabilitation des zones de pêche sensible et dégradées par la pêche illicite.

Les modules choisis par ce programme ont une nouvelle architecture qui prend en considération les recommandations de l'expérience pilote réalisé avec la coopération du Japon. 1200 récifs ayant un poids plus important (600 et 800 kg) ont été immergés dans les mêmes sites du projet de coopération avec le Japon.

Depuis 2011, de nouveaux modules ont été conçus qui sont mieux adaptés aux objectifs escomptés : protection et réhabilitation des zones de pêche dégradés. Ces modules, qui pèsent entre 800 kg et 1600 Kg, n'ont pas la même architecture et peuvent jouer plusieurs fonctions en même temps (Fig. 14). 2)

Profondeur d'immersion

La profondeur d'immersion d'un récif artificiel influe sur sa colonisation par la faune et la flore, mais aussi sur sa tenue dans le temps.

A l'analyse du Tableau 1, il apparaît une nette différence entre les profondeurs retenues pour l'implantation de récifs artificiels aux iles de Kerkennah et au sud du port de Sfax.

Aux iles de Kerkennah, les immersions sont concentrées dans une gamme de profondeur d'une dizaine de mètres (entre 5 et 10 mètres). Ce choix est justifié par la bathymétrie très faible et la profondeur varie généralement entre 0 et 5, ainsi que par l'objectif général retenu de protection et d'enrichissement des ressources halieutiques.

Dans les autres zones, la gamme de profondeur des immersions n'a pas dépassé les 20 mètres, permettant ainsi aux petits

Tableau 1: Profondeurs d'immersion des récifs du golfe de Gabés

Profondeur (m)	Est des îles Kerkennah	Ataya	Kraten	Ghannouch	kettanah	Oueled Ezzedine	OuledYang	Mahares	Zarat	Dh'har Zarat	Sidi Jmour (Djerba)	Nord-ouest d'Ajim	Sud-est de Mahares	Bermil
0														
5	■	■	■	■		■	■		■	■	■	■		■
10	■	■	■	■	■	■	■	■	■	■	■	■	■	■
15					■			■	■				■	
20					■			■	■				■	
25														

senneurs d'exercer la pêche sans rencontrer les blocs anti-chalutage qui peuvent nuire à leurs armements.

En septembre 2012, une base de données des RA du Golfe de Gabés a été créée pour réaliser un bon suivi des immersions réalisées.

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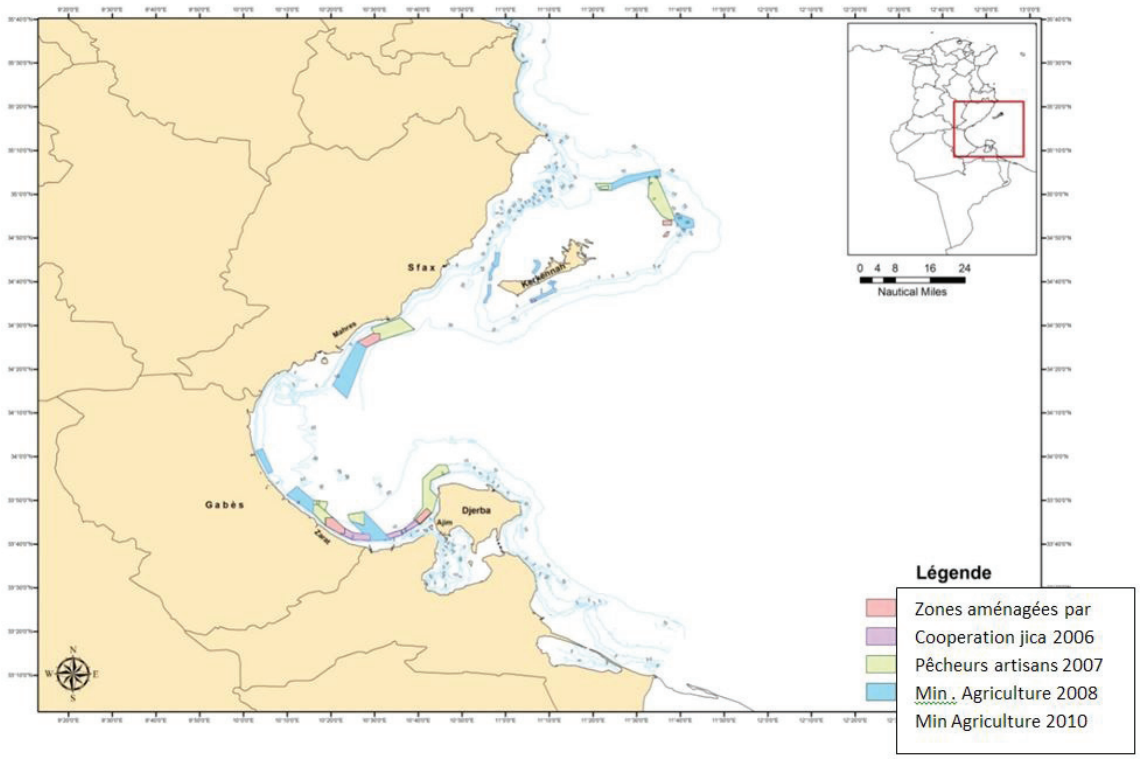

Figure 16 : Les nouveaux sites choisis pour l'immersion des RA dans le cadre du projet de protection du Golfe de Gabés contre la pêche illicite.

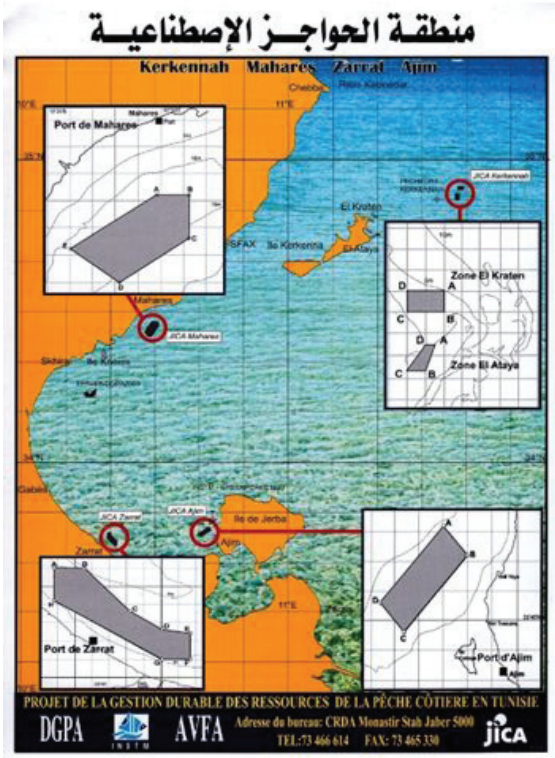

Figure 17 : un exemplaire des différents posters de sensibilisation des opérations d'immersion des RA au golfe de Gabès Tunisie.

Les campagnes de sensibilisation

Des posters ont été élaborés et affichés dans les bâtiments municipaux et les ports dans le but de présenter les activités du Projet à un large public local. Quatre types de posters ont été créés rien que dans le cadre du Projet, démarche imitée par d'autres organisations qui ont publié des posters similaires (Fig. 17).

La participation des différents acteurs a été respectée pour les différentes actions des projets d'immersion des récifs artificiels au golfe de Gabès (Fig. 18).

Evaluation des immersions réalisées

En Tunisie, plus de 16000 m3 de RA ont été immergés. Dans la plupart des cas, leur évaluation n'est constitué que d'études ponctuelles réalisées par une équipe mixte tuniso-japonaise.

Ces études ont démontré une augmentation des prises dans les différents sites et notamment à Zarat où les pêcheurs côtoient uniquement le site protégé par les RA. Dans cette zone, les récifs artificiels ont été immergés entre le mois d'octobre 2006 et le

Figure 18 : La participation des pêcheurs artisans dans le choix des nouveaux sites pour l'immersion des RA ainsi que leurs fabrications (iles de Kerkennah Tunisie).

début de l'année 2007. Les données présentent que le volume des prises de seiches a augmenté de 106%, passant de 112,69 tonnes à 231,978 tonnes, ce qui a permis une augmentation de 60% du volume total de prises, qui est passé de 161,278 tonnes à 257,758 tonnes (JICA/ DGPAq, 2009).

Deux études de l'impact socio-économique des aménagements récifaux ont été mené en 2007 et 2008, ont démontré que :

- beaucoup de pêcheurs ont constaté une augmentation de leurs captures entre la période précédant l'implantation des récifs artificiels et la période la suivant, et ont ressenti une plus grande sécurité lors de leurs activités de pêche après cette implantation.

- Presque la moitié des pêcheurs confirme que les dégâts de leurs engins de pêche par les chalutiers a diminué après l'installation de RA.

Recommandations

Une des conclusions de la dernière conférence mondiale sur les récifs artificiels est que nous sommes à la fin de l'ère de la pêche libre, du « free fishing », il est grand temps de mieux gérer les pêcheries et l'environnement marin, à travers la création d'aires marines protégées et le développement de récifs artificiels, outils de gestion à usages multiples.
Les pêcheurs artisans tunisiens conscients de l'intérêt des RA et ayant estimé leurs impacts sur les ressources et l'amélioration de leurs prises souhaitent des mesures supplémentaires dont :

- La mise en place d'un protocole participatif de gestion de chaque zone aménagée en récifs artificiels
- La réservation de l'exploitation des zones marines côtiers à la pêche artisanale tel que recommandé dans le Code de conduite pour une pêche responsable de la FAO (paragraphe 6.18). Cette disposition diminuera les conflits d'usage entre la pêche industrielle et la pêche artisanale. Donc, nous demandons une zone de pêche réservé à la pêche artisanale large de 2 mile au nord et l'ouest et atteignant les profondeurs de 20 m dans les golfes. Cette zone sera sous contrôle rigoureux par les autorités compétentes pour interdire toute opération de pêche illégale qui encourent des sanctions sévères. Ces sanctions doivent être répulsives atteignant la confiscation du navire et le retrait définitif du brevet de commandement.
- Le renforcement du contrôle en mer et notamment le suivi des activités des navires de pêche par satellites (VMS).

Il est également recommandé de :

- mettre en place un protocole type de suivis destiné aux maîtres d'ouvrage afin de :
- Définir clairement les objectifs du suivi,
- permettre la comparaison des sites d'immersion entre eux,
- permettre les comparaisons à l'échelle méditerranéenne.
- Constituer une base interrégionale de collecte et de traitement des données de suivi,
- Réaliser des suivis scientifiques tous les 3 ans pour établir un bilan global des immersions réalisées.

Référence

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Vidothéque :
https://www.youtube.com/watch?v=Auj9o3N13-I

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ADDRESSING FISHING-RELATED CONFLICTS THROUGH THE LENS OF TRANSBOUNDARY FISHERIES MANAGEMENT: CASE OF LAKE CHIUTA

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Summary

This paper reviews the process of developing transboundary fisheries management on Lake Chiuta, which is shared between Malawi and Mozambique. The Lake Chiuta small-scale fishery is important to the surrounding communities as a source of food and nutritional security and household cash incomes. Since the late 1980s, there were fishing-related conflicts among the user communities mainly due to different fisheries policy and legislation frameworks by both countries. Transboundary fisheries management was therefore advanced by the communities as a way of promoting cooperation and addressing the conflicts. Opportunities for the development of the initiative included sharing of cultural and traditional values; active participation of fishers and traditional leaders in resource management; commitment of both governments to various international conventions, agreements, and protocols. The process of establishing the Lake Chiuta transboundary fisheries management started in 2002. Since then the initiative has gone through three phases. Phase I (2002 and 2010) during which the fishing communities from both countries engaged in sharing information and ideas on how to address the conflicts. Phase II (2010 and 2013) included support from both governments as they agreed to adopt a transboundary fisheries co-management arrangement. Phase III was attained in October 2014 after signing of an agreement in form of a Memorandum of Understanding on Fisheries Management and Aquaculture Development. After signing the agreement, the conflicts have been reduced. Key lessons from the development process of the transboundary fisheries management are threefold: recognising active participation of the resource users in fish resource management; applying adaptive resource management approach; and providing space to resource users to define their goal and objectives of the initiative. Finally, signing of agreements by countries at policy making levels should recognize needs of the user community and not only be ceremonial.

Key words: conflicts, shared ecosystems, cooperation, community-based fisheries transboundary management, fish resource sustainability

TRAITER LES CONFLITS RELATIFS À LA PÊCHE PAR LA GESTION TRANSFRONTALIÈRE DE LA PÊCHE : LE CAS DU LAC CHIUTA

Résumé

Le présent document examine le processus de mise en place d'un système de gestion transfrontalière de la pêche sur le lac Chiuta, situé entre le Malawi et le Mozambique. La pêche artisanale sur le lac Chiuta est d'une importance capitale pour les communautés environnantes en tant que source de sécurité alimentaire et nutritionnelle et de revenus en espèces pour les ménages. Depuis la fin des années 1980, des conflits liés à la pêche sont apparus entre les communautés d'utilisateurs, principalement en raison des différents cadres politiques et législatifs de la pêche des deux pays. La gestion transfrontalière de la pêche a donc été proposée par les communautés comme moyen de promouvoir la coopération et de résoudre ces conflits. Les opportunités de développement de l'initiative comprenaient le partage des valeurs culturelles et traditionnelles ; la participation active des pêcheurs et des chefs traditionnels dans la gestion des ressources; l'engagement des deux gouvernements pour diverses conventions, accords et protocoles internationaux. Le processus d'établissement d'un système de gestion transfrontalière de la pêche sur le lac Chiuta a commencé en 2002. Depuis lors, l'initiative a connu trois phases. Pendant la Phase I (2002 et 2010), les communautés de pêcheurs des deux pays se sont engagées à partager les informations et les idées sur la façon d'aborder les conflits. La phase II (2010 et 2013) comprenait le soutien des deux gouvernements, qui ont convenu d'adopter un accord de cogestion transfrontalière de la pêche. La phase III a été réalisée en

octobre 2014 après la signature d'un accord sous forme de protocole d'entente sur la gestion de la pêche et le développement de l'aquaculture. La signature de cet accord a conduit à une réduction des conflits. Trois principales leçons ont été tirées du processus de développement de la gestion transfrontalière de la pêche : la reconnaissance de la participation active des utilisateurs des ressources dans la gestion des ressources halieutiques ; l'application d'une approche de gestion adaptative des ressources ; et la fourniture d'un espace aux utilisateurs des ressources leur permettant de définir leur but et les objectifs de l'initiative. Enfin, la signature d'accords par les pays au niveau de l'élaboration des politiques devrait reconnaître les besoins de la communauté des utilisateurs et ne pas uniquement avoir un aspect cérémonial.

Mots-clés : conflits, écosystèmes partagés, coopération, gestion transfrontalière de la pêche par les communautés, durabilité des ressources halieutiques

Introduction

There is a growing interest in transboundary natural resource management in Africa and the rest of the world. Transboundary natural resource management has always been associated with protected areas (Katerere *et al.,* 2001; Sandwith *et al.,* 2001; Lanjouw *et al.,* 2001). Over the past few years, issues like globalisation and promotion of regional economic integration have contributed to a wide recognition of transboundary natural resource management by various actors including non-governmental organisations (NGOs), development partners and the private sector Katerere et al. (2001). A transboundary natural resource management initiative, as van der Linde *et al.,* (2001) and Whande et al. (2006) assert, is considered an important approach to achieving sustainable natural resource management and biodiversity conservation; a way to promote regional economic development, address conflicts among communities and as a way to make use of other opportunities. In many areas, natural resources including fisheries transcend across national boundaries, which demand appropriate cooperation between or among the riparian countries to address fishing-related conflicts among the resource users. This is the case with Lake Chiuta that is remotely located and shared between Malawi and Mozambique.

Usually, "transboundary" implies the context of international co-operation. However, it may also cover co-operation between neighbouring sub-national jurisdictions, including autonomous regions or provinces (Sandwith *et al.,* 2001:3). Transboundary natural resource management can be defined as a process of collaboration across boundaries to increase the effectiveness of attaining goals of natural resource management or biodiversity conservation (van der Linde *et al.,* 2001). Griffin *et al.,* (1999) came up with a similar definition but added that the transboundary natural resource management is for the benefit of the parties concerned in the initiative.

Based on the above understanding, transboundary fisheries management can refer to a collaborative approach across boundaries that concerned parties pursue to achieve goals of equitable and sustainable fish resource utilisation. It is also observed that the approach encompasses a wide continuum of transboundary natural resource management initiatives and activities ranging from transboundary community-based natural resource management and transboundary protected areas management to large-scale natural resource management integrated in regional economic development. In this approach some ecological, social, political and economic considerations are made (van der Linde *et al.,* 2001).

However, there are some challenges in implementing transboundary natural resource management initiatives. Katerere *et al.,* (2001) in their critique asserted that there could be some concerns arising from the initiatives ranging from marginalization of the surrounding community to inequity in the distribution of benefits within a given country. The authors observe that there could be fears that the border communities that are dependent on particular natural resources and are already at the margins of social, political and economic opportunities would become further isolated

through transboundary natural resource management initiatives introduced in their areas.

Jones *et al.,* (2001) identify four types of transboundary natural resource management initiatives. These include transfrontier conservation areas, transboundary natural resource management areas informal transboundary use, spatial development initiatives and development corridors. In the context of this paper, Lake Chiuta fisheries transboundary initiative fits into transboundary natural resource management area and informal transboundary use types.

Some regional and global agreements and conventions with articles support transboundary collaboration. For example, in terms of fisheries, Food and Agriculture Organisation Code of Conduct of 1995; Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries in the Context of Food Security and Poverty Eradication of 2015; and the recently approved 12 steps on Ten Steps to Responsible Inland Fisheries, specifically Step 6 which highlights the need to "improve governance, especially for shared water bodies" (Taylor *et al.,* 2016). There are also other cooperation agreements and treaties that are primarily set up to facilitate transboundary collaboration between two or more nations like the Joint Permanent Commission of Cooperation between Malawi and Mozambique and the Malawi-Mozambique Memorandum of Understanding on Fisheries Management and Aquaculture Development that was signed on 23 October 2014. Additionally, Whande *et al.,* (2006) note that the Southern Africa Development Community treaty for regional integration and co-operation in the management of shared natural resources provides a basis for the resolution of conflicts around transboundary inshore fisheries. The Southern Africa Development Community has also put in place the SADC Protocol on Fisheries of 2001 which is aimed at increasing co-operation in conservation and natural resources management efforts.

This paper reviews the process of developing a transboundary fisheries management as means of addressing fishing-related conflicts on Lake Chiuta that is shared between Malawi and Mozambique. There are recommended steps to be considered when implementing a transboundary natural resource management arrangement (Knox & Meinzen-Dick 2001; van der Linde *et al.,* 2001; Lanjouw *et al.,* 2001). I adapt three transboundary natural resource management phases (Box 1) as outlined by Lanjouw *et al.,* (2001:32) which were applied in the International Gorilla Conservation Programme.

Box: Phases of establishing a transboundary fisheries management arrangement

Phase I: Field-based co-ordination and collaboration: This phase focuses on harmonisation and co-ordination of management approaches, and development of field-based informal mechanisms for collaboration. These approaches and mechanisms respond to the objectives of transborder cooperation. This phase emphasises regular communication between field staff and management staff of the ecosystem, sharing information on resource monitoring and joint planning and implementation of activities.

Phase II: The existence and use of the harmonised approaches in the respective countries will facilitate the second phase of the strategy, which is formalisation of the transborder collaboration and harmonised policies. The second phase, however, is dependent on a minimal level of political support among the respective official governments. It is believed that improved management of the shared ecosystem is a function primarily of field-based collaboration, rather than official agreements.

Phase III: A final phase could involve the signing of a formal agreement between or among the respective governments to establish a transboundary natural resource

management area. The agreement should outline in its preamble the legislative background of the TBNM, define its purpose, describe the parties and the endorsing partners, and define the ecosystem area and its structures (a joint commission or other mechanism) and modes of operation.

Adapted from Lanjouw et al. (2001:32)

Furthermore, secondary sources are used. In particular, published reports, articles on Lake Chiuta transboundary fisheries management initiative, for example, Donda (1997); Njaya *et al.,* (1999), and Njaya (2002 and 2006), as well as monthly and annual field reports prepared for the Department of Fisheries are referred to for description of the fishery, earlier reviews of the transboundary initiatives and status of the fishery mainly in terms of threats.

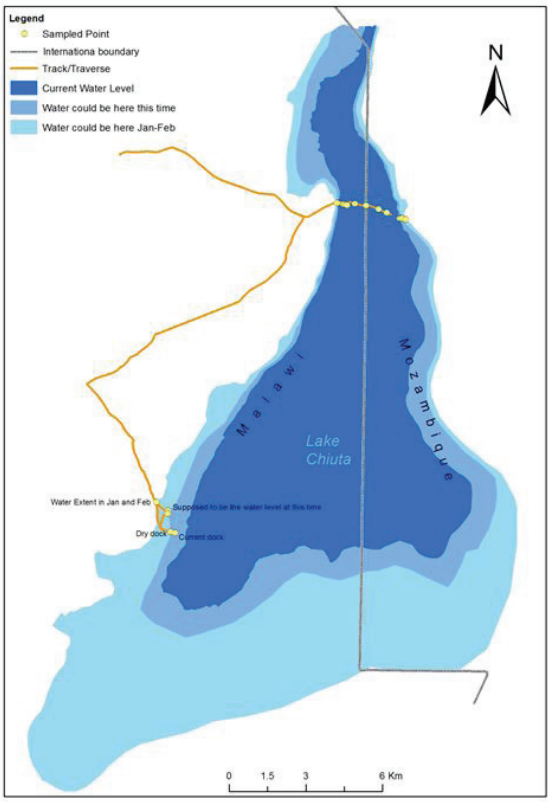

Figure 1: Map of Lake Chiuta showing Malawian and Mozambican sides of the lake

The article is structured by outlining objectives and framework in Section 1. The Lake Chiuta fishery is described in Section 2 after which Section 3 presents the main source of fishing-related conflict on the lake. Section 4 presents opportunities for transboundary management while synthesis and conclusion are in Section 5.

The Fishery

Lake Chiuta fishery is dominantly artisanal or small-scale in nature but some sort of "subsistence" fishery is also available. In the Fisheries Conservation and management Act of 1997 "subsistence fishing" means fishing for the primary purpose of providing food for household consumption while a "small scale commercial fisherman" means: (a) in the case of an individual, a person who is engaged or intends to engage in fishing for sale throughout the year or a specified season or part of a season each year and who relies on his fishing activities for part of his income; or (b) in the case of a corporate body or association of persons, one that has an appreciable investment in the fishing industry or intends to make one.

Lake Chiuta is a shallow lake with a mean depth of 5 m and is shared between Malawi and Mozambique. It is located at an altitude of 620 m in the southern part of Malawi. It has a total surface area of about 200 km^2, of which 49 km^2 lie in Mozambique (FAO, 1994) as shown in Figure 1. The southern part is more or less permanently covered with emergent vegetation penetrable by canoes but not larger craft. The waters are clearer and less saline than those of Lake Chilwa.

Lake Chiuta is a multi-species fishery (Donda, 1997: Njaya *et al.,* 1999 and Njaya 2013) with annual harvests estimated at between 1,200 and 1,500 tonnes for the Malawian side (GoM 2015; Njaya 2013). The fishery is predominantly small-scale with fishers using traditional craft (dug-out canoes) and gears like fish traps and gillnets. In 2015, Lake Chiuta registered 822 fishers using 298 dug-out canoes, and 1,869 gillnet units were counted on the Malawian side of the lake (GoM 2015).

Fish is sold either fresh to neighbouring

villages or processed (smoked or sundried) before transported to distant urban markets. Fish processors use chorkor kilns introduced in the area in the 1990s or traditional open pits to smoke fish (Njaya *et al.,* 1999).

The lake habitat is less degraded than most, with muddy bottom and submerged vegetation. The commonly exploited fish species include *Oreochromis shiranus* (local name: Makumba), *Tilapia rendalli* (local name: Chambo), *Clarias gariepinus* (local name: Mlamba), *Barbus paludinosus* (local name: Matemba), and Nkhalala (*Alestes imberi*). The fishers use gill nets, fish traps and long lines and individually placed hooks locally termed as nchomanga while dug-out canoes and few planked boats are commonly used on the lake for fishing activities (Njaya *et al.,* 1999; Njaya 2013).

The Lake Chiuta fishery is dominated by two ethic groups, namely Lomwe and Yao. In terms of religious groupings, Muslims and Christians are commonly found in the area. The community shares socio-economic and cultural background together with their counterparts on the Mozambican side. Reports from the fishing communities show that in times of hunger or food shortage, people from cross over the border to either side in search of food. The same happens for businesses (Njaya *et al.,* 1999; Njaya 2013).

Table 1: Fishing regulations for Lake Chiuta

Rule/regulation	Malawi	Mozambique
1. Fishing gear types:	allowed	allowed
(a) Gill nets	allowed	allowed
(b) Fish traps	allowed	allowed
(c) Long lines	prohibited	allowed
(d) Beach seine	prohibited	allowed
(e) Open water seine (nkacha)		
2. Minimum mesh size for gill nets was set at 69mm		not yet
3. Closed season for seines – 1 November to 30 April	not applicable as the seines are prohibited	applied

The local communities are dependent on fishing, farming and small-scale businesses for their livelihood. Some men migrate to urban areas for work while others work abroad especially in South Africa. In some cases, people work as casual labourers in gardens belonging to the affluent.

Main Source of Conflicts

Two types of fisheries management systems exist in many fishing communities. The first is an informal management system, which is developed and implemented by a community of resource users and often coexists with a centralised fisheries management system. Outsiders to the community are often not aware of informal systems as these are not easily observed or understood. An informal management system refers to a 'rights-and-rules system collectively sanctioned by fishers' (Pido *et al.,* 1996). Table 1 outlines the fishing rules for Lake Chiuta.

Based on the regulations, it is evident that the main source of conflict is with regard to seining operations. Seines are allowed on the Mozambican side, but they are prohibited on the Malawian side. There is need for continued dialogue between the two fishing communities to address this problem.

Opportunities for Establishment of Lake Chiuta TBFM

Transboundary natural resource management initiatives including TBFM are developed and implemented in a broad framework including ecological, social, economic, political and institutional aspects van der Linde (2001). Within this broad framework there are issues at both in-country and international levels that have a direct or indirect impact on the success of the transboundary initiatives. Van der Linde (2001) recommends a need to be aware of the opportunities, enabling conditions and constraints to assess the likelihood of achieving transboundary natural resource management objectives. There are several opportunities exist that facilitated the introduction of the Lake Chiuta transboundary fisheries management initative at local/ community, national and international levels. These include socio-cultural issues; policy and political context; dependence on the resource for economic gains; willingness to engage in dialogue; and international obligations and commitments by both Malawi and Mozambique.

Socio-cultural issues

In terms of ethnicity, the majority of the people around the lake are Nyanja, Yao and Lomwe. They share a common history, language, socio-cultural values and traditions. Many practices such as land tenure systems, marriage traditions and initiation ceremonies are also common among the villagers around Lake Chiuta. The fact that many Malawians came from Mozambique and some of them have intermarried during the past decades bodes well for a common level of understanding on resource management between the two fishing communities. Griffin *et al.,* (1999) assert that transboundary natural resource management facilitates the movement of people across borders for trading of fish and other commodities, which can strengthen cultural ties and traditions that might have been affected by political boundaries. Van der Linde et al. (2001) also outlined opportunities like social and cultural dimensions for development transboundary natural resource management. In their analysis they looked at trust among key stakeholders for commitment to the process; participation by all key stakeholders; addressing potential conflicts among stakeholders; empowerment of the actors for benefits; common history; ethnic grouping; language; and traditional resource management systems across a border to enhance the likelihood of success at local level.

Recognition of traditional powers by both Malawi and Mozambique offers an opportunity for a sustainable transboundary natural resource management framework that is built upon the ongoing CBNRM arrangements with incorporation of local knowledge. Hara and Nielsen (2003) contend that traditional structures in Africa play significant roles in terms of resource management as they serve as a link between the user community and the government. Traditional authority structures in southern Africa are considered a legacy of colonialism. In both countries, traditional authorities are based on a lineage system of indirect rule that was introduced in the 1940s by the colonialists (Lopes *et al.,*1998; Nhantumbo *et al.,* 2003). The main responsibilities of chiefs included collection of taxes, fees and dues as demanded by the Portuguese in Portuguese East Africa (now Mozambique) and the British in Nyasaland (now Malawi). After independence many African countries maintained traditional authority structures but reviewed their duties, including control over their villages, settling disputes and allocating customary land. In Mozambique, their customary powers were revoked in early 1990s, but recently the government has begun to recognise the role of traditional leaders.

Policy and institutional context

Both Malawi and Mozambique are implementing co-management programmes in various water bodies. Natural resource policy reforms in Malawi began in the 1990s with emphasis on community participation mainly due to fiscal constraints and seeking ways of regulating access. In this context, recognition was given to environmental management as

an essential element in sustainable economic development by establishing the Environmental Affairs Department in 1991. The National Environmental Action Plan was completed in 1994 following the United Nations Conference on Environment and Development (the Earth Summit) held in Rio de Janeiro in 1992.

The Government of Malawi approved the National Environmental Policy and the Environment Management Act (EMA) in 1996. Malawi's National Fisheries and Aquaculture Policy of 2000 and Fisheries Conservation and Management Act 27 of 1997 provide for participatory fisheries management and international co-operation in fisheries. These legal instruments create an enabling condition for a transboundary natural resource management framework.

In Mozambique, the Fisheries Master Plan was approved by the Government in October 1994. The document outlines priorities and strategies for development to be pursued in subsequent years. In terms of small-scale fisheries, the plan emphasises the involvement of fishers in formulating and enforcing regulations (Lopes *et al.,* 1998). The Regulamento de Pesca Maritima was formulated in 1997, which facilitated the establishment of the Comissão de Administração Pesquerra. This committee is charged with the responsibility of advising on resource management.

In 1984, Malawi and Mozambique signed a Permanent Joint Commission on Cooperation, which can facilitate implementation of the proposed Lake Chiuta transboundary co-management. Both countries are also parties to various international conventions, agreements and protocols that deal with management of natural resources such as the 1992 Convention on Biological Diversity (CBD) and Food and Agriculture Organisation (FAO) Code of Conduct for Responsible Fisheries. Of particular importance is the Southern African Development Community 2001 Protocol on Fisheries, which can legally facilitate introduction of the transboundary fisheries co-management. However, van der Linde et al. (2001) say, since establishing a transboundary natural resource management initiative may be a lengthy and difficult process, it may be necessary to start implementation before all the enabling conditions are in place. In support of this point, Lanjouw et al. state that 'it is unrealistic to consider that a transboundary natural resource management area needs to be formally designated before regional collaboration can take place' (2001:37). They assert that collaboration can take place at a lower political level since there are more preconditions for obtaining higher-level political support.

Like most African countries, Malawi and Mozambique are decentralising their authority in the management of natural resources. Since transboundary natural resource management requires democracy, Griffin et al. (1999) advocate that stakeholder involvement should occur at all stages of the process, particularly during decision-making stages. In this context, a centralised approach to the formulation of the transboundary natural resource management arrangement is not recommended in Lake Chiuta. Rather, local fishing communities should participate actively at local level since in most cases they share the same culture and traditions.

A decentralisation process in Malawi started in the mid-1990s. In terms of fisheries the devolved functions include extension services, inspectorate, and licensing of vessels and gear. Despite progress having being made towards the devolution of tasks to local district councils and user groups such as beach village committees that constitute fishing-related actors, there is still a long way to go. There is need for the formulation of by-laws for empowerment of the beach village committees. There is also need to fit these committees into decentralised structures such as village development committees, area development committees and district assemblies.

In Mozambique, amendments to the Mozambican Constitution that promoted a regime based on democratic principles and multi-party politics were introduced in 1990. With regard to the decentralisation process, Nhantumbo et al. (2003:6) argue that this has not been implemented as expected. In

both countries conflicts arise because parallel structures for development projects are often formed alongside the traditional ones. For example, where the beach village committees were formed, the process did not take into account the existing institutional arrangements and conflict resolution mechanisms.

Legislation on fisheries co-management

On the Malawian side a review of the Fisheries Policy of 1973 was done in 2001 to incorporate issues about community participation within the context of either community-based management or co-management. A follow-on review of the National Fisheries and Aquaculture policy of 2001 has however just been done in 2016. The current National Fisheries and Aquaculture Policy of 2016 strengthen fisheries governance issues.

Nhantumbo et al. (2003:7) observe that community-based natural resource management is still 'evolving in Mozambique, in terms of approach and depth; therefore, a model best suited for conditions in the country have yet to be completed'. However, the Forestry and Wildlife Policy has the social objective of ensuring greater involvement of local communities in the management of natural resources and ensuring that they derive benefits from such resources. Community-based natural resource management is the strategy for realising this objective. A fundamental implementation framework for this strategy is outlined in the Land Law, which establishes that communities can have access to land delimitation process and acquisition of land use certificates.

In their assessment, van der Linde et al. (2001) also outlined opportunities like policy issues for development transboundary natural resource management. The authors recommended some enabling conditions like strong political will and commitment to transboundary collaboration; developing policies and legislative frameworks to support sustainable natural resource management; transparent and democratic policy and law-making process representing the majority; political stability and security; support to local-level stakeholders; strong regional integration; regional protocols and economic agreements; and integrated land-use and fisheries management plans on both sides of the border.

Institutional capacity of the respective countries

On institutional aspects, both Malawi and Mozambique has several key actors in the fisheries management. At community level, there are beach village committees and fisheries associations representing interests of the fishing community in Malawi. Equally in Mozambique, there are Community Fishing Councils (Conselho Comunidade das Pescas) and inter-district co-management committees - as is the case of Kwirikwidge - that have roles in the management of the fisheries resource together with the National Department of Fisheries in a co-management approach (Lopes and Gervásio (1999). Van der Linde *et al.,* (2001) highlighted some eenabling conditions for institutional context including existence of well-established partners in each country; strong and balanced capacity among institutions; resources to invest in capacity building and the transboundary process; need for a long-term commitment of the organizations involved, and motivated staff; defined transboundary planning and coordination process; networks to be established for collecting and sharing information; existence of organizations to support natural resource management (NRM) and appropriate structures and systems as a basis for transboundary natural resource management . Study visits were organized and supported by IUCN-ROSA between 2002 and 2003 to Lake Kariba to enhance capacity of the Malawian and Mozambican fishing communities especially in conflict management (Hachileka 2003).

Dependence on the resource for economic gains

Fish provides a livelihood to many people on both sides of Lake Chiuta. The growth of the urban centres of Mecanhelas in Mozambique and Liwonde in Malawi mean that fishing and fish trading are important sources of income for the majority of the

population around the lake. Regulation remains a critical issue and is being pursued by both fishing communities and fisheries management authorities. Lake Chiuta lies in a remote area where alternative fish supply from other sources such as Lake Chilwa may not be reliable. Its stable fish supply ensures provision of much-needed nutrients and income to the villagers.

Van der Linde et al. (2001) also presented opportunities like economic aspects for development transboundary natural resource management. Some enabling conditions for consideration include the benefits of transboundary natural resource management to be greater than the costs; national financial policies to be supportive of transboundary natural resource management initiatives and approaches; status of the overall economy to be attractive to investors; benefits for on both sides of the border; resources to be mobilised to start up the initiative and long-term sustainability to be considered and built at the planning level especially if externally funded; and there should be a flexible and diverse funding sources.

Willingness to engage in dialogue

In 2002, a meeting was organised for the two fishing communities and exchange visits continue between the district officials from both countries. This demonstrates the willingness of local communities to address and solve their problems and determine their future. It is expected that a transboundary natural resource management framework based on mutual understanding of the communities would be efficient as it involves building upon existing resource management systems and institutions (Griffin *et al.,* 1999).

International obligation and commitments

Both Malawi and Mozambique are committed to various international conventions, agreements, and protocols like the FAO Code of Conduct of 1995; Southern African Development Protocol on Fisheries of 2001; and the AU/NEPAD Policy Framework and Reform Strategy for Fisheries and Aquaculture in Africa of 2014 in providing a framework of cooperation for shared ecosystems. This provides an opportunity for a common understanding and pursuance of a goal towards sustainable fish resource management.

Status of Lake Chiuta Fisheries Transboundary Management

The process of establishing the Lake Chiuta transboundary fisheries management initative started in 2002 with support from the International Union for Conservation of Nature and Natural Resources (IUCN) that provided a negotiation platform for the Malawian and Mozambican fishing communities. It was also engaged in building capacity for both fishing communities in areas of conflict management, entrepreneurship, business management, fish resource management and environmental issues. Two major activities including a study tour to Zambia/Zimbabwe to learn about Lake Kariba transboundary initiative on fisheries management and organising a training session for riparian representatives of the fishing communities (fisheries, traditional leaders, fisheries technical assistants) were conducted in Malawi in 2003. The immediate result was reduced conflicts on the lake but after two years there was escalation of the conflicts as before with one side pointing fingers at the other.

As a way of seeking permanent solutions to the fishing-related conflicts on the lake, some cooperation initiatives at the local (district/provincial) level involving both countries started around 2012. There were exchange visits by traditional leaders and district/provincial authorities between the countries which gave rise to seeking support at a higher level. An idea to have a cooperation framework in form of a Memorandum of Understanding was reached after high level authorities from both countries visited some Njerwa beach on Malawian side and Muhara beach on the Mozambican side in October 2013. After that some paper work was exchanged between the two countries until October 2014 when the Memorandum of

Understanding was signed to mark a milestone in the transboundary fisheries management on Lake Chiuta.

Based on the framework by Lanjow et al. (2001) as shown in Box 1, Lake Chiuta transboundary fisheries management is currently in Phase III. This is where an agreement between Malawi and Mozambique was reached in 2014. However, subsequent activities by the Joint Fisheries Technical Committee and Joint Fisheries Steering Committee involving the two countries have delayed. So far a plan of action is yet to be formulated to guide implementation of the Memorandum of Understanding as was agreed soon after signing the agreement

Already the transboundary fisheries management initiative has gone through the first two phases as follows:

- The Phase I was between 2002 and 2010 during which the fishing communities from both countries engaged in sharing information and ideas through meetings on how to develop the common management strategy to reduce conflicts.
- Phase II (2010 and 2014) which involved joint field consultations with facilitation of technical teams from both governments (Malawi and Mozambique). The main result of the consultations was to develop an agreement through which harmonisation of fishing rules and policies would be done.
- Phase III included signing of the Memorandum of Understanding (MoU) between the Governments of Malawi and Mozambique on Fisheries Management and Aquaculture Development in October 2014 which among others, highlights areas of information sharing, research, aquaculture development and monitoring control and surveillance activities.

Field reports and observation show that after the two countries signed the agreement on Fisheries Management and Aquaculture Development in 2014, conflicts have been greatly minimised. Various stakeholders including the fishing community, local and central government authorities and civil society groups attribute the reduced conflicts to political and policy support from the two countries. Sustainable utilisation of the fisheries resources for Lake Chiuta can be achieved where resources share a common vision, goal and objectives of the resource. In this context, the Memorandum of Understanding will provide a framework to guide to ensure sustainable manage the fisheries resources for sustainable fish resource management and development of aquaculture within the Lake Chiuta basin. Adoption of co-management arrangement seems to be agreed by both Malawi and Mozambique giovernments.

However, there are some environmental or ecological threats to the Lake Chiuta aquatic ecosystem as documented by Njaya (2013). The major threats include variability and change of climate and emerging destructive fishing methods which are due to reduced water level changes. These may have adverse effects on the cash incomes of the riparian communities from fishing activities, food and nutritional insecurity, and limited employment opportunities. Eventually the fishing dependent communities will put pressure on other natural resources like forestry resources to earn incomes.

Synthesis and Conclusion

Fishing-related conflicts emerged on Lake Chiuta largely due to different fishing regulations between Malawi and Mozambique. The differences were exacerbated by the fact that when the co-management arrangement was introduced on the lake, there was lack of recognition on cross-border collaboration among institutions at a local level. Thus, despite the articulation of ecosystem benefits such as sustained fish resources through transboundary natural resource management, conflicts may still emerge due to free-riding effect. There could also be an elite capture within the fisheries governance as some government official may take advantage of the initiative to advance their policy aspirations with minimal community consultations as negotiations could be done at higher levels. Therefore, establishment of the Lake Chiuta transboundary initiate with a common goal of pursuing fisheries co-management would address the issues about

different fishing rules and regulations hence allow the fishers to operate in harmony.

This review has shown that transboundary fisheries management initiative can be implemented with minimal centralised authority if participation of user community is guaranteed. The Lake Chiuta fishing community demanded cooperation among themselves (Malawians and Mozambicans) in resource management but needed political support considering the international boundary that exists on the lake. Nevertheless, the support from the two governments appears not readily available as evidenced by the delay in putting in place necessary processes and systems for implementation of the Malawi-Mozambique Memorandum of Understanding on Fisheries Management and aquaculture Development. Being a five-year (2014-19) agreement, there is a fear that the agreement may expire with less to be achieved.

Time frames attached to agreements on transboundary natural resource management programmes are necessary. There is a need to consider long term initiatives rather than shorter ones. Management of natural resources need to be looked into with a long vision. For example, we can argue that the first five years may be for putting in place systems and processes including approaches and legal issues for implementation of the agreement. The second ten years could be for working on agreed activities for sustainable utilisation of the resources while focusing on long-terms changes that might be brought about by climate change or variability. This means that some targeted programmes on adaptive capacity would need to be formulated to address such problems within a proposed long-term agreement.

Further lessons from this paper especially on the transboundary fisheries initiative process include recognising active participation of the resource users in fish resource management; applying adaptive resource management approach; and providing support to fishing communities in their quest for long-term and sustainable resource management by addressing conflicts. Finally, signing of agreements by countries at policy making levels should recognize needs of the user community and not only be ceremonial. Conflicts that were prevalent in Lake Chiuta for decades have, to a certain extent, been minimised. Communities from both sides of the lake are able to meet and engage in dialogue to resolve issues affecting the fishery and the fisheries governance system.

There are, however, threats to their livelihoods key one being change or variability of climate that has resulted in receding of the lake. This is a critical issue that affect socio-economic status of the fishing communities considering that fishing is their dependent source of livelihood. Finally, there is a need to adopt an ecosystem approach, which is a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way.

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LE SSN: UN OUTIL EFFICACE DE LUTTE CONTRE LA PÊCHE INN

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Résumé

Le secteur de la pêche a connu pendant ces dernières décades des changements importants dans les conditions d'exploitation: En effet, pour répondre à la demande grandissante en produits de la mer, les activités liées à la pêche sont devenues plus dynamiques et la flottille de pêche a enregistré un accroissement notoire produisant parfois une exploitation intense et incontrôlée. Pour redresser la situation des ressources affectées par ce type d'exploitation, différents outils sont admis pour rétablir des stocks et lutter contre la surpêche dont l'adoption du système de suivi et de surveillance des navires par satellite (SSN ou VMS en anglais). La Tunisie a débuté la mise en œuvre de ce système par une opération pilote en 2008 au moyen de 34 navires pendant 6mois. Aujourd'hui ce système couvre 60 navires et il est envisagé détendre l'emploi de de système pour couvrir tous les navires supérieurs à 15 m conformément à la Rec. FCM/33/2009/7 de la CGPM et la loi national promulgué en 2013. Une balise baptisée U3C a été fabriquée par une entreprise tunisienne qui a signé le marché. D'après son concepteur, l'U3C, une invention 100% tunisienne, permettra aux pêcheurs qui sont équipés par ce système d'accéder aux prévisions météorologiques et aux lois réagissant le secteur de la pêche, sous forme de cartes interactives, ainsi que de rédiger un rapport de capture ou de lancer des détresses dans les cas urgents ou en cas d'accidents. Les informations émises par la balise U3C sont sécurisées et codées, ce qui empêche leur infiltration. Le système assure ainsi, la souveraineté de l'Etat tunisien sur les données de suivi de sa flotte.

Mots clés : SSN, VMS, Satellite, pêche, balise, CSP

MS: AN EFFECTIVE TOOL FOR COMBATING IUU FISHING

Abstract

Over the last few decades, the fishery sector underwent significant changes in operating conditions: in response to the growing demand for sea products, fishing activities became more dynamic and the fishing fleet notably increased, sometimes leading to intensive and uncontrolled exploitation. In order to redress the situation for resources affected by this type of exploitation, various tools are allowed to restore stocks and combat overfishing, including the adoption of the Vessel Monitoring and Surveillance System (VMS). Tunisia began implementing this system through a pilot operation in 2008 with 34 ships for 6 months. Today this system covers 60 ships, and it is envisaged to expand the use of the system to cover all ships above 15 m in accordance with Rec. FCM / 33/2009/7 of the GFCM and the national legislation enacted in 2013. A device known as U3C was developed by the Tunisian company that was awarded the contract. According to its developer, the U3C, a 100% Tunisian invention, will allow fishermen equipped with this system to access weather forecasts and legislation governing the fishing sector in the form of interactive maps, as well as to write reports on capture or to send distress alerts in emergency cases or in case of accidents. Information transmitted by the U3C device is secured and coded, and is therefore protected. Thus, the system ensures sovereignty for the Tunisian State regarding the tracking data on its fleet.

Keywords : VMS, Satellite, Fishing, Device, CSP

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Introduction

Les ressources halieutiques ont été longtemps considérées comme ressources inépuisables qui pouvaient donner lieu à un accroissement continu de la production. On sait depuis le début du XXème siècle que cette notion est erronée; le développement du secteur est maintenant tributaire de la mise en place de mesures assurant la conservation à long terme et l'utilisation durable des ressources halieutiques qui sont certes renouvelables mais limitées. Le développement de la pêche n'est pas la croissance continue de la production par l'augmentation de l'effort de capture, mais une utilisation optimale des ressources halieutiques et du maintien de leur disponibilité pour les générations présentes et futures. En Tunisie, par l'étendue de ses côtes méditerranéennes sur environ 1250 Km avec 3 golfes (golfe de Tunis, golfe de Hammamet et golfe de Gabès), la pêche représente une activité importante sur les plans aussi bien socio-économique qu'alimentaire.

Les produits de la pêche tunisienne représentent environ 8.5% de la production de la mer méditerranée et environ 1‰ de celle du monde entier.

Ces résultats sont obtenus grâce aux mesures de l'Etat encourageant la pêche par le développement de l'infrastructure et superstructures portuaires et au niveau de l'investissement. Ainsi pas moins de 40 installations (ports hauturiers, ports côtiers et digue-abri) sont actuellement fonctionnels, équipés des services nécessaires et la formation d'une importante flottille de pêche constitué de 11500 unités dont 430 chalutiers exerçant principalement au Golfe de Gabès (70%).

Par ailleurs la pêche est devenue un facteur dynamique de développement de l'industrie agro-alimentaire poussant à l'investissement pour la construction d'unités de transformation et de conservation des produits de la mer et cela en réponse à une demande soutenue de ces produits. La pression sur les ressources halieutiques qu'en résulte conduit à une situation d'exploitation non contrôlée.

Les signes nets de surexploitation, de modifications des écosystèmes, de pertes économiques et de conflits d'intérêts entre armateurs commencent à se manifester. En effet, l'accroissement de la production halieutiques nationale a suivi les attentes des décideurs jusqu'à 1988, année durant laquelle elle atteint un pic de 102 000 tonnes.

Tableau 1: Evolution de la production halieutique en Tunisie (source M. Bradii, A. Bouain)

Taux d'accroissement	Années	Taux annuel
35.8 %	De 1956 - 1960	9%
29.3 %	De 1961 à 1970	3.3%
98 %	De 1971 à 1980	10.9%
78 %	De 1981 à 1988	11.2%
Moins 7 %	De 1989 à 2003	Stagnation
25 %	De 2004 à 2014	2.3 %

La production a connu un fléchissement durant les années 90, puis elle a repris doucement pour atteindre une production de 130 tonnes en 2014 (voir fig. n°1).

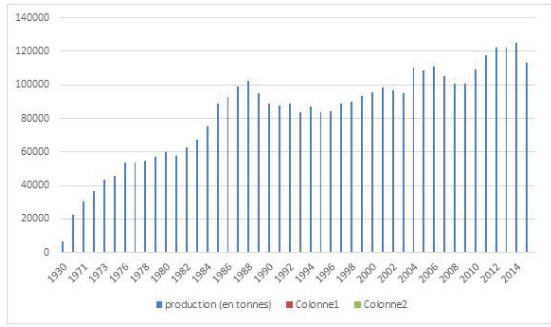


Figure 1: Evolution de la production halieutique en Tunisie 1930-2015 (source DGPA)

Les types de pêche les plus importants sont la pêche artisanale, la pêche à la senne et la pêche au chalut. La pêche artisanale, qui occupait la première place au plan de production jusqu'en 1988, année où celle-ci a atteint 50 000 tonnes, diminue continuellement depuis cette date pour tomber à moins de 26500 tonnes en 2003.

Dans le même temps le chalutage qui oscillait autour de 17000 tonnes jusqu'à

1995 a vu sa production grimper relativement pour atteindre presque 26182 tonnes en 2003 (presque autant que la pêche artisanale).

Si on compare les pertes de la pêche artisanale aux gains du chalutage, on note une diminution globale des captures en ressources halieutiques de 8000 tonnes (OTEDD). Cette perte est compensée à partir de 2005 par la production de poisson bleu (petits pélagiques) grâce à l'acquisition de 100 sardiniers.

Quant aux ressources démersales, on a signalé une exploitation intense au niveau du golfe de Gabès et l'aggravement du conflit entre la pêche artisanale et la pêche au chalut.

En effet devant la rareté des ressources, l'augmentation du prix des carburants ainsi que le vieillissement de la flotte, le chalutage benthique dans les faibles profondeurs du Golfe de Gabés s'était accentué au cours de ces dernières années, causant une détérioration de l'écosystème marin, et la destruction des engins des pêcheurs artisans.

Face à l'inertie des gestionnaires de la pêche, certains pêcheurs artisans ont changé l'armement de leurs embarcations: ils se sont transformés en petits chalutiers (appelé kyss en arabe), aggravant d'avantage l'érosion des ressources halieutiques, dans le Golfe de Gabés notamment.

Pour redresser la situation des ressources affectées par ce type d'exploitation, différents outils sont mis en place pour rétablir les stocks et lutter contre la surpêche et la pêche illicite, non déclarée et non réglementée (INN) qui appauvrit les stocks de poissons, détruit les habitats marins, entraîne une distorsion de concurrence pour les pêcheurs honnêtes et affaiblit les communautés côtières, notamment dans le sud tunisien. Deux principaux outils ont été mis en place:

- L'aménagent en récifs artificiels pour restaurer et réhabiliter des zones maritimes endommagées par le chalutage illicite.
- La mise en place du système de suivi et de surveillance des navires par satellite (SSN ou VMS en anglais) en équipant les navires de pêche professionnelle de plus de 15 mètres (LHT) d'un dispositif de repérage par satellite.

L'expérience d'implémentation de ce système en Tunisie est l'objet de cet article.

Les Composantes et Fonctions d'un SSN

Le SSN est un outil qui permet d'assurer le suivi, le contrôle et la surveillance (SCS) des activités halieutiques de manière efficace et rentable. Il fournit à l'institution responsable de la gestion des pêches des informations précises, en temps réel, sur la position et l'activité des navires de pêche dans sa zone de règlementation (source FAO).

Tout programme SSN est constitué d'un centre de surveillance des pêcheries (CSP) et un équipement électronique de bord installé de façon permanente à bord de chaque navire de pêche. Presque tous ces types d'équipement de bord utilisent des technologies par satellite.

Les données du SSN sont envoyées à un satellite, transmises à une station sur le terrain, puis elles sont automatiquement acheminées au CSP par le fournisseur de services de communications. Les données sont reçues en temps quasi réel à des intervalles prédéterminés. Elles sont stockées dans une base de données centralisée qui permet au CSP de passer en revue et d'examiner les emplacements géographiques précédents et actuels des navires.

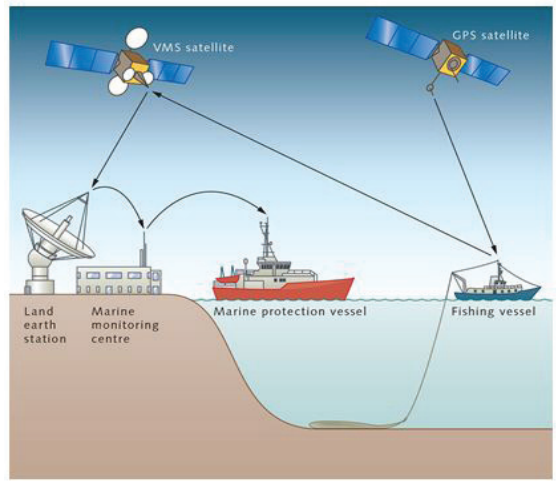


Figure 2 : les composantes du SSN (source worldoceanreview.com)

Mise en Place du SSN en Tunisie

En 2003, la Tunisie a testé un équipement de base utilisant le réseau national GSM. Cette équipement, construit par une start-up tunisienne, a permis de reconnaitre l'utilité du SSN pour le contrôle des navires mais aussi d'élaborer un référentiel d'exigences techniques à partir du besoin de l'administration. L'équipement utilisé a démontré les limites de l'usage du réseau téléphonique bi-mode Satellite/GSM GSM.

Figure 3 : le premier équipement testé à bord de 6navires de pêche (source Ministére de l'Agriculture Tunisie)

En 2004, les termes de référence technique ont été élaborés, elles définies clairement les besoins de l'administration et exigent un développement spécifique de toutes les composantes du SSN national. L'exécution du projet, confié en 2006 à une entreprise tunisienne, s'articule sur deux phases:

Première phase: conception et installation de toutes les composantes du système et son expérimentation sur 20 navires pilotes pour tester et valider le SSN.

Deuxième phase: Extension du système sur tous les navires ayant une longueur supérieur à 15m de LHT.

Les Caracteristiques Techniques du SSN National

1. Le centre de surveillance des pêcheries (CSP): est doté d'équipement et applications suivantes:

a. un serveur SSN raccordé à 3 lignes spécialisées « CSP/CSC » et une antenne pour permettre le rapatriement des demande de détresse via le satellite INMARSAT dans le cas d'une coupure de la liaison Internet "CSP/LES". Cette antenne a été installée sur le toit des locaux de l'administration.

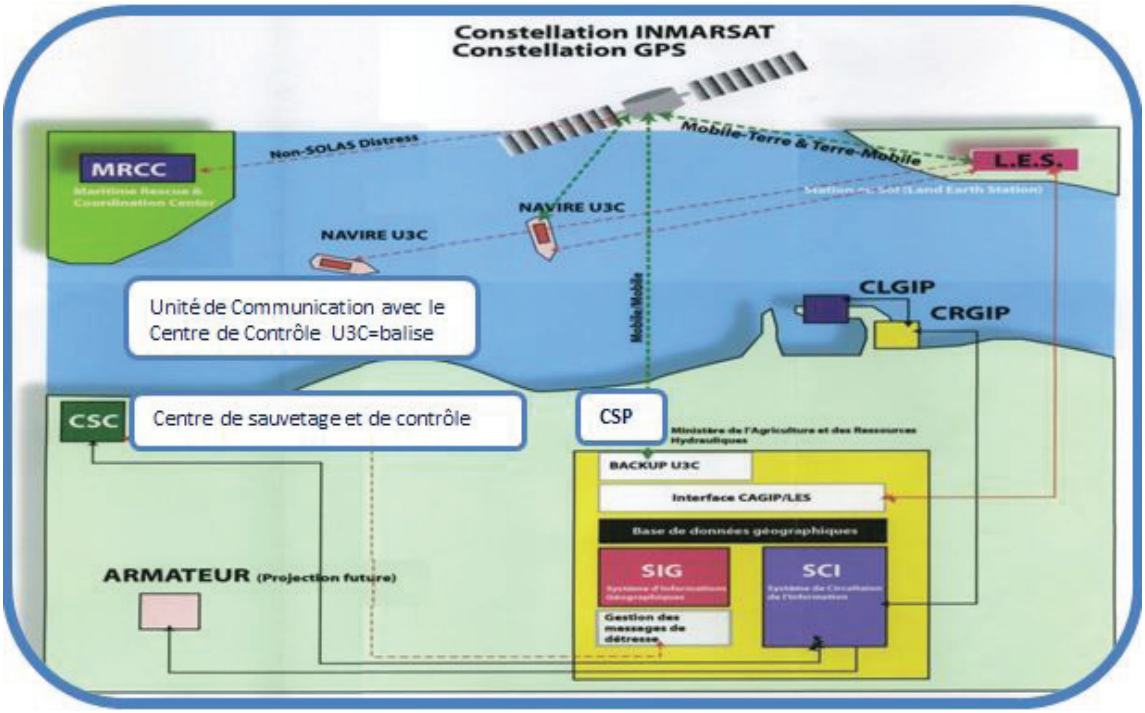
b. INTERFACE CSP/LES: C'est l'application qui permet de relier les interfaces "utilisateur" à la base de données et au système de communication. En effet, Cette application reçoit les messages relayés par la station satellite terrestre (LES) et qui sont initiés par les équipements (U3C) à bord des navires. Les messages bruts sont par la suite prétraités par le module "décryptage, décodage, décompression" pour les rendre lisible et utilisable. Les messages sont aussitôt pris en charge par le module "Interprétation" pour, extraire les informations, les mettre en forme puis les insérer dans les tables et les champs qui leurs sont dédiés dans la base de données centrale.

   Dans le sens opposé "CSP/U3C", cette application se connecte à "LES" de l'opérateur satellite pour effectuer les opérations de changement de configuration des U3C et l'envoi de tout autre message vers l'ensemble des navires.

   Pour le suivi de l'état de fonctionnement global du système le module "contrôle" vérifie continuellement les états d'interconnections du système pour en aviser les différents centres de contrôle.

   Cette application intègre un module "détresse" qui se charge de gérer et d'acheminer les messages de détresse en temps réel vers les différents centres d'intervention.

c. BASE DE DONNEES GEOGRAPHIQUES: Le système de gestion de base de données utilisé est "PostgreSQL" qui est un SGBD relationnel et qui permet, entre autre, de gérer la concurrence d'accès, la réplication, et l'intégration native des données géographiques.



d. SYSTEME D'INFORMATION GEOGRAPHIQUE (SIG): a été déployé pour subvenir aux besoins du SSN en informations géographiques tel que :

- Délimitation des eaux territoriales tunisiennes,
- Délimitation des zones de mouillage pour les chalutiers
- Délimitation des zones de pêche interdites selon le mode de pêche et les campagnes périodique,
- Délimitation des zones interdites à la navigation pour les chalutiers.

Le SIG/SSN permettra aussi d'effectué des opérations d'analyse avancées sur les informations à références spatiales rapatriées à partir des U3C.

Le logiciel SIG utilisé est GRASS/QGIS (Geographic Resources Analysis Support System) qui est un système d'information géographique libre sous licence GPL supportant une panoplie de formats de données standard et commerciaux (ERDAS LAN, SPOT, ARC/INFO…)

e. SYSTEME DE CIRCULATION DE L'INFORMATION : fonctionne sur la plateforme Linux. Il est constitué d'une interface de consultation et de suivi à distance des navires. Il s'agit d'un progiciel de diffusion et de monitoring des données géostatistiques sur Intra-Internet. C'est un système conçu avec une vision modulable pour permettre son extension par l'ajoutant de nouveaux modules et fonctionnalité.

Ce système constitue le cœur battant du CSP. En effet, il permet aux autres acteurs sur le continent de consulter et de saisir, si besoin, les informations sur les navires, les équipages, les infractions notées, la consommation de carburant, etc.

Le système de circulation de l'information est développé suivant une architecture trois tiers (Serveur d'applications/Serveur de données/Client léger). Le client, en consultation ou en administration, n'a besoin que d'un navigateur web pour se connecter au système.

Interface de consultation: Cette interface permet de visualiser les informations

géographiques. Il s'agit d'une interface graphique avec de nombreuses fonctions d'assistance, qui permettent de:

- Afficher les dernières positions reçues sur un fond cartographique personnalisable.
- Afficher des cartes relatives à l'exercice de pêche (eaux territoriales, zones réglementées etc.)
- Gérer le journal d'événements et permet la génération d'alerte en cas de problème
- Effectuer des opérations classiques de visualisation (ZOOM IN/OUT, PAN, etc.)
- Cadrer automatiquement la carte sur le navire choisi.
- Afficher la trajectoire d'un navire.
- Visualiser les alarmes reçues (entrée de zone interdite par exemple),
- Importer/Exporter des données permettant l'usage des environnements bureautiques (Tableur/Excel, Word de MSWORD ou celui d'OpenOffice, PowerPoint, etc.)

Interface d'administration : Cette interface permet à l'utilisateur du système d'effectuer des opérations de mise à jour et d'intégration des informations dans la base de données centrale. Cet outils permettent l'administration et la gestion de:

- Des navires (Type, nom, classe, propriétaire …).
- Des historiques (marée, capture, infraction …)
- Des personnes
- Des zones (zones de pêche, zones interdites, …)
- Des informations de références (port, gouvernorat, communication ….)

f. MODULE DE COMMUNICATION CPC / ICCAT : Ce module a été réalisé pour répondre au besoin de communiquer/ transférer les positions des navires de pêche au thon ainsi que leur cap et vitesse vers la base de données de La Commission Internationale pour la Conservation des Thonidés de l'Atlantique (ICCAT) pendant la saison de pêche du thon rouge. Les rapports de positions sont formatés et envoyés vers l'ICCAT dès leur réception par le CSP (dénommé CPC par l'ICCAT). Cette application prend en charge le contrôle du bon déroulement de la communication des rapports de position vers l'ICATT.

g. SYSTEME DE GESTION DES MESSAGES DE DETRESSE: est principalement utile à la diffusion des messages de détresse. Il permet aussi de recueillir les infractions détecté pour informer les CSC.

2. CENTRE DE SAUVETAGE ET DE CONTROLE (CSC): a été équipé d'un ordinateur (Système d'exploitation Linux) et possède un accès en consultation au système de circulation de l'information (interface de consultation) via la liaison spécialisée. Il dispose du module de traitement des messages de détresse en provenance du CSP pour :

- La réception des messages de détresse en temps réel par tous les CSC
- L'impression directe des messages de détresse sur support papier,
- Le suivi de l'état des interconnections du système

Le CSC a la responsabilité du suivi et la coordination des détresses reçus par le SSN. Il a une indépendance dans le traitement des messages de détresse. En effet, une antenne a été reliée à son ordinateur pour permettre le rapatriement des demandes de détresse via le satellite INMARSAT dans le cas d'une coupure de la liaison spécialisée "CSP/CSC".

3. LES EQUIPEMENTS A BORD DES NAVIRES DE PECHE (U3C): permettent la communication avec le CSP. L'U3C est composée principalement de deux parties une antenne de communication et d'un boîtier d'interfaçage et de contrôle.

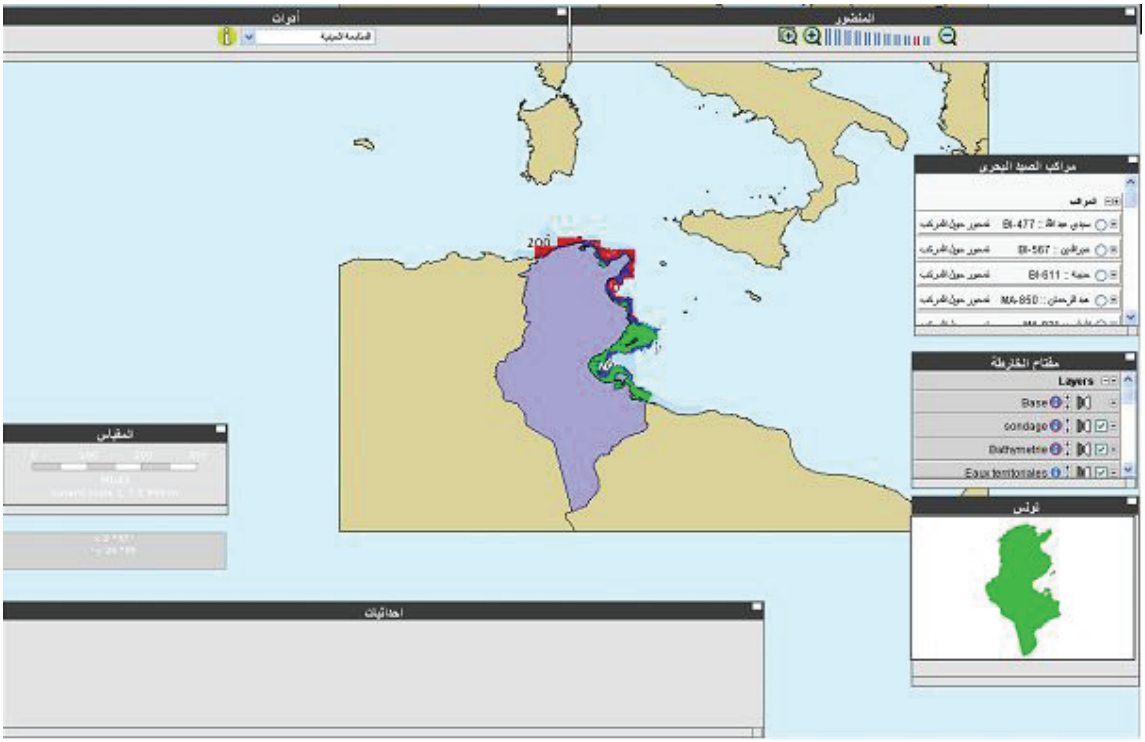


Figure 5 : L'interface de suivi des mobiles (source DGPA 2013)

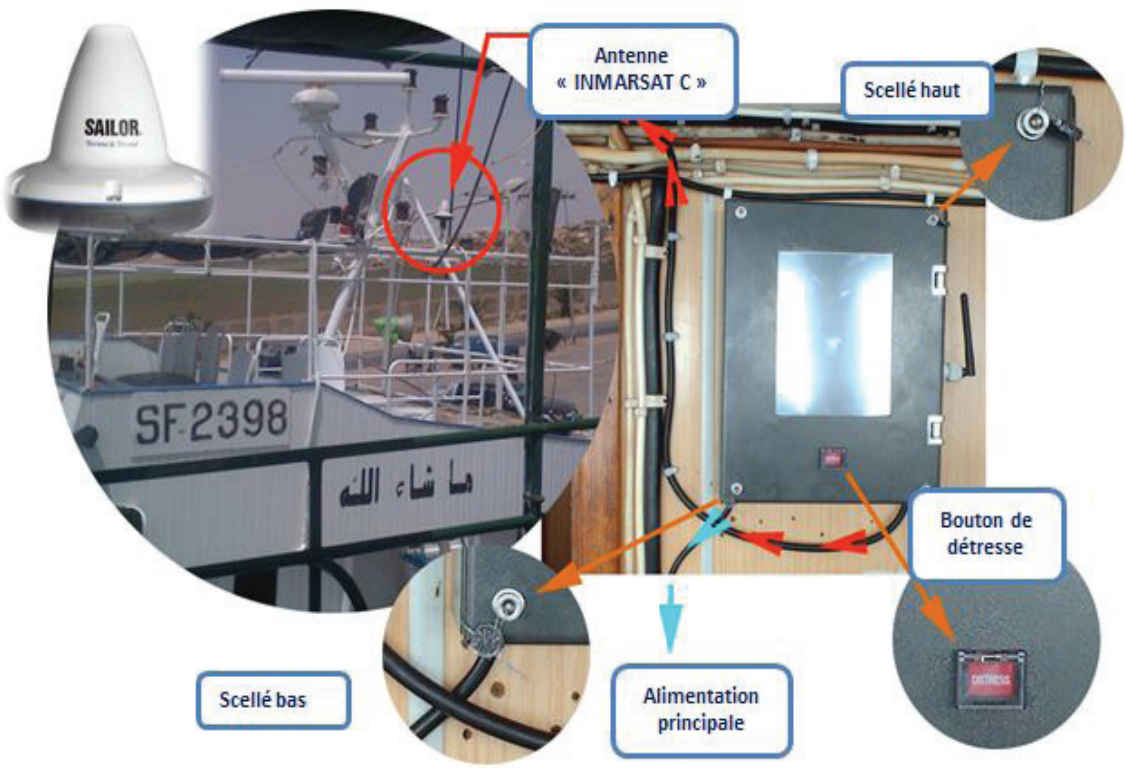


Figure 6 : Architecture générale du SSN national (source DGPA 2013)

a. **L'antenne de communication:** Il s'agit d'une antenne marine externe "TT3026D" intégrant l'électronique nécessaire au bon fonctionnement du module de communication, et le module de positionnement GPS (antenne et électronique). Cette antenne assure à la fois l'émission et réception de données via le satellite INMARSAT ainsi que la mesure de la position du navire en utilisant le système GPS.
   Assemblé dans un boîtier en fibre de verre non oxydable. Ce boîtier est fermé sous vide, ce qui rend pratiquement impossible son ouverture (ouverture possible seulement par des outils spéciaux) et améliore ainsi son étanchéité.
   Le module ainsi conçu peut supporter les conditions météorologiques, atmosphériques et fonctionnelles rencontrées dans un environnement marin. Cette antenne est montée à l'extérieur, en hauteur dans un espace dégagé.
b. **Terminale d'interfaçage et de contrôle (NAWRAS):** est installé à l'intérieur de la passerelle du navire. Il est connecté d'un coté à l'antenne par un câble qui assure l'exploitation et l'alimentation de ce dernier et d'un autre côté, aux accumulateurs du navire qui assure son alimentation en courant continue de 24V. Ces câbles sont montés à l'intérieur du boîtier via des presse-étoupes pour éviter les infiltrations d'eau vers l'intérieur de la terminale.

Ce Terminale d'interfaçage est contenue dans un boîtier étanche et sellé contenant les composantes suivantes :

- **Un circuit d'alimentation:** qui assure l'alimentation en 12V de l'antenne et de l'unité centrale. Il permet de :
  - » Convertir les courants 24V du navire en un courant de 12 V stable
  - » Convertir les courants 12V de la batterie interne en un courant de 12 V stable (dans le cas de panne de l'alimentation principale)
  - » Bascule automatiquement et sans coupure entre l'alimentation principale (24V du navire) et le courant de secours (12V de la batterie interne)
  - » Fonctionne avec un courant de 9-36 V (courant nominal 24V)
  - » Isole une surtension de 1500 VDC
  - » Supporte les sur-ampérages, les courts-circuits et l'inversement de l'alimentation
- **Un circuit d'alimentation de secours:** Ce circuit est composé d'un circuit de charge et d'une batterie de secours. Le chargeur alimenté par les 24V du courant principal assure la charge de la batterie de secours et son maintien en bon fonctionnement. Il détecte l'état et la qualité de l'alimentation principale de la batterie pour alerter l'unité centrale de tout disfonctionnement. Ce circuit est capable de prendre en charge le fonctionnement de l'U3C pour une période dépassant les 7 jours. La batterie de secours est une batterie de "12V 7AH étanche", conçue pour un usage extrême sans maintenance.
- **Une unité centrale:** Articulé autour d'une carte processeur ARM cadencé à 200MHz. Elle comprend 2 ports série

Figure 7 : Terminal d'interfaçage et de contrôle de l'U3C (source DGPA2013)

RS232, 8 ports numérique et 4 entrée/ sortie analogiques configurables. Elle contient une mémoire non volatile de 128MB pour la sauvegarde de données. La carte est conçus pour fonctionnée dans un environnement rustre. Elle intègre un système d'exploitation LINUX embarqué temps-réel permettant une gestion efficace et robuste.

Elle reçoit toutes les informations au niveau du navire ou les messages de commande et de configuration reçus par l'antenne. Elle prend en charge:

- » La mise en forme de tous les messages et rapports qui seront envoyé au CSP.
- » Elle exécute les requêtes et configurations envoyées par le CSP.
- » Crypte, décrypte, compresse et décompresse les données qui transitent via le satellite.
- » Inspecte continuellement les états des instruments qui lui sont reliés et consigne les anomalies observées.
- » Détecte les violations (ouverture boîtier, coupure de l'alimentation principale, etc.)
- » Détecte la position du navire et exécute les actions définies selon la zone de navigation.

- **Une unité de stockage:** Il s'agit d'une mémoire flash pour le stockage des données suivantes :
  - » Les fichiers shapefile relatifs à l'exercice de pêche (zone portuaire, zone réglementée, zonage maritime …)
  - » Les fichiers de configuration.
  - » Les messages EGC du satellite reçus par l'antenne
  - » Le journal des états des instruments à bord.
- **Une unité d'affichage:** C'est un écran tactile qui assure l'interfaçage homme/ machine. Il affiche les messages et les avertissements. Pour attirer l'attention de l'équipage, tout nouveau message apparu sur l'écran est accompagnée d'un bip sonore.
- **Un circuit de détresse:** Le bouton de détresse, monté directement sur le terminal permet de déclencher la demande de détresse. Un contact doublé assure l'acheminement de l'information à l'unité centrale. La détresse n'est prise en compte qu'après maintien du bouton appuyé pour éviter les fausses manipulations. Un signal lumineux au niveau du bouton ainsi qu'un signal sonore pour informer "le capitaine" de la transmission du message de détresse. Les capteurs Un ensemble de capteurs sont installés pour détecter les anomalies et les violations. Ils sont reliés directement à l'unité centrale qui prend en charge l'exécution des procédures nécessaires.

D'autres capteurs peuvent être intégré au système pour rapatrier d'autre mesure (tel que profondeur, régime moteur, fonctionnement treuil). Ces capteurs peuvent être numériques ou analogiques et peuvent même être audiovisuels (camera, micro …).

Les Resultats Obtenus

Après la réussite de la phase pilote, la solution technique a été validée. Actuellement 60 navires de pêche tunisiens sont équipés des U3C dont la majorité sont des thoniers. Jusqu'à ce jour nous n'avons observé aucun problème de fonctionnement majeur, sauf quelques pannes matériel qui ont été observées et immédiatement réparées. L'équipe technique a même intervenu en haute mer pour la maintenance du système afin de garantir un fonctionnement continuel.

Depuis son installation la solution SSN national fonctionne normalement et aucun signe de dysfonctionnement majeur n'a été observé. Bien que l'expérience tunisienne en matière de suivi des navires de pêche est considérée relativement jeune, elle a présenté des signes de maturité notamment au niveau de la robustesse des équipements embarqués et des mécanismes d'envoie et de suivi entre les U3C et le CSP. Le SSN national a donné les performances suivantes :

1. **SYSTEME CENTRAL:** Le système central été stable pendant toute la phase pilote. Mais le choix judicieux du matériel et des plateformes logicielles laisse une grande marge de manœuvre quant à la montée en charge du système impliquant des améliorations précises et mineures du système. Il est aussi possible d'envisager un doublement des ressources afin d'améliorer l'opérationnalité du système avec une solution Haute Disponibilité locale et un autre serveur jumeau dans une localisation physique différente pour se prévenir contre tout désastre.
   Une seule panne a été observée et réparée au niveau du serveur. Elle consiste au blocage du serveur suite à la saturation de son disque dur. Nous avons constaté que l'augmentation continuel de la taille des fichiers « historique des accès » (log) relatif au serveur web sont à l'origine de ce défaut. Cette panne a été réparée en utilisant la technique de rotation du log. Cette technique a permis de limiter la taille de ce fichier.
2. Les U3C installées ont fonctionné d'une façon continue pendant la phase pilote. Un ensemble de tests ont été réalisés. Ces essais fonctionnel consistent principalement en :

- Autonomie, l'U3C peut fonctionner pendant plus de 7 jours sans alimentation principale,
- Configuration particulière par zone : par exemple dans les zones portuaires, si l'U3C est configuré pour envoyer un rapport périodique de position, elle arrête l'envoi de ce type de rapport tant qu'elle se trouve dans la zone portuaire,
- Détection de franchissement: par exemple l'U3C détecte l'entré d'une zone et peut envoyer un rapport au CSP selon la configuration choisi. Le rapport début de marée/fin de marée envoyé au franchissement de la limite de la zone portuaire,
- Réaction par rapport aux capteurs: par exemple le rapport open-move box envoyé à l'ouverture ou au déplacement du boîtier,
- Actionnement manuel: Par exemple message de détresse envoyé après un appui prolongé sur le bouton de détresse.
- Enregistrement de données: par exemple journal des états des instruments
- Aucune panne ou anomalie n'a été observée pendant la période de test.
- Fonctionnement sans interruption en cas de transition courant principale / courant de secours et vice versa.
- Les contrôles réguliers ont montrés que tous les circuits sont intacts après la phase pilote, d'où l'efficacité des différents mécanismes de protection mis en œuvre.

3. **Les Rapports échangés:** Tous les messages qui ont transités par le système ont été stockés dans la base de données du CSP. 6000 messages ont été reçus dont 400 messages de détresse (test) et 500 messages ont été envoyés.

a. Messages émis par le CSP: Ce sont des messages ou requêtes de configuration qui peuvent être envoyé à un navire donné ou à tous les navires enregistrés dans un groupe d'appel.

- Demande de position (pooling): Il est aussi possible d'envoyer cette demande aux navires situés dans une zone géographique circulaire ou rectangulaire. Toute U3C réagit automatiquement à la réception de ce message et envoi un rapport de position.
- Déclenchement de l'envoi automatique de rapport de position: Toute U3C réagit automatiquement à la réception de ce message et déclenche l'envoi automatique de rapport de position en respectant la dernière résolution temporaire reçue.
- Arrêt de l'envoi automatique de rapport de position: Toute U3C réagit automatiquement à la réception de ce message et déclenche la suspension de l'envoi automatique de rapport de position.
- Résolution temporelle de l'envoi automatique de rapport de position: Toute U3C réagit automatiquement à la réception de ce message et modifie la résolution temporelle de l'envoi automatique de rapport de position.

- Acquittement: C'est un accusé de réception envoyé à un navire en détresse. L'U3C informe l'équipage de cet acquittement visuellement à l'écran et par un bip sonore spécifique.

b. Message émis par l'U3C: Tous les rapports mis en forme par l'U3C sont envoyés au CSP. Ces rapports sont traités pour en extraire les informations à intégrer dans la base de données. Les CSC via le système de circulation de l'information peuvent accéder à ces informations. Dans le cas des messages de détresse, ils sont pris en charge par le module de détresse pour être directement acheminer vers les CSC.

- Rapport de position: (automatique avec résolution temporaire configurable à distance ou sur demande) comprend les informations suivantes :
  - » l'identité du navire,
  - » la date et l'heure de mesure de chaque position du navire,
  - » les positions du navire (longitude et latitude).
  - » Affichage de l'itinéraire sur carte
- Rapport de la marée (sortie en mer): comprend les informations suivantes :
  - » l'identité du navire,
  - » date et heure de départ,
  - » départ et port de partance,
  - » durée de la marée,
  - » Positions intermédiaires
  - » date et heure de retour au port,
  - » accostage et port d'accostage
  - » analyse de la marée du navire selon sa vitesse, son cap, les opérations de pêche déclarées, et l'état de la mer (présentations graphiques).
- Rapport d'infraction à la pêche (émis automatiquement à l'introduction dans la zone réglementée) comprend les informations suivantes :
  - » l'identité du navire,
  - » les infractions à la pêche commises en indiquant date et heure et positions :
  - » pêche dans une zone interdite
  - » navigation dans une zone interdite
  - » mouillage dans une zone interdite

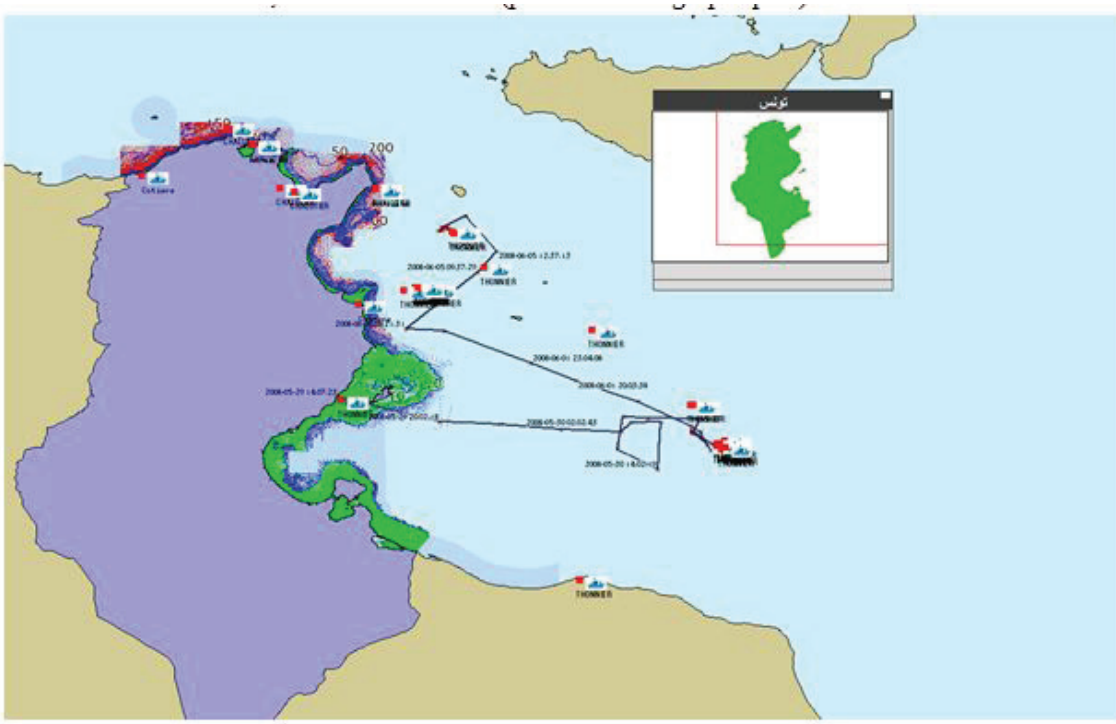
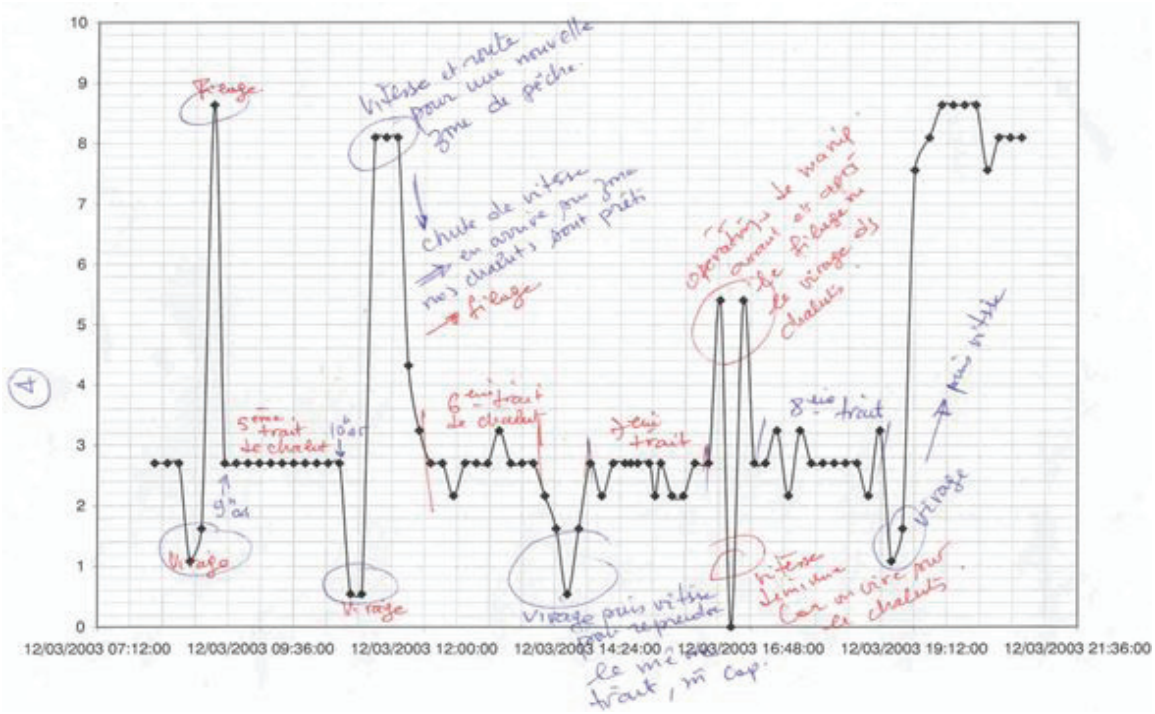


Figure 8 : Résultat de suivi d'un navire de pêche (source DGPA 2013)



L'analyse des vitesses d'un chalutier peuvent dégager ses manœuvres de pêche d'une manière géoréférencée.

Fig. n°9 : Courbe des vitesses d'un chalutier dans la zone de pêche illustrant ses manœuvres : filage de train de pêche, halage, virage et route vers la zone de pêche (source N. Haddad)

- Rapport d'un navire en infraction à la sécurité (émis automatiquement à l'infraction) comprend les informations suivantes :
  - » l'identité du navire,
  - » la dernière position du navire enregistrée (position, date et l'heure de mesure)
  - » Infractions possibles :
  - » Au niveau du système de positionnement
  - » Au niveau du système de communication
  - » Identité erronée
- Journal de l'état des équipements à bord
  - » l'identité du navire,
  - » date d'installation de l'U3C
  - » date de panne
  - » motif de la panne
  - » date de remise en état
- Rapport d'un navire en détresse (émis à l'appui prolongé sur le bouton de détresse)
  - » l'identité du navire,
  - » la date et l'heure du déclenchement du bouton de détresse,
  - » la position du navire (longitude et latitude) en continu

D'autres informations peuvent être intégrées dans le système de circulation de l'information via des applications tierces au niveau des entités qui les détiennent et/ou via des interfaces de saisie sur le système installé au niveau du CSP :

- Rapport météorologique national: (Ce rapport peut être envoyé par zone)
  - » Etat de la mer
  - » Vitesse et direction du vent
  - » Correspondance à l'échelle Beaufort
- Rapport d'information sur les autorisations du navire
  - » l'identité du navire,
  - » zone de pêche autorisée
  - » Type du permis de pêche
  - » validité du permis de pêche
- Rapport d'information sur l'équipage du navire

  - » l'identité du navire,
  - » Les identités de chaque membre d'équipage,
  - » Les infractions commises par chaque, membre d'équipage.
- Rapport d'approvisionnement en carburant subventionné
  - » l'identité du navire,
  - » port d'approvisionnement en carburant subventionné,
  - » quantité et montant,
  - » Date
- Rapport des captures du navire
  - » l'identité du navire,
  - » Les captures réalisées (espèce, quantité, qualité),
  - » date et heure de début et de fin de la marée,
  - » port de débarquement.

Coût des transmissions

La compression des messages échangés ont permis de réduire le coût des transmissions d'à peu près le tiers (1/3). Nous présenterons ci-dessous un coût estimatif de la communication

Désignation	Coût
Frais mensuel de raccordement	20 $
Un message court navire-terre (tel que rapport de position, de détresse…)	0.02 $
Un message court terre-navire (tel que demande de position, configuration…)	0.08 $

Ces prix sont approximatifs vue que nous n'avons pas encore reçu de factures, il sont données à titre indicatif.

Conclusions et Recommandations

Le Système mis en œuvre a fait preuve de robustesse, efficacité, maniabilité, d'extensibilité et stabilité. Le système est capable d'assurer le rapatriement et le stockage dans une base de données structurée (les informations relatives à l'exercice de pêche des navires). Dans le souci d'atteindre un niveau optimal d'opérationnalité, plusieurs points fonctionnels, matériels, et humains doivent nécessairement être étudié et éclairci :

- Etablissement de procédures de suivi et de contrôle des navires de pêche : Il s'agit d'instaurer des manuels de procédures pour gérer certaines situations (Navigation suspecte dans une zone réglementée, détresse …)
- Clonage du serveur CSP pour assurer la continuité de fonctionnement en cas de panne et le rendre capable de gérer plusieurs types de fournisseurs satellitaires.
- Dédoublement des moyens de communication CSP/CSS pour une meilleure fiabilité du réseau de communication central.
- Une liaison INTERNET par satellite au niveau du CSP est souhaitable pour surmonté tout aléa de la liaison Internet CAGIP/LES.
- Le SSN est une solution matérielle et logicielle de pointe qui doivent être uniquement fournis à un personnel qualifié ou confié à un prestataire privé dans le cadre d'un partenariat Public-Privé.
- L'élaboration d'un cadre de référence de la collecte et d'échange de données au niveau d'un SSN centralisé de la méditerranée sous la tutelle de la commission générale des pêches pour la méditerranée (CGPM). Un cadre d'interopérabilité entre les systèmes opérationnels dans les différents pays de la méditerranée doit être élaboré.

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KNOWLEDGE MANAGEMENT AND INVESTING IN HUMAN CAPACITY DEVELOPMENT FOR AQUACULTURAL EDUCATION AND TRAINING IN AFRICA

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Abstract

The rapid growth of the aquaculture industry, whilst driven by emerging market opportunities, has been enabled through developing knowledge and application of new scientific and technological innovations supported by private and public investments. While there are numerous initiatives directed at accessing, managing, documenting, publishing, communicating and disseminating research information and data, the present scale of 'knowledge management' is insufficient to achieve wide accessibility and use, particularly in Sub-Saharan Africa. Paradoxically, too much potentially valuable knowledge produced by committed researchers languish in libraries, unused by society; and too many of society's greatest needs for new knowledge remain relatively unexplored by researchers. In this paper, we review recent initiatives to promote sustainable aquaculture development through improvements in education and training capacity, and innovations in the use of new web-based technologies, with emphasis on use of digital e-learning tools. At the broad level, we present three development trends likely to shape the sector: educating for global competencies; knowledge sharing via use of Web 2.0 technologies and open learning resources; and emerging role of flexible and lifelong learning. The paper also present use of various digital e-learning platform tools and websites that are expected to change aquaculture education and knowledge exchange. Finally, we offer four recommendations to increase aquaculture knowledge exchange and human capacity building in Africa: (1) promote networking and mobility in aquaculture education and research; (2) develop new generic skills and competencies approaches; (3) continued professional development via eLearning and other innovative approaches; and (4) position lifelong learning in aquaculture studies.

Keywords: Aquaculture, Knowledge management, capacity development, education, training, e-learning

GESTION DES CONNAISSANCES ET INVESTISSEMENT DANS LE DÉVELOPPEMENT DES CAPACITÉS HUMAINES POUR L'ÉDUCATION ET LA FORMATION EN AQUACULTURE EN AFRIQUE

Resume

La croissance rapide de l'industrie de l'aquaculture, stimulée par les débouchés émergents, a été facilitée par le développement des connaissances et l'application de nouvelles innovations scientifiques et technologiques appuyées par des investissements privés et publics. Bien qu'il existe de nombreuses initiatives visant à accéder, à gérer, à documenter, à publier, à communiquer et à diffuser les informations et les données de la recherche, le niveau actuel de la « gestion des connaissances » n'est pas suffisant pour permettre une large accessibilité et une utilisation accrues, en particulier en Afrique subsaharienne. Paradoxalement, une importante partie des

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connaissances potentiellement précieuses produites par des chercheurs engagés languit dans les bibliothèques, inutilisées par la société ; et un trop grand nombre d'importants besoins de la société en matière de connaissances nouvelles demeurent relativement inexplorés par les chercheurs. Dans cet article, nous examinons les initiatives récentes visant à promouvoir le développement durable de l'aquaculture par l'amélioration de la capacité d'éducation et de formation et les innovations dans l'utilisation de nouvelles technologies basées sur l'Internet. Au niveau général, nous présentons trois tendances de développement susceptibles de façonner le secteur : l'éducation pour les compétences globales ; le partage des connaissances grâce à l'utilisation de technologies Web 2.0 et de ressources d'apprentissage ouvert ; et le rôle émergent d'un apprentissage flexible et durable (tout au long de la vie). Le document présente également l'utilisation de divers outils de plateforme d'apprentissage numérique en ligne et de sites internet susceptibles de changer l'éducation aquacole et l'échange de connaissances. Enfin, nous proposons quatre recommandations visant à accroître l'échange des connaissances en aquaculture et le renforcement des capacités humaines en Afrique : (1) promouvoir la coopération en réseau et la mobilité dans l'éducation et la recherche en aquaculture ; (2) développer de nouvelles approches génériques de connaissances et de compétences ; (3) poursuivre le perfectionnement professionnel via l'apprentissage en ligne et d'autres approches novatrices ; et (4) le positionnement de l'apprentissage tout au long de la vie dans les études de l'aquaculture.

Mots-clés : aquaculture, gestion des connaissances, développement des capacités, éducation, formation, apprentissage en ligne

Introduction

Aquaculture is the fastest growing food-supply industry in the world with an annual average growth rate of 8.6 percent over the last three decades (FAO, 2014; Troell *et al.,* 2014). The Food and Agriculture Organisation of the United Nations (FAO) defines aquaculture as "the farming of aquatic organisms such as fish, crustaceans, molluscs and aquatic photosynthetic organisms" (FAO, 2002). Global aquaculture production reached 73.8 million tons in 2014, nearly 50 percent of global fish production, with an estimated value of US$ 160.2 billion (FAO, 2016b). This share is projected to rise to 62% by 2030 as catches from wild capture fisheries level off and demand from an emerging global middle class substantially increases (World Bank, 2013; Kobayashi *et al.,* 2015). A milestone was reached in 2014 when the aquaculture's contribution to the supply of fish for human consumption overtook wild-caught fish for the first time (FAO, 2016b; Golden *et al.,* 2016). Given this milestone, and the fact that world population is projected to reach 9.6 billion in 2050 (UN 2015 Revision of World Population Prospects), aquaculture is understandably receiving considerable attention as a source of food and economic development (Hall *et al.,* 2013). Aquaculture's rapid expansion is often referred to as the 'blue revolution'. Currently, governments and international organisations worldwide are responding to the blue revolution by becoming increasingly interested in expanding aquaculture to foster food security, nutrition and income generation (Krause *et al.,* 2015). The rapid growth of the aquaculture industry, whilst driven by emerging market opportunities, has been enabled through developing knowledge and application of new scientific and technological innovations supported by private and public investments (Bostock and Seixas, 2015; FAO, 2015b).

Several studies have been conducted in the field of aquaculture, fisheries and aquatic resource management to support processes of knowledge creation, knowledge exchange and innovation (collectively known as "knowledge management"), particularly through the processes of education, training and skills development in Europe (Bostock and Seixas, 2015; Eleftheriou and Seixas, 2015; Pita *et al.,* 2015; Seixas *et al.,* 2015). The

practice of engaging knowledgeable and skilled individuals within the aquaculture sector and investing further in developing their capacities is referred to as "investing in human capacity development". Capacity, as we use the term here, includes the capability to act and the competence to do so effectively (van Kerkhoff and Lebel, 2015). Capacity development is a related concept in development that refers to "the process of unleashing, strengthening and maintaining such capacity" (Aerni *et al.,* 2015). Capacity development has become a core aim of development more broadly, reflecting a shift from more technical, top-down "knowledge transfer" approaches to more supportive, bottom-up, endogenous development strategies (van Kerkhoff and Lebel, 2015).

As aquaculture develops and matures, greater emphasis on knowledge management is likely to generate further innovations in education and training in response to technological and social developments (Bostock and Seixas, 2015). Another important concept is "knowledge governance" (as a scale above knowledge management) concerned with the formal and informal rules that govern knowledge processes, including production, sharing, access, and use (van Kerkhoff, 2013). While there are numerous initiatives directed at accessing, managing, documenting, publishing, communicating and disseminating research information and data, the present scale of knowledge management and governance is insufficient to achieve wide accessibility and use, particularly in Sub-Saharan Africa (SSA). Paradoxically, too much potentially valuable knowledge produced by committed researchers languish in libraries, unused by society; and too many of society's greatest needs for new knowledge remain relatively unexplored by researchers (Clark *et al.,* 2016; Tella *et al.,* 2009). A transition toward sustainable intensification in aquaculture is an urgent task that requires mobilizing more and better knowledge of ways to secure and sustain inclusive improvements in human well-being.

In this paper, we review recent initiatives to promote sustainable aquaculture development through improvements in knowledge management, education and training capacity, and innovations in the use of new internet-based technologies, with specific consideration on use of digital e-learning tools. The paper is intended for higher education teachers, administrators, informal educators, policymakers, researchers, graduate students, and all other stakeholders interested in preparing our next generation for the 21st digital century. Becoming better at educating and teaching for global competence involves rethinking practices and recognizing that there are no simple recipes for success. The next section reviews literature on aquaculture status and dynamics at global and regional scales. This is followed by broader analysis of recent trends in tertiary education and training that is expected to shape specific needs of the aquaculture sector. Finally, we offer some perspectives on areas of interest to promote sustainable aquaculture development through improvements in education and human training capacity in Africa.

Aquaculture Status and Dynamics at Global and Regional Scales

The total world fishery production (capture plus aquaculture) is projected to expand over the period 2016–2025, reaching 196 million tonnes in 2025 (FAO, 2016; OECD and FAO, 2014). Surging demand for fish and fishery products will mainly be met by growth in supply from aquaculture production, which is expected to reach 102 million tonnes by 2025. Globally, aquaculture production has doubled every decade for the past 50 years, representing the fastest growing food sector (Bostock and Seixas, 2015; FAO, 2014; Samuel-Fitwi *et al.,* 2012). In the period from 1983 to 2013, capture fisheries production increased from 71.1 to 92.6 million tonnes. Aquaculture production meanwhile expanded from 6.2 to 70.2 million tonnes (FAO, 2015a). Global aquaculture outlook reports by the World Bank projects the total fish supply will increase from 154 million tons in 2011 to 186 million tons in 2030, with aquaculture entirely responsible for the increase (Kobayashi *et al.,* 2015; World Bank, 2013). The FAO and OECD

state that capture fisheries output will rise at lower rates with a projected 5 percent growth by 2022 while the output from aquaculture will increase by 35 percent (OECD and FAO, 2014). However, this global figures masks some important regional distinctions. Asia accounts for nearly 90 percent of global production, with 62 percent coming from China alone (FAO, 2014). Recent statistics reveal that annual aquaculture production growth during 2000–2012 was fastest in Africa (11.4 percent), Latin America and the Caribbean (10 percent) (FAO, 2015). Thus, it can be foreseen that aquaculture will be the main source of fish for human consumption in the next years (Béné *et al.,* 2015).

Although Africa has the fastest growing industry by rate of growth—at more than 20% per year between 2007 and 2014—this is from a low baseline, as the region currently contributes less than 2 percent of global production (FAO, 2016b; HLPE, 2014; Waite *et al.,* 2014). However, the situation is different in Egypt, Africa's largest aquaculture producer, and a major contributor to the higher production volumes reflected by this continent (Ottinger *et al.,* 2016). Africa, however, has large natural resources that offer great potential for aquaculture development in the coming years (AUC-NEPAD, 2014; Brummett *et al.,* 2008; Ottinger *et al.,* 2016). The latest estimate for total aquaculture production in Africa is 1.6 million tons (AUC-NEPAD, 2014). In 2012, FAO reported that ten of fastest growing aquaculture sectors were in Africa (Egypt, Uganda, Kenya, Zambia, Ghana, Madagascar, Tunisia, Malawi and South Africa) (FAO, 2014). African aquaculture production is projected to expand over the projected period by 35 percent (reaching 2.3 million tonnes) due partly to the additional capacity put in place in recent years, but also in response to rising local demand from higher economic growth, and local policies promoting aquaculture (FAO, 2016b).

Trends and Drivers in Tertiary Education and Training

Tertiary education sector, i.e. post-secondary education, is often divided into further education (focusing on technical skill-based training) and higher education (focusing on academic subjects and research-led curricula). Higher education is classed as formal education as it is built around planned programmes involving assessment and accreditation of learning outcomes (e.g. the awarding of degrees, diplomas or certificates at the end of the study period). Formal education may be complemented by non-formal learning (structured/programmed but usually not assessed or accredited) and informal learning (unstructured/non-programmed) which can be particularly important for life and work skills (Bostock and Seixas, 2015). Recognising the role and significance of each type of learning throughout an individual's life and career is important to find ways to better integrate formal and informal learning or forms of instruction. The future of aquaculture education and training, whilst influenced by the specific needs of the sector, will be heavily shaped by broader developments in educational policy, practice and organisation (Bostock and Seixas, 2015). In particular, we present three broad development trends likely to shape the sector: (i) educating for global competencies; (ii) knowledge sharing via use of Web 2.0 technologies and Open Learning Resources; and (iii) promoting flexible and lifelong learning.

Educating for Global Competence

The emergence of a knowledge based economy has put higher education at the centre of policy development in many parts of the world since the beginning of the 21st Century. Globalization, the digital revolution, mass migration, and the prospect of climate instability are triggering new concerns and demanding a new kind of graduate (Mansilla and Bughin, 2011; Mansilla and Jackson, 2013). There is an increasing call for a more powerful and relevant learning in response to these new demands and opportunities (Mansilla and Jackson, 2013; Reimers, 2010). The definition of "Global Competence" proposed by the Economic Co-operation and Development (OECD) encompasses a complex learning

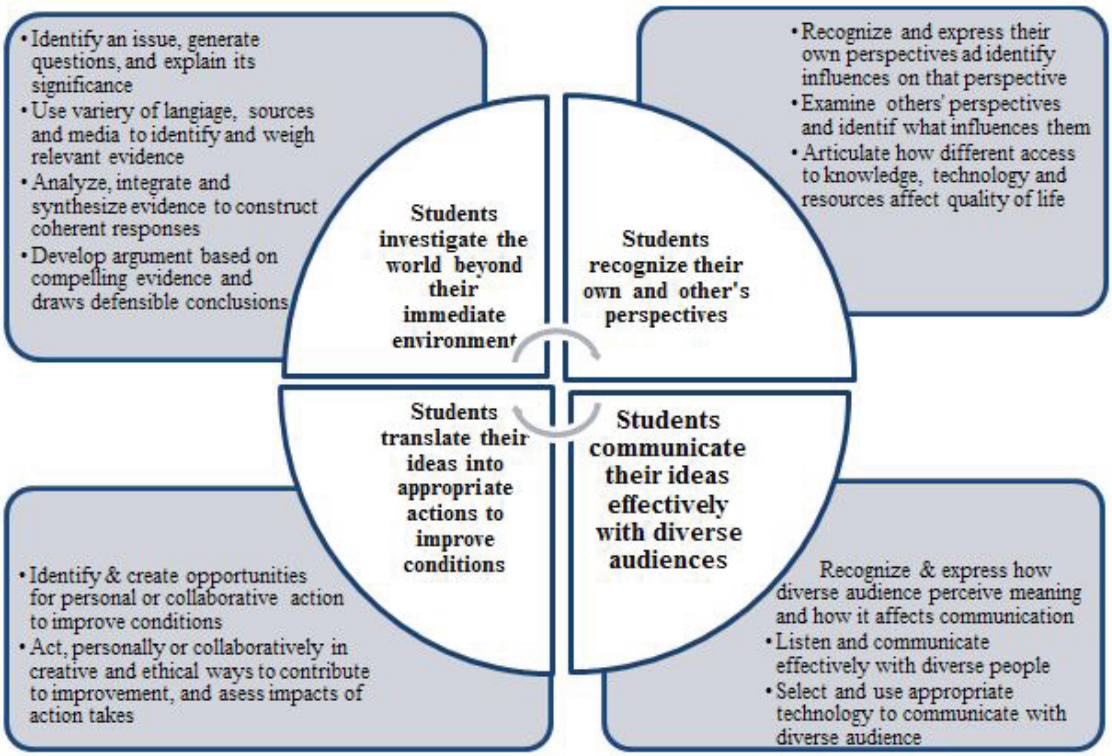

Figure 1: Framework for Global Competence. Modified from: Mansilla and Bughin, 2011

goal: Global Competence (OECD, 2016). is the acquisition of in-depth knowledge and understanding of global and intercultural issues; the ability to learn from and live with people from diverse backgrounds; and the attitudes and values necessary to interact respectfully with others" (OECD, 2016). Specifically, globally competent students are able to perform the following four competences (Figure 1):

i. Investigate the world beyond their immediate environment, framing significant problems and conducting well-crafted and age-appropriate research;
ii. Recognize perspectives, others' and their own, articulating and explaining such perspectives thoughtfully and respectfully.
iii. Communicate ideas effectively with diverse audiences, bridging geographic, linguistic, ideological, and cultural barriers.
iv. Take action to improve conditions, viewing themselves as players in the world and participating reflectively.

The OECD recognizes that the development of Global Competence can also support graduate student employability. Effective and appropriate communication and behaviour, within diverse teams, is already a component of success in the majority of jobs, and will become an even bigger component over the years ahead. Rapidly advancing technologies and global economic and social integration are redefining the scope of communication skills at the workplace. Students thus need to acquire the skills and develop the attitudes to interact effectively and appropriately with people in different countries and with people of different cultures in their local context (OECD, 2016).

Web 2.0 Technologies and Open Educational Resources

In recent decades, the widespread use of the Internet and ubiquitous presence of portable digital devices e.g. computers, laptops, tablets, mobile phones, and digital assistants paired with the evolution of Web

2.0 technologies has opened new avenues for the application of digital e-learning tools, which are expected to change both the teaching and learning experiences (Gaebel, 2014; Seixas *et al.,* 2015). Tella et al. (2009) explore the wealth of literature to exploit the potentials of emerging technologies such as wiki, blog and social networking site (SNS) for knowledge sharing in higher education institutions (HEIs). Seixas et al. (2015) analysed the current status of the use of e-learning and information and communication technologies (ICT) to support learning in aquaculture and aquatic sciences education. The social Web 2.0 technologies and platforms used for knowledge management in aquaculture include social networking sites, blogs, online forums, podcasts, wikis, multi-media platforms, Voice over Internet Protocol (VoIP) systems, games/ simulations, electronic portfolio and social media (Seixas *et al.,* 2015). One notable trend has been the rise of social networking, and in particular professional networking through the Internet (Bostock and Seixas, 2015). The best-known service is probably LinkedIn which has thousands of special interest discussion groups and promotes networking across the usual barriers of organisations, ages and location. For our purposes, we briefly describe some of the new information technologies that offer opportunities for aquacultural education and learning in Table 1.

Open Educational Resources (OER) aim to promote open access to digital educational resources "that are available online for everyone at a global level" (Caswell *et al.,* 2008). The term was introduced by UNESCO (2002), which defined OER as the "technology-enabled, open provision of educational resources for consultation, use and adaptation by a community of users for non-commercial purposes." OER can be full courses, course materials, modules, textbooks, streaming videos, tests, software, and other materials or techniques used to support access to knowledge (McGreal *et al.,* 2013). The use of OER to facilitate the efficient creation, distribution and use of knowledge and information is a recent innovation. Massive Open Online Courses (MOOCs) are one among a wide range of OER that may bring transformation in teaching and learning in HEIs. Although MOOCs have gained popularity in other parts of the world, focus is still in the United States of America, with providers such as Coursera, edX and Udacity not only growing in size, but also developed distinct profiles (Gaebel, 2013, 2014). There are a number of MOOC providers, the four major players are presented in Table 2. So far, the vast majority of MOOC participants are higher education students, former students or upper secondary schools pupils, who are likely to enter higher education (Gaebel, 2014).

The implications of MOOCs for learning and teaching is still unclear, partly because MOOCs are a relatively new development, their use is still in experimental phase and not much research has been published. Since MOOCs generally do not award credits or grades, and therefore no degrees, MOOCs do not replace institutional higher education provision, but supplement it. For example, MOOCs can be used in blended learning within universities, as individual lifelong learning opportunity (predominantly during or after higher education studies) or as a means to reach out to new target groups through continued professional education (Gaebel, 2014). Overall, online learning has not replaced face-to-face instruction, but offers an alternative for learners who are not able to attend "brick-and-mortar" institutions and allows flexibility in teaching and learning.

For students in aquaculture, fisheries and related aquatic resource management courses, the increasing amount of information available requires more effective information management. To find the right information quickly and at the right time, it is necessary to be aware of available and accessible sources of scientific and technical information that are useful for their projects (FAO, 2016a). Scientific and technical information includes all information produced by research and necessary for scientific activity. The main sources of scientific and technical information, including those related to aquaculture and fisheries sectors include: Web of Science

Table 1: Web 2.0 Technologies and platforms used for knowledge sharing in education and online learning. Source: Synthesis of information from (Ajjan and Hartshorne, 2008; Grosseck, 2009; Seixas *et al.,* 2015; Tella *et al.,* 2009 and Wikipedia)

Web 2.0 Technology	Characteristics
Social and professional networking sites	In their simplest form, social networking services have three main components: a profile page where information is posted, a network of relationships that categorizes and connects profile page to contacts (for example, friends, colleague, business associate), and a messaging system that allows communication with profile contacts. Popular social networking sites include Facebook, Twitter, Google+, Instagram, Snapchat, WhatsApp, LinkedIn (for business and professional networking).
Learning Management System (LMS)	LMS are software applications for the administration, documentation, tracking, reporting and delivery of e-learning education courses or training programmes. Digital LMS were mainly created to manage learning content in a central location. Teachers and students can upload and download learning resources and can use collaborative tools. The most common LMS are Moodle and Blackboard.
Blogs	Blogs (abbreviated from weblogs are online user's journal entries or "posts" typically displayed in reverse chronological order (the most recent post appears first) on webpages. In education, a blog can be used to publish articles for discussion, including links to other sites of interest, and others can leave responses. There are many free applications available, such as WordPress, Blogger, which can be used to create a blog.
Podcast	The word "podcast" derives from "POD" (play on demand) and "broadcast". A podcast is a digital medium consisting of an episodic series of audio, video, PDF, ePub, files that end users can subscribe to through web syndication or using special software known as a podcatcher (e.g. iTunes, Feedbook). A podcast can be played online or alternatively downloaded to a computer or a mobile device for on-demand offline playback. The success of the iPod? device popularised the term podcast, as audio podcasts are often listened to on portable media players. One well-known open access application to produce audio podcasts is Audacity.
Mobile handheld devices	Handheld devices can store, process and access data, such as smartphones, conventional mobile phones, tablet computers or personal digital assistants (PDAs).
Wiki	A wiki is usually a web application which allows people to add, modify or delete content in collaboration with others. While a wiki is a type of content management system, it differs from a blog or similar systems in that the content is created without any defined owner, and wikis have little implicit structure, allowing structure to emerge according to the needs of the users. For example, Wikipedia allows users to modify entries by creating a reviewer and editing structure.
Voice over Internet Protocol (VoIP)	VoIP is a category of technologies for delivery of voice communications and multimedia sessions over Internet Protocol (IP) networks, such as the Internet. One of the most extensively used applications is Skype.

Web 2.0 Technology	Characteristics
Multimedia-sharing platforms	These are online applications that allow authors of multimedia materials to share them with other users. They usually offer several levels of accessibility, i.e. materials can be made available to the general public or they can be restricted to smaller audiences. Numerous applications are available on the web to share digital pro- ducts such as photos, videos, sound clips and slide presentations, either with the wider public or with closed user groups where access is provided upon invitation. These applications can, e.g. be used by teachers to share learning resources with students or for exchange of learning materials among the student community. Some of the best-known platforms are video portals—YouTube, photo sharing portals—Flickr and slide presentation-sharing portals—Slideshare.

Table 2: Brief description of major providers of MOOCs and online sources. Given the rapid development, it is impossible to keep up-to-date even in the processes of writing, and only MOOC development up to July 2016 were taken into consideration.

MOOC Provider	Description	Online Sources
Coursera	• Education platform launched in April 2012 that partners with top universities and organizations worldwide, to offer courses online for anyone to take. • As of January 11, 2016 Coursera offers 1,563 courses from 140 partners across 28 countries. • All Coursera courses are "accessible for free"; some have an option to pay a fee to join the "Signature Track". Students on Signature Track receive verified certificates, appropriate for employment purposes.	*https://www.coursera.org/ https://en.wikipedia.org/wiki/Coursera* Accessed on 21/07/16
edX	• Founded by Harvard University and MIT in 2012, offering high-quality courses from the world's best universities and institutions to learners everywhere. • The edX consortium currently comprises more than 90 global partners, including the world's leading universities and non-profits as members. • As of 24 March 2016, edX has more than 7 million students taking more than 700 courses online. • EdX courses consist of weekly learning sequences. EdX offers certificates of successful completion, but does not offer course credit.	*https://www.edx.org/ https://open.edx.org/ https://en.wikipedia.org/wiki/EdX* Accessed on 21/07/16
Udacity	• Udacity is a for-profit educational organization founded in February 2012 to offer MOOCs. • As of 28 April 2014, Udacity had 1.6 million users in 12 full courses and 26 free courseware.	*https://www.udacity.com/ https://en.wikipedia.org/wiki/Udacity* Accessed on 21/07/16

MOOC Provider	Description	Online Sources
	• Udacity used to issue certificates of completion of individual courses, but since May 2014 have stopped offering free non-identity-verified certificate.	
NovoEd	• NovoEd is a for-profit educational technology company, founded in April 2013. The company partners with universities, foundations, and corporations to offer MOOCs as well as small private online courses (SPOCS). • It offers over 400 courses (most of them for a fee) on management, design thinking, sales skills, and other business competencies. • NovoEd's unique selling point is that students can collaborate in small teams and submit assignments with classmates around the world. • In terms of global outreach, NovoEd has over 800,000 learners from over 180 countries formed over 100,000 teams.	*https://novoed.com/* *https://en.wikipedia.org/wiki/NovoEd* *https://novoed.com/corporate-learning* Accessed on 21/07/16

(https://www.webofknowledge.com/), Scopus (https://www.scopus.com/), Google Scholar (https://scholar.google.com/), ResearchGate (https://www.researchgate.net/) and Academia (https://www.academia.edu/). The last two sites combine professional networking with the sharing of research results and more academic discourse. Some of the websites are open archives that allow researchers to share and access scientific output, knowledge, and expertise, and grant an opportunity to access full text of their publications via hyperlinks.

Considering the growing public interest in aquaculture in Africa, professional networking platform—Sustainable Aquaculture Research Networks in Sub-Saharan Africa (SARNISSA) has greatly facilitated knowledge exchange and promoted research and learning among all value chain actors in aquaculture. This project, which was implemented for three years (2009–2012), is still active and draws it membership from all parts of the world, majority representing all major academic institutions and research organizations in Africa. The principle objective of SARNISSA was to strengthen the capacity of African researchers and development professionals by enabling them to have access to information. In addition to a mailing list, there is also a bilingual website for English and French speakers (https://www.sarnissa.org/) which serves as a repository for various information. SARNISSA has capitalized on modern information technology to disseminate knowledge over the Internet as well as in hard copy and by direct contact. For instance, the electronic outreach by the SARNISSA's Facebook page has over 3,330 followers (accessed on 21 July 2016) from among the general public, and the number is growing by the day.

Flexible and Lifelong Learning

The newly adopted Sustainable Development Goals (SDGs) are directly relevant to fisheries and aquaculture and to the sustainable development of the sector, and one goal expressly focuses on the education and lifelong learning. The SDG Goal 4 aims to "Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all". In common with other sectors, there is a growing appreciation

within the aquaculture sector of the need for more responsive, flexible and collaborative approaches to learning and the accreditation of learning that properly respond to the needs of the industry and individuals (Seixas *et al.,* 2012). Concepts of defining lifelong learning (LLL) are gradually evolving from early versions based on learning that take place at all stages of life cycle (from the cradle to the grave) and, in more recent versions that it should be life-wide; that is embedded in all life contexts from the school to the workplace, the home and the community (Laal, 2011). Jarvis (2001) observes that LLL takes place throughout life and is the process whereby human beings create and transform experiences into knowledge, skills, attitudes, beliefs, values, senses and emotions. In general, two separate interpretations of the concept have emerged; (1) all provision of education is viewed in a lifelong perspective and includes all formal, informal and non-formal learning; and (2) LLL is a means of providing a series of activities such as professional upgrading, continuing education, distance education, university courses for junior, mature and senior learners, preparatory courses, and part-time education (Sursock and Smidt, 2010). This approach means that LLL enables students and adult learners to learn at different times, in different ways and for different purposes at various stages of their lives and careers (Omolewa, 2009).

Promoting sustainable aquaculture development through improvements in education and training capacity

The Bangkok Declaration and Strategy on Aquaculture Development (NACA/ FAO, 2000), endorsed in 2000, provide the necessary guidelines to stimulate and promote the development of a sustainable and environmentally friendly aquaculture sector globally. Two of these guidelines are: (a) investing in people through education and training and (b) investing in research and development. The recommendations for education and training included:

- participatory approaches to curriculum development;
- co-operation and networking between agencies and institutions;
- multidisciplinary and problem-based approaches to learning;
- modern training, education and communication tools, such as the internet and distance learning, to promote regional and inter-regional co-operation and networking in the development of curricula, exchange of experiences and the development of supporting knowledge bases and resource materials; and
- a balance of practical and theoretical approaches to train farmers and provide skilled and innovative staff to industry.

Building on these guidelines, we offer four recommendations to increase aquaculture knowledge exchange and human capacity building in Sub-Saharan Africa: (1) promote networking and mobility in aquaculture education and research; (2) develop new generic skills and competencies approaches; (3) continued professional development via e-learning and other innovative approaches; and (4) position lifelong learning in aquaculture studies.

Networking and mobility in aquaculture education and research

Networking, diversity and mobility are essential components for global capacity building in education. Although there is an opportunity to establish close linkages between academic and research institutions in sub-Saharan Africa, significant challenges still remain. While SSA is home to several academic institutions with aquaculture research capacity, they tend to be geographically isolated with minimal networking and sharing of resources (FAO, 2015b). Recent attempts have been made to promote networking and human resource mobility between institutions to promote regional research and teaching capacity. For example, the NEPAD Regional Fish Node (RFN) was established in 2006 at Bunda College in partnership with University of Malawi to develop a regional aquaculture PhD

training programme. The programme supports the training of students from Eastern, Central and Southern Africa to build and strengthen a network of researchers involved in refining and implementing projects to enhance fisheries, aquaculture production and biodiversity. Building on this progress, the World Bank has approved Lilongwe University of Agriculture and Natural Resources (LUANAR) as a Centre of Excellence in Aquaculture and Fisheries Science (AquaFish) (LUANAR News, 2016). With the closure of the NEPAD fisheries desk, the African Union Inter-African Bureau for Animal Resources (AU-IBAR) has taken over the mantle for the Partnership for African Fisheries; with its Aquaculture Working Group (AWG) being a potential platform for coordination aquaculture research in the continent.

At the policy level, the African Union Agenda 2063 recognizes the need to "Catalyse an Education and Skills revolution and actively promote science, technology, research and innovation, to build knowledge, human resources, capabilities and skills for the African century".. To achieve this goal, the Agenda proposes "[…] faster movement on the harmonization of continental admissions, curricula, standards, programmes and qualifications and raising the standards of higher education to enhance the mobility of African youth and talent across the continent by 2025" (African Union Commision, 2014). To kick-off this movement, the Continental Education Strategy for Africa (CESA 2016–2025) was adopted by the Summit of Heads of State and Government of the African Union in January 2016 to provide the framework that links education to the human resource needs of Agenda 2063 and the Sustainable Development Goals (SDGs), as well as national development goals (African Union Commission, 2015). Notably, the Association of African Universities has identified the need to upgrade curricula of African universities to ensure they deliver professionals with skill sets required by the labour market (FARA, 2014). The African Union Policy Framework and Reform Strategy for Fisheries and Aquaculture in Africa also emphasized awareness enhancing and human resource capacity development in the sector as a key policy pillar and is noted that Capacity development is a key building block for creating knowledge, empowerment and enablement for effective participation in decision-making and for improved governance of the fisheries and aquaculture sector. Another laudable attempt that can facilitate intra-Africa mobility and academic integration is AU's recent announced plans to introduce single passport to create a 'continent without borders' by abolishing visa requirements for all African citizens in all Africa countries by 2018. All these efforts can "unlock the gates of higher education" and promote the skills revolution that is required for Africa to harness its youth demographic dividend and build prosperity through building value chains for expanding productive aquaculture sector.

Developing new generic and competencies approaches

The dynamic world faced by new graduates from aquaculture, fisheries and aquatic resource management degrees presents them with new demands and challenges for employability. According to Dearing (1997) key generic skills consist of four components: communication, numeracy, information technology and learning how to learn. Pita et al. (2015) identified additional generic skills relevant to the needs of for graduate employment in fisheries, aquaculture and marine sectors, such as scientific methods, management, career development and practical skills in Europe. The various respondents (employers, students, post-graduates, and university teachers) identified 39 generic skills under investigation as important, with none classified as unimportant (Pita *et al.,* 2015). Additionally, Pita et al. (2015) argued that there remains a need to place generic skills and employability attributes and attitudes at the centre of higher education curriculum. Since most aquaculture production growth is expected to be highest in African countries in the coming years, initiatives should focus on developing generic skills and human capacity to drive the changes via vocational and university

education.

Towards this end, the British Council commissioned a three-year (2013-16) research and advocacy study, "Universities, Employability and Inclusive Development" to explore the role universities can play in promoting graduate employability in four Sub-Saharan Africa countries: Ghana, Kenya, Nigeria, and South Africa (McCowan, 2014). All the four countries have concerns about graduate employability and work readiness of graduates. Employability can be defined as the possession of relevant knowledge, skills and other attributes that facilitate the gaining and maintaining of worthwhile employment. While employers are generally satisfied with the disciplinary knowledge of students, they perceive significant gaps in their information technology (IT) skills, personal qualities (e.g. reliability) and transferable skills (e.g. team working and problem solving). Research carried out in Nigeria has shown a significant 'skills mismatch' between employer requirements and graduates display of skills in the workplace, particularly in relation to communication, IT, decision-making and critical thinking (Pitan and Adedeji, 2012). The extent to which graduate unemployment is due to a skills gap, or to a simple lack of jobs is as yet unresolved (McCowan, 2014).

Nevertheless, the British Council study identified three compelling reasons for enhancing the quality of university education in order to improve graduate student employability. First, there is need to improve the quality of taught courses. Analytical, problem solving and written communication skills, for example, depend on high quality teaching and learning provision. Second, universities can enable a broader learning experience for students. Experiential learning in the community—whether through work attachments, voluntary placements or other experiences—as well as on-campus, through student societies and other extra-curricular activities should be facilitated. Employers increasingly value global perspectives and understanding of diversity and these qualities can be developed through these forms of engagement on campus and beyond. Thirdly it is the provision of targeted employability input by universities. Careers advisory services are an obvious focal point in this regard, as well as job fairs and other interactions with employers. Closer links with employers are urged, to update curricula and involve industry representatives in course delivery and quality work placements. More importantly, transferable skills and critical thinking that will allow graduates to adapt to make a positive impact on a rapidly changing economy and society are essential (McCowan, 2014).

Continued Professional Development via eLearning and innovative approaches

The dependence of researchers on a limited range of formal experimental designs has become a straightjacket when it comes to understanding responses in farmer fields. Several relevant lessons have emerged from a combination of field experiences and scholarly study over the last several decades that provide a rich trove of experiences and approaches to draw on (Vanlauwe *et al.,* 2016). These lessons and experiences range from the pioneering efforts highlighted in the "Green Book" (Patel *et al.,* 2004) that intended to equip young African scholars with an understanding of the complexity of smallholder farming systems to the hundreds of academic programs now addressing complex agricultural systems (Vanlauwe *et al.,* 2016). However, despite the Green Book being around for a decade, the next generation of young agricultural research scientists are still trained in a classical mode to strive to reduce complexity and focus on single factors in heterogeneous farming systems (Vanlauwe *et al.,* 2016).

To build capacity beyond traditional training regimes, new approaches are needed that incorporate additional skills and perspectives to facilitate knowledge creation that is not only academically rigorous, but also usable in practice. Usable knowledge for sustainable development has long been produced by researchers in the absence of formal training, suggesting that informal and experiential approaches should not be underrated (Clark *et al.,* 2016). Many training

models and modes are possible. Clark et al. (2016) suggest that effective training should usually involve some mix of specially developed curriculum materials, innovative ways of integrating those materials into the existing training regimes of researchers, and internships in established programs that are effectively crafting usable knowledge for sustainable development.

As aquaculture is a global activity, substantial scope also exists for more rapid dissemination of innovations through e-learning (Seixas *et al.,* 2012). E-learning has considerable potential to improve learning opportunities for participants in the aquaculture sector. For example, there is little need to travel when pursuing an e- learning course, thus making considerable savings in terms of time, effort and money (Seixas *et al.,* 2015; Seixas *et al.,* 2012). When workers can participate while remaining in the workplace, work flow will suffer less interruption. In addition, learners from different regions can participate and interact within a single virtual classroom, which can help in the exchange of experiences and ideas (Seixas *et al.,* 2012). Moreover, in order to facilitate uptake and utilisation of technologies,African countries have in recent years laid the foundation for long-term strategy for professional, technical and vocational education aimed at enhancing the skills and expertise of its professional and technical human resources (FARA, 2014). For example, the e-learning Africa Report 2015 recognize the importance of Technical Vocational Education and Training (TVET) as the key to a country's competitiveness, prosperity and social inclusion (Manji *et al.,* 2015). On a positive note, ninety-five per cent of people surveyed by eLearning Africa reported that ICTs are the key to improving education. Majority of respondents have taken online courses or self-taught themselves skills using online resources (Manji *et al.,* 2015).

Promotion of Lifelong learning in Aquaculture studies

Lifelong learning is not a novel idea in Africa. Indeed, many scholars have posited that it was deeply embedded within African culture and epistemology long before the start of colonialism (Omolewa, 2009). Long before then, Africans knew and adopted the idea that learning generally involves a deliberate effort that must be made in order to acquire (and increase) skills, knowledge or understanding, and strengthen values, interests and attitudes. It was expected that effective learning would lead to change, development and a desire to learn more. Within the lifelong learning concept, Africans knew that the critical areas to increase participation in learning processes involved: (i) discovering and sharing new knowledge on how to stimulate the demand for learning; (ii) creating new opportunities for, and awareness of, formal, non-formal and informal learning; (iii) providing access to resources that empower learners; and (iv) extending the campaign's influence and presence as a powerful advocate for learning.

Lifelong learning is now the guiding principle for policy strategies concerned with objectives ranging from a nation's economic well-being and competitiveness to its people's sense of personal fulfilment and social cohesion. One of the guiding principles to guide the implementation of the Continental Education Strategy for Africa (CESA 2016-2025) is a "Holistic, inclusive and equitable education with good conditions for lifelong learning is sine qua non for sustainable development". It has taken decades for the Informal and non-formal Education and training to be recognized as an important sector contributing to educational development in Africa. Alternative modes of education that fall under the informal and non-formal education and training label have provided learning and training opportunities to millions of African children, youth and adults. Therefore, lifelong learning needs to be implemented in such a way that all users can fill their gaps in lack of knowledge and skills.

Conclusion

There is substantial social benefit in promoting an innovative and sustainable aquaculture industry that contributes positively to food security and human health. Absolutely

crucial for this is a higher education level of science communication, including the targeted utilization of the new media. This provides a wide range of opportunity for interactive, participative sharing of the social dialogue for societal transformation. The current status quo of the scientific knowledge should be presented in an understandable, yet also blended way, and should be actively and participatively shared with society. To facilitate this, education offers should attempt to establish a relation to the key factors of social transformation. At the same time, opportunities for life-long on-the-job learning should be extended through publicly funded further education courses and post-graduate qualifications, for example, in the form of a relevant 'sabbatical' for employees. Besides, new curricula and degree courses and modules, completely new professions might be needed. In this regard, continued professional development involving e-learning and other innovative approaches can make an important contribution to the sector. Finally, there is need to better recognise and value non-formal and informal learning and skill development and develop approaches that are more learner-centred and take account of the increasing availability and diversity of potential learning channels and materials.

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PRODAP—UCN-BURUNDI AUTORITE DU LAC TANGANYIKA BANQUE AFRICAINE DE DEVELOPPEMENT

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PROJET PRODAP UCN-BURUNDI :

De simples séchoirs à poissons qui ont changé l'existence des transformateurs, des mareyeurs de poissons et l'alimentation des populations du Lac Tanganyika

Nous présentons ici les améliorations apportées ces dernières années aux procédés de séchage du poisson utilisés antérieurement au Burundi dans la transformation des produits de la pêche au lac Tanganyika en vue de pallier aux insuffisances de la technique traditionnelle et réduire sensiblement les pertes après captures.

En effet, les communautés locales de pêcheurs ont adopté une technique de transformation du poisson extrêmement efficace et peu onéreuse, à savoir le séchage sur les claies surélevées qui grâce à la circulation de l'air réduit le temps de séchage complet du poisson de trois jours à 20-24 heures. Initié au départ par des divers projets qui se sont succédés dans le temps, elle a été amplifiée par des particuliers qui l'ont adapté aux divers matériaux locaux. Au niveau des résultats, les séchoirs des particuliers et ceux initiés par des projets ont le même rendement (30% du produit frais)

Les coûts des claies de séchage

Les coûts d'une claie des particuliers varient entre 80.000-100.000 Fbu (50-60 USD) en fonction des périodes et de la disponibilité des matériaux. Les treillis synthétiques utilisés en fibre d'éthylène sont achetés par rouleaux de 20 m ou 50 m auprès des stations de lavage du café et le mètre revient à 2000 Fbu (1.2 USD) alors que les treillis métalliques se retrouvent dans le commerce et coûtent 6500 Fbu/mètre (4 USD). Une aire complètement aménagées de 12 m^2 par les différents projets avec 24 claies de séchage et bâche revient en moyenne à 233.000 Fbu(144 USD).

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Les raisons qui ont conduit à l'adoption des séchoirs surélevés :

Au Burundi le Séchage traditionnel à même le sable était il ya une quinzaine d'années, une activité obligée en l'absence de bonnes structures de commercialisation du frais. C'était un moyen supposé de sauvegarder des protéines avant leur dégradation quoiqu'en réalité, il fût surtout un moyen supplémentaire de dégradation sans que les opérateurs s'en rendent compte suite aux changements physiques dûs à l'environnement, à la manutention humaine, aux changements bactériens et aux températures. Donc les risques liés à l'environnement ; au traitement et/ou à la transformation, à la distribution ou ceux induits par les consommateurs étaient importants sans parler de répercussions économiques négatives préjudiciables aux opérateurs de la filière. La qualité commerciale (fraîcheur, hygiène, apparence générale, taille, couleur,) était affectée et l'innocuité des produits finis était douteuse.

PRODAP—UCN-BURUNDI AUTORITE DU LAC TANGANYIKA BANQUE AFRICAINE DE DEVELOPPEMENT

C'étaient des opérations menées en général précipitamment et la chair du poisson devenait trop dure. Cette méthode était la plus répandue car exigeant moins d'investissement. Elle était plus rapide que la technique sur les claies. Le séchage se faisant à même le sol naturel, le produit qui en résultait contenait du sable et il était contaminé par le contact avec les insectes, les animaux ou d'autres matières contaminantes se trouvant sur le sol , de plus en cas de pluie, les pêcheurs étaient obligés de mettre leur poisson en tas afin de le protéger avec des sacs en jute, ce qui retardait beaucoup l'opération de séchage.

Pour le reséchage, le poisson était dispersé en le jetant en l'air et le retournement

comme le ramassage se faisait à l'aide d'un râteau.

Cette habitude malgré qu'elle était bien ancrée a été modifiée rapidement suite à la création d'aires de séchages surélevées et convenablement équipées qui assurent une qualité du produit et dont les retombées économiques n'ont pas tardé à se faire voir notamment par la location des claies, et le prix élevé du produit ainsi séché de loin rémunérateur et les consommateurs de plus en plus nombreux et satisfaits

L'adoption des séchoirs surélevés par les opérateurs de la filière

Avec le Projet PRODAP (Projet d'Appui au Programme Régional d 'Aménagement Intégré du Lac Tanganyika) en complément aux actions menées initialement par d'autres partenaires comme la FAO(Organisation Mondiale pour l'Alimentation et l'Agriculture), le PPCDR(Programme Post-Conflit pour le Développement Rural), le PRASAB (Projet de Réhabilitation Agricole et de Gestion durable des Terres)et la DEPA (Direction des Eaux Pêches et Aquaculture), les buts du séchage ont été bien orientés afin de faciliter la conservation (surtout des clupéidés qui représentent plus ou moins 80% de la production) par l'inhibition de la croissance des microorganismes et réduire le poids du poisson à transporter. Comme cette opération se déroule en général à l'air libre, au soleil ou à l'ombre, on a veillé à ce que la teneur en eau de l'atmosphère ambiante pour la bonne conservation du produit soit maîtrisée.

Le séchage au Burundi est actuellement pratiqué sur deux types de claies avec des supports en divers matériaux.

1. Le séchage sur les claies inoxydables, amovibles initiées par les projets et facilement nettoyables par des brosses
2. Les claies fixes de séchage des particuliers en divers matériaux (grillages métalliques et/ou synthétiques)

Les claies ou grillages fixes de séchage du poisson sont protégées des intempéries par des bâches en plastique ou divers caoutchoucs disponibles localement.

Pour éviter que les grillages fixes s'abîment rapidement et que les bâches disparaissent, un gardiennage est assuré par les propriétaires.

Les supports des claies sont en divers matériaux :

Ils sont métalliques et/ou en bois ou une combinaison des deux. Il en existe aussi en perches de bois d'Eucalyptus ou de bois de forêt (espèce de brachystegia), en bambous ou en chevrons provenant des madriers de divers essences de bois d'oeuvre et ils sont fixés dans le sol à l'aide du béton

Les traverses qui constituent la charpente et sur lesquelles sont fixés les treillis sont en divers matériaux (branches de palmeraies, bambous (bambousa striata), lattes en bois divers en provenance des menuiseries, des bois de forêt et ainsi de suite.

Les distances entre traverses varient (25 cm-60cm) et elles sont fonction du degré d'inclinaison des claies pour faciliter l'égouttage du poisson.

Les treillis sont fixés à l'aide des clous sur les supports et traverses et les claies sont inclinées soit des deux côtés ou à un seul côté.

Des dimensions des claies de séchage

Les dimensions des claies des particuliers sont variables de 16 à 18m de long sur 1.50-1.80m soit approximativement entre 24 et 30 m2. Ceux des projets sont standards (12mx2m) soit 24m2.

De la capacité des aires de séchage

Une aire de séchage peut contenir une caisse de 80 kgs de poisson frais avec un rendement de 25-30 kgs en fonction de l'exposition au soleil et l'intensité du séchage soit 30 à 35% et les produits sont de conservation longue.

De la construction

Les claies sont construites à 1-1.5 m du sol.

De l'entretien

Pour combattre la rouille des treillis métalliques pour ceux qui sont oxydables, on utilise les

chiffons trempés dans de l'huile de palme.

Les treillis synthétiques obtenus auprès des usines de lavage du café sont lavables à l'aide des morceaux secs de filets de pêche mais ils restent avec une humidité résiduelle dans les fils après séchage, ce qui constitue une source de contamination surtout en saison pluvieuse

La durée d'utilisation des séchoirs est en fonction des matériaux utilisés et de l'entretien. Les treillis synthétiques et/ou métalliques sont rafistolés régulièrement comme le montre les images en dessous. Ils sont préférés aux treillis métalliques car ils se nettoient facilement à l'aide des chiffons en morceaux de filets de pêches et leur durée de vie est en général de plus ou moins trois ans. L'amortissement des aires de séchage des projets est de 10-15 ans.

Du séchage du poisson

Afin d'avoir un produit de bonne facture, le poisson est rangé soigneusement sur les claies un à un de façon à ne pas altérer sa qualité. On évite de les agglutiner de façon à ce que le produit séché soit de qualité uniforme. Grâce à la circulation de l'air, le temps d'égouttage du poisson est de trois heures en moyenne et un produit bien sec s'obtient après au moins 20-24 heures en fonction des conditions du milieu ambiant. Sur un même treillis, les meilleurs poissons sont rangés séparément de ceux qui ont subi des chocs dans les caisses ou ceux qui sont en état de dégradation qui sont éliminés.

De l'amplification du phénomène de séchage au Burundi

Depuis 1977 avec l'avènement de la Supobu (Société et Usines des poissons du Burundi), un projet du Gouvernement financé par la Banque mondiale, de nouvelles claies ont été installées dans divers sites du projet (Nyamugari-Gitaza-Kagongo-Rumonge et Gifuruzi) à la fin de ce projet, l'état n'a pas su assurer la relève car la gestion centralisée ne le permettait pas et les équipements ont disparu.

Séchage sur les claies surélevées à Nyamugari (1977)

Avec les autres projets, on a essayé de travailler avec les associations qui sont devenus propriétaires des équipements et l'intérêt pour cette activité a commencé à croître au vu des bénéfices importants tirés de l'activité. Les particuliers ont commencé aussi à investir massivement.

Selon les estimations avec les pêcheurs, seuls 30 % des clupéidés de la production nationale sont vendues en frais actuellement, le reste étant séché.

Le poisson séché sur les claies s'égoutte facilement et il est de bonne qualité tant commerciale qu'alimentaire.

En plus d'afficher des prix intéressants sur le marché, celui qui était séché sur le sable accusait trop souvent des pertes sèches car lors des fortes pluies, il était emporté par les eaux de ruissellement.

Actuellement sur dix huit plages de débarquement actives seules les plages de Cadillac et Kanyosha n'ont pas de claies car le poisson est vendu frais dans divers marchés de la capitale à cause de la proximité.

Le succès du séchage a été dû en grande partie au renforcement des capacités des acteurs à travers divers projets qui se sont succédés et ceci à plusieurs niveaux (fédérations et associations des pêcheurs, administrations partenaires au Minagrie (Intérieur, Mini santé, sécurité publique).

Des sanctions dissuasives comme la saisie et distribution du poisson séché sur le sable à la population et une amende de 20000 Fbu à chaque infraction qui alimentait les caisses des comités locaux de pêches ont fini par dissuader les récalcitrants à abandonner les mauvaises pratiques.

Même les commerçants tanzaniens ont dû abandonner le marché burundais faute de preneurs du mauvais produit et des amendes imposées. Ils vont actuellement en RDC.

Actuellement, on dispose de 897 claies de séchage parmi lesquelles le PRODAP a déjà aménagé 60 sur deux sites des antennes de surveillance réhabilitées de Gitaza et Gifuruzi et bientôt une trentaine le sera sur le site du débarcadère de Kabonga.

Les plages de Rumonge et celles de Mvugo occupent respectivement 33% et 32% du total des claies.

Le nombre de propriétaires est de 140 dont 100 hommes et 40 femmes

Pour ce qui est des retombées économiques, les pêcheurs affirment que le séchage est de loin plus rémunérateur et nous avons comparé les prix du frais et du séché au moment des pics de production et les périodes maigres.

Une caisse de frais varie en mauvaise saison entre 300. 000 Fbu à 400. 000 Fbu (185-250USD) et en bonne saison, le prix est de 150.000 Fbu à 200.000 Fbu (90-150 USD).

Le prix de vente du poisson séché varient au cours de l'année entre 5000-8000 Fbu(3-5 USD) et 18000-25000 Fbu(11-15 USD). A cela, il faut réduire des marges les coûts de production par claie comme suit:

- Main d'ouvre pour le retournement du poisson par claie : 1000 Fbu
- Location d'une claie en moyenne: 3000-5000 Fbu/jour
- Gardiennage: 1000-2000 Fbu/jour
- Transport marché: 6000 Fbu/ sac 35 Kgs
- OBR (office burundais des recettes): 12000 Fbu/sac
- Taxe communale: 1000 Fbu/sac
- Pertes dûs aux vols, mauvaise manutention 5% du poids du produit
- Transport caisse de l'embarcation à la claie: 200 Fbu.
- Les frais de management, les coûts d'opportunité du capital car le plus souvent c'est de l'argent emprunté sous diverses formes (traditionnel, banque ou micro finances).
- Amortissement des claies des projets 15.500 Fbu/an

Globalement, le compte d'exploitation est présenté en annexe comme les outils d'évaluation de la qualité du poisson et des barèmes de cotation que les pêcheurs, transformateurs et commerçants utilisent pour les transactions à partir du poisson frais au produit fini sec. Il faudrait souligner que le stockage ne pose aucun problème aux commerçants car le produit est bien traité.

Table 1: Examen organoleptique du poisson séché de petite taille (Ndagala Séché Stholothrissa Tanganicae et Limnothrissa Miodon, et Luciolates Stappersii juvénile : Nyamunyamu)

Critères d'évaluation	**Appréciation**		
Bon	**Moyen**	**Mauvais**	
Aspect			
Couleur de la peau	Luisante, translucide, uniforme clair	Légèrement luisante	Terne, colorée, brunâtre foncée
Texture	Ferme, facilement pliable	Légèrement ferme et pliable	Friable et émiettement facile
Odeur	Odeur caractéristique	Légèrement forte	Forte, ammoniacale, piquante
Goût	agréable	Légèrement rance	Désagréable, rance, acide
Corps étrangers	Exempt de sable, de tâches et de moisissure	Exempt de sable, de tâches et de moisissure	Présence de corps étrangers et/ou de sable, de tâches et de moisissure.

Table 2 : Compte moyen d'exploitation d'une claie de séchage

Intitulé	Dépenses en Fbu	Prix de vente	Marge bénéficiaire Fbu et %
1. Achat caisse poisson frais (80 kgs)		400 000	
2. Rendement après séchage (30 kgs)		750 000	
3. Main d'ouvre pour le retournement du poisson par claie		1 000	
4. Location d'une claie en moyenne /jour		5 000	
5. Gardiennage/24 heures		2 000	
6. Entretiens et réparation 5%		6 250	
7. Managment 10%		52 500	
8. Transport marché		6 000	
9. Transport caisse de l'embarcation à la claie		200	
10. Office Burundais des recettes/sac de 35 kgs		12 000	
11. Taxes communale/sac de 35 kgs		1 000	
12. Pertes dûs aux vols, mauvaise manutention 5% du poids du produit final		43 750	
13. Amortissement mensuel des claies		2 000	
TOTAL	531 700	750 000	218 300 41%

Table 3: Barème de cotation du Poisson séché de petite taille: Stholothrissa tanganicae

Qualité	Catégorie (Qualité)	Note	
Couleur de la peau	Bon	Luisante, translucide, uniforme clair	10
Texture, chair	Ferme, facilement pliable	9	
Odeur	Odeur caractéristique	8	
Goût	agréable	7	
Corps étrangers	Exempt de sable, de tâches et de moisissures	6	
Couleur de la peau	Légèrement luisante		
Acceptable	Texture	Légèrement ferme et pliable	
Odeur	Légèrement forte	5	
Goût		Légèrement rance	
Corps étrangers	moyen	Exempt de sable, de tâches et de moisissures	4
Seuil (limite) d'acceptabilité			
Rejet	Couleur de la peau	mauvais	Terne, colorée, brunâtre foncée
3			
Texture	Friable et émiettement facile		
Odeur	Forte, ammoniacale, piquante	2	
Goût	Désagréable, rance, acide		
Corps étrangers	Présence de corps étrangers et/ou de sable, de tâches et de moisissur		

POLICY PAPERS

TRADE, MARKETING AND DISTRIBUTION OF INDIGENOUS TROPICAL ORNAMENTAL FISHES OF AFRICA

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This paper provides highlight on Trade, Marketing and Distribution of Indigenous Tropical Ornamental Fish of Africa

The Ornamental Fish Trade constitutes a veritable sector of the Fishery Industry in Agriculture and is estimated to worth about Fifty Billion US Dollars, worldwide (World Customs Organization; World Resources Institute; Convention on the Trade In Endangered Species of Wild Flora & Fauna-CITES). It is to be noted that this industry is predominantly Foreign Exchange based, because the trade is both Inter-Continental and Intra-Continental; uniting various continents and cultures together through the exportation of Ornamental Fish Species (both Freshwater and Marine) endemic to the countries and regions. The status of ornamental fish trade and its contribution is not well documented

Ornamental Fish Trade in Africa

Commercial activity in Ornamental Fish in Africa has progressed beyond the subsistence stage. Africa is endowed with variety of water bodies (Freshwater & Marine); with them comes very colourful and exotic species of Ornamental Fishes that are highly sought after in the International Market. From the Niger River Basin, Benue River Basin, Lake Chad, Lake Victoria, Malawian Lake, the great Tangayika, etc., has with them uncountable species of Ornamental Fishes. As a source of Foreign Exchange earnings and a contributor to the Gross Domestic Product (GDP) and National Income of Nations, Africa should encourage the trade in order to benefit optimally from this industry; especially trading on the highly sought after species where Africa has comparative advantage. Presently, Africa is lagging behind and not exploring this lucrative source of income and economic diversification.

Species like *Tetraodon postulatus*, *Polypterus Bichir Bichir, Tetraodon Euruptus, Protopterus Annectensudollot*, *Lates Niloticus*, *Hydrosynus Guttatus*, *Gymnarchus Niloticus*, *Hepsetus Odoe*, *Popycrocranus Afer*, *Ostoglossymm Biccirhosum*, *Phractolemus Ansorgei*, *Aphyosemion Species*, *Aplocheiliths & Killifish Species*, *Polypterus Delhezi*, *Lapradei*, *Gnathonemus Petersi, Pantondon Bucholzi*, *Megalops Atlanticus*, The Malawian and Tangayikan Cichlids and many more, should be given needed attention for the Trade to thrive in Africa.

Marketing and Distribution:

Presently, Africa exports its Ornamental Fish species to U.S.A., United Kingdom, Canada, Mexico, Argentina, Colombia, Brazil, Malaysia, Indonesia, Japan, Taiwan, South Korea, China, Hong Kong, Thailand, Philippine, United Arab Emirate, Germany, Netherlands, Belgium, Finland, Norway, Denmark, Portugal, Italy, Spain, Austria, Poland, Switzerland, France, Russia, etc.

Countries like, Nigeria, Ghana, Guinea Konakry, Guinea Bissau, Cameroun, Malawi, Kenya, Congo Kinshasha, Congo Brazzaville, South Africa, Egypt, etc are engaged in the exportation of Indigenous African Ornamental Fish species;

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while Nigeria is the largest exporter in Africa. It is recommended that pragmatic and genuine effort is needed in the Marketing and Distribution of the Fish Trade in Africa. Encouragement of practicable and applicable policies by the Regulators will boost the Fish trade. Government at all levels should provide the enabling environment for the ornamental fish trade to thrive in Africa. Practitioners should be encouraged with the provision of soft loans at single digit interest or interest free, to enable them maximize the potentials inherent in the trade. Same is done in China, Japan, Sri-Lanka, Malaysia, Indonesia, etc. In view of the foregoing, all hands should be on deck for the betterment of Africa and its citizenry.

In this regard, Africa should graciously commend the efforts of AU-IBAR in developing templates for the industry and encouraging African member States of African Union (AU) in the development of workable, practicable, applicable and result-oriented policies and programs that promote Trade, Marketing and Distribution of Fish generally and the Ornamental Fish in particular in Africa.

OVERVIEW OF ORNAMENTAL FISH PRODUCTION IN KENYA: CURRENT STATUS, OPPORTUNITIES AND CHALLENGES

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Abstract

Kenyan ornamental fish industry is the fastest growing ornamental industry in Africa. It includes locally wild caught marine species and captive bred freshwater species. Presently, the industry contributes to the economy of the country by generating income through export earning, creating employment and enhancing livelihood of the fisher community and fish farmers. Marine ornamental fish industry in Kenya has an annual collection of approximately 300,000 pieces of fish of different species. The most collected fish are from the families Labridae, Pomacentridae, Serranidae, Blenniidae, Scorpaenidae, Pomacanthidae and Acanthuridae. Fresh water ornamental industry is still at its infancy and accounts only for 3% of fish under aquaculture. There are numerous unexploited wild species with great potential in the Kenyan fresh water bodies especially Lake Victoria and other small water bodies in the Lake Victoria Basin. The freshwater ornamental fish trade is dominated by the non-indigenous species comprising of Gold fish (*Carassius auratus*), Koi carps (*Cyprinus carpio*) and Mollies (*Poecilia spp*.). The demand of ornamental fish presents a considerable challenge to conservation and management of the industry as a result of unsustainable fishing practices which targets juvenile fish making them vulnerable to depletion. Wild collection of ornamental fish is also faced with numerous challenges including inadequate stock assessments, limited data on population structure, inefficient fisheries management measures as well as instances of illegal, unreported, and unregulated fishing. Address to these challenges can lead to success in sustainable management and exploitation of the industry for increased economic benefits.

Key words: Kenya, ornamental fish, opportunities, challenges

PERÇU DE LA PRODUCTION DE POISSONS ORNEMENTAUX AU KENYA : SITUATION ACTUELLE, POSSIBILITÉS ET DÉFIS

Résumé

L'industrie de poissons ornementaux au Kenya constitue l'industrie ornementale qui connaît la croissance la plus rapide en Afrique. Elle comprend les espèces marines sauvages capturées localement et les espèces d'eau douce élevées en captivité. À l'heure actuelle, l'industrie contribue à l'économie du pays en générant des revenus par l'exportation, en créant des emplois et en améliorant les sources de revenus des pêcheurs et des pisciculteurs. L'industrie des poissons marins ornementaux au Kenya peut se targuer d'avoir une collection annuelle d'environ 300 000 pièces de poissons d'espèces différentes. Les poissons les plus recueillis proviennent des familles Labridae, Pomacentridae, Serranidae, Blenniidae, Scorpaenidae, Pomacanthidae et Acanthuridae. L'industrie de poissons ornementaux d'eau douce en est encore à ses débuts et ne représente que 3% des poissons en aquaculture. Il existe de nombreuses espèces sauvages inexploitées ayant un grand potentiel dans les masses d'eau douce du Kenya, en particulier le lac Victoria et d'autres petits plans d'eau dans le bassin de ce lac. Le commerce du poisson ornemental d'eau douce est dominé par les espèces non indigènes comprenant les poissons dorés (*Carassius auratus*), les carpes de Koi (*Cyprinus carpio*) et les mollies (*Poecilia spp*.). La demande de poissons ornementaux pose un défi considérable à la préservation et à la gestion de l'industrie en raison des pratiques de pêche non durables

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qui ciblent les poissons juvéniles, les rendant ainsi vulnérables à l'épuisement. La collecte de poissons ornementaux est également confrontée à de nombreux défis, notamment l'évaluation insuffisante des stocks, l'insuffisance des données sur la structure des populations, l'inefficacité des mesures de gestion de la pêche ainsi que des cas de pêche illégale, non déclarée et non réglementée. La solution à ces défis peut engendrer la réussite dans la gestion et l'exploitation durables de l'industrie pour un accroissement des bénéfices économiques.

Mots-clés: Kenya, poissons ornementaux, opportunités, défis

Introduction

Ornamental fish industry is considered as one of the high value fish industry in the world trading at USD 200 to USD 330 million annually (Grey *et al.,* 2005; Dee *et al.,* 2014) with negligible quantities being traded compared to food fish (FAO, 2016). Kenya is among 45 source countries that supply the global trade with ornamental fish and is a major supplier among countries of the Western Indian Ocean region (Okemwa *et al.,* 2016). The Kenyan ornamental fisheries comprises of freshwater (mainly farmed) and marine (coral reef fishes collected from Indian Ocean). Despite the slow growth of the industry, it plays an important role in the country's economy through foreign exchange earnings. Freshwater ornamental fish culture is fast emerging as a major branch of aquaculture globally including Kenya and accounts only for 3% of fish under aquaculture in Kenya. The ornamental fish breeding, fry rearing and grow out are conducted by a few commercial farmers (SDF, 2013) and the marine aquarium fish market is controlled by 144 aquarium fishers and 8 aquarium exporters located at the Kenyan Coast (Okemwa *et al.,* 2016).

The expansion of this industry among the low income population is an important aspect of the economy of Kenya due to its ability to generate considerable income, with high export earnings, as well as its potential for raising the living standards among rural communities and providing employment opportunities for fish farmers and fish collectors (Okemwa *et al.,* 2009; SDF, 2013). The success of such an industry depends on the availability of appropriate resources, market information, local and international market demand, and an institutional framework within the country to favour sustainable growth of the sector and trade. Given the present status, it is important to analyze these various aspects in order to promote expansion of the industry. This study aims to assess the present status, challenges and future prospects in the ornamental fish industry in Kenya.

Current status of marine ornamental fish production

The marine ornamental trade in Kenya began in the late 1960s and has grown over the years. The diversity of species collected has risen from about 48 in 1980's to over 200 species (Okemwa *et al.,* 2009). Kenya ranks first among other countries within the Western Indian Ocean that include Mauritius, South Africa, Madagascar and Tanzania in marine ornamental fish trade (Okemwa *et al.,* 2016) with an annual collection of approximately 300,000 pieces of fish of different species. This represents a minimum of 235,000 pieces collected in 2007 and a maximum of 326,700 pieces collected in 2008 (Figure 1). There exists 250 species of fish from 35 families targeted for ornamental fish trade including Acanthuridae, Labridae, Serranidae, Blenniidae, Scorpaenidae, Pomacanthidae, Microdesmidae, Gobidae, and Chaetodontidae. The most harvested marine ornamental fishes include Labroides dimidiatus, Sea goldie (*Pseudanthias squamipinnis*), Fire goby (*Nemateleotris magnifica*), Sixline wrasse (*Pseudocheilinus hexataenia*) and Twobar anemonefish (*Amphiprion allardi*) (Okemwa *et al.,* 2009; Okemwa *et al.,* 2016). The industry is experiencing tremendous growth with registered fish collectors increasing from 65 to 144 (Okemwa *et al.,* 2016).

The marine ornamental fish from the wild is monitored and the catch data by area and species are available at State department

of fisheries and Kenya Marine and Fisheries Research Institute (KMFRI). Kenya exports approximately 300,000 pieces of marine ornamental fish annually with and FOB value of USD 66,000 and CIF value of USD 700,000. The marine ornamental fish are exported to United Kingdom, USA, South Africa, Hong Kong, Germany, France, Japan, Netherlands, Austria, Israel, Denmark, Poland, Hungary, Italy, Romania, United Arabs Emirates and Austria (Okemwa *et al.,* 2009). The domestic market is also growing with individuals holding aquaria in hotels, homes and offices as decorations. The export market percentages are shown in Figure 2. The EU is the largest market for the ornamental fish from Kenya with 42% followed by the US with 31% of the market share and the other countries having rather equal market share (Figure 2). In 2014, Kenya exported only 1% of ornamental fish to the EU worth €705,000 and is listed the 5th among the top 10 non-EU sources of marine ornamental fish imported to the EU (OATA, 2015).

Status of fresh water ornamental fish production

Fresh water ornamental fish production is majorly done in captivity whereby fish farmers propagate and rear the fish in ponds, hapas and tanks. The farmed species are dominated by 2 families; Cichlidae and Cyprinidae. This includes different varieties of Gold fish (*Carassius auratus*), Koi carps (*Cyprinus carpio*) and Mollies (*Poecilia spp*.). The varieties of Gold fish farmed include Black moor, Bubble eye, Fantail, Oranda, Lion head, Veintail, Ryukin, White/red comet and Yellow comet. Documentation of the fresh water ornamental fish farmers and other ornamental fish practitioners such as aquarium dealers are not adequately done, for example in 2016, Aquacultural Association of Kenya recorded only 24 ornamental fish farmers in Kenya. The Fresh water ornamental fish produced in the country are non indigenous species which are imported from other countries including Israel and Singapore. In 2013, the importations of fresh water ornamental fish were 20,649 valued at USD 6,290 (SDF, 2013). The freshwater ornamental fish produced by farmers are graded according to intensity of coloration and size according to market requirements and eventually sold both locally and in the East African region.

There are many indigenous fish species with great potential of being ornamental fish in the Kenyan fresh waters especially the fresh water *Cichlids Haplochromis spp*. found in the Lake Victoria basin (Ngugi and Manyala, 2009). The *haplochromis* species with potential of being collected for the ornamental fish include; *Haplochromis nubilus*, *Haplochromis sp*. "blue obliquidens, Haplochromis sp. "Kenya gold", *Haplochromis sp*. "carp", *Neochromis omnicaeruleus*, *Pseudocrenilabrus multicolor victoriae*, *Pundamilia nyererei* and *Astatoreochromis alluaudi*. Other fresh water fish with potential of being collected for aquarium are *Schilbe spp*, *Synodontis afrosfischeri*, *Synodontis victoriae* and *Barbus spp*. There is a great market opportunities for freshwater ornamental fish locally, within the East Africa region and outside the region (Mbugua, 2008). The same markets are being exploited by African countries including Malawi (UNDP, 2011) whose colorful Lake Malawi Cichlids have dominated the EU and US markets. This potential in indigenous fish species need to be tapped for economic gains.

Legal status and regulations in ornamental fish industry and trade

The laws and regulations covering aquatic resources conservation, management and sustainable utilization of aquatic resources rely on the effective implementation of national rules and regulations. Several regulations have been developed to conserve fisheries resources of Kenya. This includes national legislations that have been put in place to deal with the prevention of diseases, introduction of unwanted species into the country and protection of the endangered aquatic resources. The various acts and relevant institutions responsible for their implementation are presented in Table 1.

Table 1: The Acts and regulations related to ornamental fish industry

Name of the Act	Responsible Institution
1. The Fisheries Act CAP 378 (Revised 2012) *The Fisheries (Safety of fish, Fishery Products and Fish Feed) Regulations, 2007*	State Department of Fisheries and Blue Economy, Ministry of Agriculture, Livestock and Fisheries.
2. Animal diseases Act Cap 364 (Revised 2012).	State Department of Livestock, Ministry of Agriculture, Livestock and Fisheries.
3 Pharmacy and Poisons Act Cap. 244 (Revised 2009)	Ministry of Public Health and Sanitation
4 Environmental Management and Co-ordination Act (revised 2015)	National Environmental Management Authority, Ministry of Environment, Natural Resources and Regional Authorities
5 Wildlife Conservation and Management Act Cap.376 (revised 2013) *Legislation on Marine Protected Areas (MPAs).*	Kenya Wildlife Service, Ministry of Environment, Natural Resources and Regional Authorities

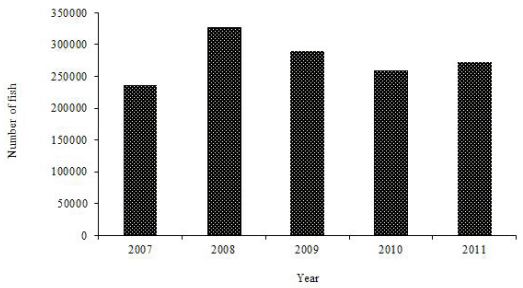

Figure. 1: Annual number of marine ornamental fish collected from 2007 to 2011 (Adapted from SDF, 2011 and Okemwa *et al.,* 2016).

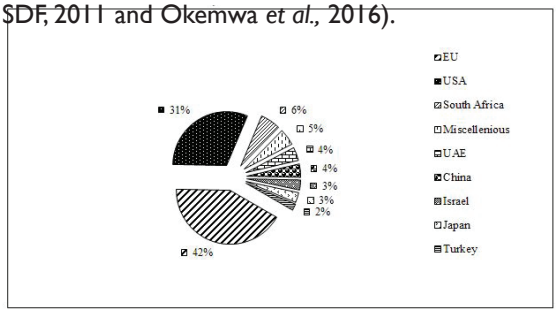

Figure 2: Average Market percentages of ornamental fish from Kenya (Adapted from SDF, 2011).

Quality assurance and biosecurity

Quality control in the ornamental fish industry is by licensing aquarium dealer, fishing or collection of the ornamental fish; control of live fish movement, export and import permits; transfer of ownership and inspections done at the holding facilities to ensure quality. There exist general guidelines for handling of live fish applicable to ornamental fish (SDF, 2015). Generally, the harvested fish are temporarily packaged in plastic bags or containers at the jetty and transported in vans to the holding facilities where they are kept in quarantine for acclimatization to life in captivity, as well as to detect and treat any injuries or infections before shipment. Any fish with infections are isolated and treated, but treatment depends on the level of expertise of the handlers. The fate of fish that do not recover remains unknown although it can be assumed that they eventually succumb to injuries or infections of a fatal nature. The exporters are required to obtain an export permit from the State Department of Fisheries before any consignment can leave the country. Once this is done, the fish that have been certified to be in good condition are then packaged in plastic bags filled with oxygen and sealed. The sealed plastic bags are placed in insulated Styrofoam boxes and taken to the airport where they are cleared by the customs department, and then air freighted to the destination markets.

Limited biosecurity measures have been put in place to monitor new introductions and occurrence of diseases in fish in Kenya. This is due to inadequate human resource specialized in fish diseases. Ornamental fish trade involves introduction of exotic species; possible introduction of diseases and parasites;

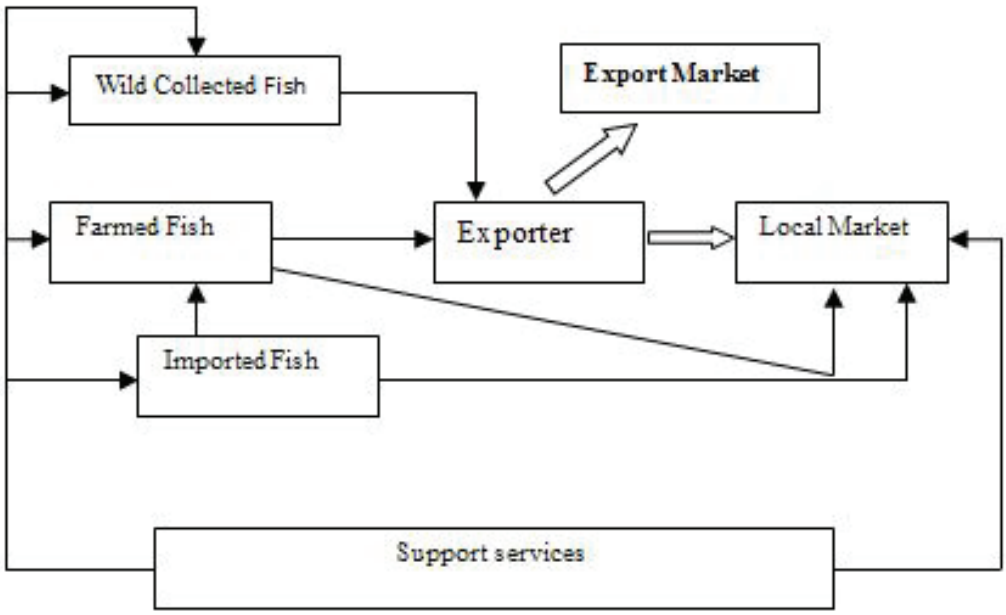

Figure 3: Supply network for ornamental fish in Kenya (Adapted from Okemwa *et al.,* 2016)

possible escapes of fish to the wild leading to ecological and genetic interference with the wild species. Common diseases encountered in Kenya are mainly in the freshwater fish and includes the fish louse (*Argulus spp*) and white spot disease (*Ichthyophthirius multilifis*). The viral disease common in Koi (Koi Herpes Virus) (KHV) has not been reported in Kenya but measures need to be put in place to ensure it does not emerge in Kenya. The Department of Veterinary Services is the Competent Authority for compliance with aquatic animal health, animal welfare measures, and international health certification according to Aquatic Health Code of the World Animal Health Organization (OIE) (SDF, 2015). They are required to check the health status of the fish during quarantine where the fish are held to be shipped from or into the country and in the farms. One of the measures is the issuance of health certificate for transboundary fish movement and the fish health monitoring according to OIE aquatic animal health code. Although this is usually done, there is little monitoring of the fish health in the country and quarantine facilities are not well established in different ports to cater for the different species of fish being traded. In most cases, there is inadequate competence of the Veterinary Officers with regard to fish health management which has posed a great challenge to biosecurity in ornamental fish industry.

Ornamental fish supply network

The supply network for marine ornamental fish in Kenya is simple and short without involvement of middlemen (Okemwa *et al.,* 2016). It runs directly from the collectors to the exporters (Figure 3). The freshwater ornamental fish value chain involves the farmer selling directly to the local market or to the exporter. The value chain of ornamental fish industry is not well structured and the players in the value chain are not clearly defined. The major player in the value chain include the ornamental fish farmer or collector from the wild, aquarium dealer and other support service providers who sell packaging materials and aquarium accessories. Support services in the ornamental fish industry includes; feed supplier (bioflakes and granules); broodstock supplier; research; extension services; veterinary services; infrastructure; maintenance and servicing.

Opportunities in ornamental fish industry

Government policy intervention

The primary goal of the policy is to ensure increased and sustainable fish production and utilization by properly managing the ocean and other fisheries waters. The policies developed focuses on the promotion of aquaculture, implementation and monitoring of sustainable management and responsible fishing practices. The policy guides the development and management of the fishery sector in an effective and coordinated manner in tandem with the national development policy objectives. This is to hasten and enhance the sector's contribution to the country's development objectives of poverty alleviation and wealth creation (MoFD, 2008; Ngugi and Manyala, 2009; MoFD, 2011). Other efforts include the development of marine aquarium fishery management plan which is being carried out to ensure development of a vibrant sustainable ornamental fish industry that provides equitable benefits to all while conserving the long term ecological integrity of the targeted species (Maina, 2012). An enabling policy environment will ensure sustainable growth of the industry.

Industrialization and Employment opportunities

Since ornamental fish is regarded as high value fish, it provides foreign earnings and improves the livelihood of the people involved it the value chain. The industry has served as a source of direct employment in different capacities as fishermen, fish packers, aquarium maintenance personnel, drivers, shallow water and deep sea scuba divers. The sector has also allowed industries to produce materials and equipment used in handling and transportation of live fish. This includes; fish packaging bags, styrofoam boxes, carton boxes, rubber bands, sealing tapes and medicinal oxygen. Other key areas of industrialization include; development of marine aquariums, farming of ornamental fishes, fabrication of aquariums and accessories and production of ornamental fish feeds. These support service industries contributes to employment in the ornamental fish industry.

Unexploited indigenous freshwater ornamental fishes

Lake Victoria and small water bodies in the L. Victoria basin have got numerous indigenous colourful fish which have never been exploited for ornamental fish business. Their exploitation will give a wide variety of aquarium fish to meet the market demand.

Major challenges facing the growth of the industry

Some of the most important challenges include:-

Environmental issues

i. Most of the marine ornamental fishes inhabit the coral reef; therefore the collection of species such as damselfish could lead to habitat degradation and possible threat to the coral reef ecosystem.
ii. The collection of marine ornamental fish targets juveniles and brightly-colored males since they are more colorful and attractive. This affects the population's age structure, and leads to imbalanced sex ratios of the female and male community making the fishery vulnerable to depletion (Dee *et al.,* 2014).
iii. The biology and ecology of the fish species being exploited for the ornamental trade is not always put into consideration. There are some species which cannot survive in aquaria due to their feeding habits like Chaetodon spp. which feed on the coral polyps. This species are still harvested for ornamental fish trade despite the low chance of survival in captivity.
iv. There are existing loopholes with the management of escapes, disposal of unwanted fish and new introductions into the aquatic ecosystem despite the fact that they are possible source of diseases or ecological imbalance to the wild population. In most cases the incoming fish stocks are not traced to ensure they are for the intended use and the quantities monitored from time to time to ensure that there are

no escapes.

Weak implementation of regulations

There are little measures put in place to ensure adherence to regulations concerning sustainable exploitation of ornamental fishes. The management measures have been constrained by limited knowledge on the status of exploited stocks due to lack of species-specific catch data and limited resources to undertake rigorous stock assessment surveys (Dee *et al.,* 2014; Okemwa *et al.,* 2016). The country also lacks a stand alone regulatory measure specific for the ornamental fish industry that should ensure sustainable exploitation, management and development of the sector.

Losses due to high freight charges and taxation

The airlines charge a freight charge, which determines more than 50% of the final market price of the fish because any delays or mishandling of the consignments during transit can influence the ultimate quality of the fish when it lands at the destination market. Consignments are frequently rejected or returned by the airline companies due to inferior packaging resulting in leakages while in transit. Airline carriers incur the costs of transporting rejected consignments back to the exporters. Thus, they are not only major beneficiaries of the marine aquarium trade but they are also negatively affected due to tax enforcement of the set regulations.

Inadequate inputs

Number of stakeholders in ornamental fish industry is very low in comparison with other fish industries especially the food fish industry (both in capture and aquaculture). This makes access to support services and facilities required for ornamental fish trade cumbersome. For example in farmed ornamental fish, there is lack of ornamental fish feed to be used in the production of the cultured ornamental fish. The fresh water ornamental farmers usually use the feeds meant for other cultured food fish and this has a negative effect on the quality of the fish produced. Ornamental fish require carotenoids rich diet to enhance their attractive colours and pigmentations which do not exist in the feeds formulated for the food fish (NRC, 1993).

Lack of priority in investment

In freshwater ornamental fish industry, there is competition for farmland and other agricultural activities. The government agencies have also prioritized food fish production to ensure food security and most of the ornamental fish species e.g. the Cichlids are exploited for food fish industry among the fishing communities. The government funding for fisheries are often used for increasing production of food fish only with little emphasis on ornamental fish.

Conclusion and Recommendations

The ornamental fish industry in Kenya has few players in the export and farming business. However, if more players enter the market then the increased competition for fish collection and farming might result in an increase in profit to the fishers. Therefore economic evaluation of both freshwater and marine ornamental industry needs to be conducted to establish the contribution of the industry to the global trade and the country GDP. The high demand may lead to constraints in the conservation of the resource. This will require research to be focused in developing new technologies to enable captive breeding of the rare and endangered species from the capture fisheries as well as the fish of high demand in the market. It is clear that proper fish health management and quarantine regimes need to be adopted, as current procedures have got several loopholes which can lead to inefficient monitoring of fish in farms and in holding units. These various changes are necessary in order to achieve a sustainable ornamental fish industry in Kenya. Sensitization of the players in the supply network on the national and international laws and strict enforcement of the existing legislation can also improve the industry by monitoring imports and introductions to reduce the risk of ecosystem imbalances, diseases or invasive species. This

will ensure environmental sustainability and social benefits to all. A combination of efficient management strategies and a conducive policy enabling environment can offer a considerable promise for the growth of the ornamental fish industry.

Acknowledgement

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Public Brief

A stand alone policy on ornamental fish production is required to encourage sustainable management and exploitation of the wild caught marine ornamental fishes and investment in captive breeding of ornamental fishes.

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PROTECTED AREA MAINTAINS HIGH GENETIC DIVERSITY OF *LETHRINOPS TURNERI* OF LAKE MALOMBE, MALAWI

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Importance

Lake Malombe fishery is a third largest in Malawi thus contributes significantly to food and nutritional status of Malawi nation. The lake fishery provides a source of livelihoods to surrounding communities. In fact, approximately 85% of the households in Mangochi District where the lake is found are reportedly engaged in natural resources-based livelihoods including fishing (Coastal Resource Center, 2015).

Background

The Lake Malombe fishery has undergone dramatic changes over the years with decline in catches of Oreochromis species locally known as chambo from 8,000 MT/yr in 1982 to less than 200 MT/yr in 2003 (Jamu et al. 2011 as cited by CRC, 2015) instead dominated by small cichlids locally known as kambuzi of which 75% comprised of *Lethrinops turneri*, *O. argyrosoma* 'red' and *Copadichromis cf. virginalis* (FAO, 1993). This led to an increase in use of small meshed and destructive gears locally known as nkacha (a rectangular net with progression of mesh size from bunt to wing from 19 mm to 39 mm) and kambuzi seines being operated in open waters. The use of these nets increased and shifted the species size distribution in the lake over the years with about 70 % of Kambuzi fish caught being immature such that recruitment may have been supported by a limited number of mature individuals (FAO, 1993).

In order to reverse the trend of the collapse of Lake Malombe fishery, Malawi Government implemented various regulations to control fishing effort and protect breeding stock and juvenile fish. These included; implementation of Participatory Fisheries management (PFM), closed fishing seasons, mesh size restrictions, minimum harvest size limits, fishing net maximum headline length, and fishing licenses. In addition, the Government established protected areas as one of the strategies. While the impacts of most of the strategies are well known, it was necessary to assess the benefits of protected areas as a fishery management strategy in Malawi.

Advantages

Maintaining genetic diversity is very critical in natural fish populations where they are threatened by over-fishing and deterioration of aquatic environment. Fish populations are likely to decline if genetic diversity is not maintained (Wohlfarth, 1986). Protected areas provide a possible strategy to maintain genetic diversity as they restrict fishing activities thereby maintain effective breeding fish populations.

Investigation

The study was done to assess whether high fishing intensity and limited fishing as is a case in protected area and its adjacent areas of Lake Malombe, has had effect on the genetic variability of various populations of *Lethrinops turneri* in the lake. It was also necessary to know whether fish populations in the protected areas reseeded the adjacent fishing areas.

Results

DNA analysis indicated that genetic diversity of *Lethrinops turneri* fish populations of Lake Malombe was generally moderate. But pooled populations in the southern part of Lake Malombe, which has protected area, contained relatively high genetic diversity compared to northern areas. Genetic diversity in the northern areas might have reduced because of high fishing intensity than the southern areas where there is restricted fishing as a result of protected area. More important is the fact that migration rate among populations was very high. It implies that there is continuous gene flow between protected area and fishing areas. This ultimately confirms that protected areas contributed to reseeding to fishing areas thereby cushioned the effect of over fishing pressure through maintenance of genetic diversity.

Challenges

Poaching in protected area poses a challenge to the protected area. This is worsened by weak enforcement.

Opportunities

Establishment of protected areas as a fisheries management strategy, offers an opportunity for stock recovery and maintain genetic diversity in Lake Malombe and possibly in other African lakes where such protected areas could be established. Identification and establishment of protected areas in genetic hotspots of the lake would assist to restore the collapse of the fishery. Enhanced institutional arrangements such as effective involvement of communities and multi-sectoral stakeholders, instituting and enacting byelaws, would contribute to sustainability of the strategy.

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AFRICAN UNION - INTERAFRICAN BUREAU FOR ANIMAL RESOURCES (AU-IBAR)

Bulletin of Animal Health and Production in Africa
Guide for Preparation of Papers
Notes to Authors

The Editor in Chief
January 2013

Aims and scope

The Bulletin of Animal Health and Production in Africa (BAHPA) of the African Union Interafrican Bureau for Animal Resources (AU-IBAR) is a scientific journal which publishes articles on research relevant to animal health and production including wildlife and fisheries contributing to the human wellbeing, food security, poverty alleviation and sustainable development in Africa. The bulletin disseminates technical recommendations on animal health and production to stakeholders, including policy makers, researchers and scientists in member states. The Bulletin is the African voice on animal resources issues specific to Africa.

The Bulletin of Animal Health and Production publishes articles on original research on all aspects of animal health and production, biotechnology and socio-economic disciplines that may lead to the improvement animal resources. Readers can expect a range of papers covering well-structured field studies, manipulative experiments, analytical and modeling studies of the animal resources industry in Africa and to better utilization of animal resources.

The BAHPA encourages submission of papers on all major themes of animal health and production, wildlife management and conservation, including:

- Veterinary microbiology, epidemiology
- Marketing, economics
- Infectious and non infectious disease
- Parasitology
- Genetic improvement and biotechnology
- Animal production, nutrition and welfare
- Science and policy in animal health and production
- Beekeeping and honey bees
- Ecology and climate change impacts on animal resources in Africa
- wildlife management
- Fisheries and aquaculture development
- Food safety and food hygiene
- One health
- Emerging and re-emerging issues in animal resources
- Biosecurity
- Animal resources trade and value chain
- Socio economics and economics of animal resources development

Language

The language of submission should be either in U.K. English or Standard French. The abstract is translated to the other three languages of the African Union (Arabic, English, French and Portuguese), by the editors, after acceptance. Full articles submitted in French will also be published in English.

Manuscripts Submission

Authors are invited to submit electronically their manuscripts via attachment only at bahpa@au-ibar.org in a secured PDF and word format. Manuscript can be sent by post in case of unavailability of internet services (authors should be aware that in this case it will take longer time to be published).

Authors submitting articles to the BAHPA must follow the guidelines in this document. Submissions that deviate from these guidelines will be returned to the corresponding authors for changes and compliance.

To be considered for publication in the BAHPA, any given manuscript must satisfy the following criteria:

- Originality. BAHPA does not accept manuscripts that have already been published elsewhere. However, studies that replicate results that are already in the literature may be considered for publication, as the independent confirmation of results can often be valuable, as can the presentation of a new dataset.
- Audience. Manuscripts submitted must be of broad interest to animal health and production professionals in general, they must capture and hold readers' attention.
- Usefulness. Manuscripts submitted must help researchers, trainers, educators and policy makers in all regions of Africa improve their effectiveness.
- Rigorous methodology. Manuscripts submitted must be based on valid and reliable information, documentation or sound concepts, empirically, logically and theoretically supported.
- Well written to ensure clear and effective presentation of the work and key findings. The BAHPA editorial staff does not copyedit the text of accepted manuscripts, it is therefore important for the work, as presented, to be intelligible. Perfect, stylish language is not essential but it must be clear and unambiguous. If the language of a paper is not clear, Academic Editors should recommend that authors seek independent editorial help before submission of a revision. Poor presentation and language is a justifiable reason for rejection.
- Experiments, statistics, and other analyses performed are described in sufficient detail. The research must have been performed to a technical standard to allow robust conclusions to be drawn from the data. Methods and reagents must also be described in sufficient detail so that another researcher is able to reproduce the experiments described.
- Conclusions are presented in an appropriate fashion and are supported by the data. The results must be interpreted appropriately, such that all conclusions are justified. However, authors may discuss possible explanations for their results as long as these are clearly identified as speculations or hypotheses, rather than as firm conclusions. Inappropriate interpretation of results is a justifiable reason for rejection.
- The research meets all applicable standards for the ethics of experimentation and research integrity. Research to be published must have been conducted to the highest ethical standards. A brief description of the most common of these is described in our Editorial and Publishing Policies.
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Full papers providing accounts of original work: Research containing significant new findings. The material presented should be original and not have been published elsewhere, except in a preliminary form. Papers will be reviewed by three referees familiar with the subject matter of the paper.

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Letters to the Editor: the bulletin welcomes letters to the editor. The purpose of Letters to the Editor is to provide a forum for positive and constructive views on articles and matters published in the bulletin. Letters to the Editor must not exceed 300 words. Letters to the editors include technical reports from countries or projects.

Key notes and special calls: The editor will, from time, invite selected key figures in the field of animal health and production for key notes on specific topics. Book Reviews: are accepted and should provide an overview of the work's contents and a critique of the work's value. Book reviews should be limited to 1000 words.

Conference Proceedings: Special Issues of the bulletin may be dedicated to publication of proceedings of key meetings/ conferences

Obituary articles to honor prominent African scientists that have made significant contribution to animal resources research and development

News and announcements: BAHPA is pleased to publish information on animal health and production activities/meetings. Please send the following information to the Editor: Date of the event, title, organization offering the event, location and contact information.

Submission Guidelines
Full papers of original research

All manuscripts submitted to BAHPA should include the following features:

1. On cover page of the manuscript, the following should be clearly written/inserted: the corresponding author, name of the institution, , title of the manuscript, names of the authors, the addresses of the authors and the e-mail address of the corresponding author. The corresponding author should ensure that all the other authors consent to their names being included. The consent should be sent directly by co-authors to the editor via email.
2. Each original article should be divided into Abstract and Keywords, Introduction, Materials and Methods, Results, Discussion, conclusion, Acknowledgments and References. A textbox containing a public brief on the study for the benefit of policy makers should also be provided. This textbox will not be included in the published article but will be compiled and published in a separate edition at the end of the year.
3. Title, which should be concise, preferably not more than 15 words long, followed by the author(s) name(s) and institution(s) to which work should be attributed and address for correspondence, if different.
4. The Abstract should not be longer than 300 words giving a synopsis of the work and should contain the objectives, briefs description of materials and methods, highlights of significant results, conclusions and recommendations. Up to six keywords should be provided..
5. The Introduction should contain the problem statement, the hypothesis and the objective of the work and cite recent important work undertaken by others.
6. Materials and Methods should describe materials, methods, apparatus, experimental procedure and statistical methods (experimental design, data collection and data analysis) in sufficient detail to allow other authors to reproduce the results. This part may have subheadings. The experimental methods and treatments applied shall conform to the most recent guidelines on the animal's treatment and care. For manuscripts that report complex statistics, the Editor recommends statistical consultation (or at least expertise); a biostatistician may review such manuscripts during the review process. Cite only textbooks and published article references to support your choices of tests. Indicate any statistics software used.
7. Results should be presented clearly and concisely, in a non-repetitive way. Subheadings may be accepted.
8. Discussion of significance should be focused on in the interpretation of results. Subheadings are not accepted in this section.
9. Acknowledgements. Where necessary acknowledgements of grants and technical assistance should be included under this heading. . Please also include any potential conflict of interests if appropriate. Suppliers of materials should be named and their location (town, state/county, country) included.
10. State the conclusions, and any implications that may be drawn from the study.

Short Communications: Manuscripts should contain original data and be limited to 1500 words. The number of tables and figures are limited to two. A limited number of references should be included. Headings are not allowed in short communications.

Sequence of Preparation

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Examples of References

- *Journal Articles:* Ouyang D, Bartholic J, Selegean J, 2005. Assessing sediment loading from agricultural croplands in the Great Lakes basin. Journal of American Science, 1(2): 14-21.
- *Books:* Durbin R, Eddy SR, Krogh A, Mitchison G, 1999. Biological Sequence Analysis: Probabilistic Models of Proteins and Nucleic Acids. London, Cambridge University Press.

- *Chapter in a Book:* Leach J, 1993. Impacts of the Zebra Mussel (Dreissena polymorpha) on water quality and fish spawning reefs of Western Lake Erie. In Zebra Mussels: Biology, Impacts and Control, Eds., Nalepa T, Schloesser D, Ann Arbor, MI: Lewis Publishers, pp: 381-397.
- *Reports:* Makarewicz JC, Lewis T, Bertram P, 1995. Epilimnetic phytoplankton and zooplankton biomass and species composition in Lake Michigan, 1983-1992. US EPA Great Lakes National Program, Chicago, IL. EPA 905-R-95-009.
- *Conference Proceedings:* Stock A, 2004. Signal Transduction in Bacteria. In the Proceedings of the 2004 Markey Scholars Conference, pp: 80-89.
- *Thesis:* Strunk JL, 1991. The extraction of mercury from sediment and the geochemical partitioning of mercury in sediments from Lake Superior, Unpublished PhD thesis, Michigan State University, East Lansing, MI.
- *Web links:* Cerón-Muñoz M F, Tonhati H, Costa C N, Rojas-Sarmiento D and Solarte Portilla C 2004 Variance heterogeneity for milk yield in Brazilian and Colombian Holstein herds. Livestock Research for Rural Development. Volume 16, Article #20 Visited June 1, 2005, from http://www.lrrd.org/lrrd16/4/cero16020.htm

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Please send the figures as separate files and do not import them into the text file. Put all tables, figures, diagrams and artwork on separate pages. Each figure, table, and bibliographic entry must have a reference in the text. References to tables and figures in the text should be by number and not to "table below" or "figure below". The Editor will place them in the appropriate place in the text of article during the final edit. Tables and figures should be numbered consecutively. Please submit the data for figures in black and white.

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