SCIENCES AND TECHNOLOGIES for Sustainable Agriculture

Revue scientifique à comité de lecture éditée par l'Université Nationale d'Agriculture du Bénin. Journal ayant pour vocation d'inciter et d'accompagner le développement d'une agriculture durable en Afrique et ailleurs.

- Plant productions
- Animal productions
- Forestry
- Horticulture
- Veterinary Medicine
- Fisheries science
- Biotechnology
- Rural economy
- Agro industry
- Agro-climatology
- Human nutrition
- Agricultural extension
- Conservation of bio-resources
- Food science and technology
- Rural sociology and anthropology
- Rural Engineering
- Environmental management and climate change

....

UNIVERSITE NATIONALE D'AGRICULTURE

https://stsa.una.bj/index.php/st

Scanné avec CamScanner

Sciences and Technologies for Sustainable Agriculture

Revue Scientifique à Comité de Lecture

Vol 5, N°1 –Janvier-Juin 2026 - ISSN: 1659-5726 (Online) 1659-634X (Print)

Publication semestrielle

Université Nationale d'Agriculture
BP 43 Kétou Email : revues.stsa@una.b j/ unastad@gmail.com
Site web : https://stsa.una.bj/index.php/st

Comité éditorial

L'éditeur est le garant de la ligne éditoriale. Le comité éditorial est composé d'éditeurs thématiques et est présidé par un éditeur en chef et son adjoint. Le comité éditorial est nommé par une décision rectorale.

Comité Editorial:

Editeur en chef : Dr (MC) TOTIN Edmond ;
Editeur en chef-adjoint : Dr (MC) PADONOU Elie ;
Responsable du service des publications : M. ADOUN Sènan Landry.

Editeurs Thématiques:

Champs thématiques	**Editeurs thématiques**
Sciences Animale et Halieutique	Dr (MC) Brice Hervé DAKPOGAN Dr (MA) Clément Dogbé ADJAHOUINOU
Sciences Végétale, Horticole et Forestière	Dr (MA) Rodrigue IDOHOU Dr (MC) Ghislain TEPA-YOTTO Dr (MA) Félicien Djigbo BADOU
Sciences des Alimentaires et Nutrition	Dr (MC) Wilfried PADONOU Dr (MC) Harold HOUNHOUIGAN.
Economie et Sociologie rurales	Dr (MC) Nestor ALOKPAÏ Dr (MA) Jaures Cocou AMEGNANGLO Dr (MC) Alice BONOU
Génie rural	Dr (MC) Edem CHABI Dr (MA) Chaim Vivien DOTO

Comité Scientifique

DJOSSA Agossou Bruno (UNA - BENIN)
OKRY Kowouan Florent (UNA - BENIN)
FANDOHAN Adandé Belarmain (UNA - BENIN)
OLOUNLADE A. Pascal (UNA - BENIN)
BIAOU Gauthier (UNA - BENIN)
HOUNGNANDAN Pascal (UNA - BENIN)
SINSIN Brice (UAC - BENIN)
CODJIA Jean T. Claude (UNA - BENIN)
MENSAH Guy Appolinaire (INRAB – BENIN)
MONGBO Rock (UAC – BENIN)
SALIFOU Sahidou (UAC – BENIN)
TOSSOU Rigobert (UAC – BENIN)
AKLI Cokou (UL – TOGO)
van DAMME Patrick (Université de Gand - BELGIQUE)
AYSSIWEDE Simplice Bosco (EISMV – SENEGAL)
NOUT Robert (PAYS - BAS)
AHOYO-ADJOVI Nestor (INRAB – BENIN)
TAMO Manuele (IITA – BENIN)
ENGELMANN Florent (IRD – BENIN)
AFFOGNON Hippolyte (CORAF)

National University of Agriculture

Sciences and Technologies for Sustainable Agriculture (STSA)

ISSN: 1659-5726 (Online) 1659-634X (Print) https://www.stsa.una.bj/index.php/st

VOLUME 5 N° 1 (ORIGINAL ARTICLE) *Published on: 30 jun 2026*

Floating cage systems of the aquaculture industry in Benin: Assessment of opportunities and challenges on Lake Djetoe

***Missinhoun Dagoudo*[1]*, Saïdane Aboudou Abdou*[1]*, David Benhaïm*[2]*, Elie Montchowui*[1*]**

[1]*Research Unit in Aquaculture and Fisheries Management, National University of Agriculture, Republic of Benin.*

[2]*Department of Aquaculture and Fish Biology, Hólar University, Iceland.*

.**Résumé**

Les aquaculteurs doivent développer de nouvelles stratégies ou améliorer les systèmes existants afin de maintenir leur production face aux défis, tels que la hausse des coûts de production et le changement climatique, pour une aquaculture efficace et durable. Cette étude vise à évaluer les opportunités et les défis de la production aquacole en cages flottantes sur le lac Djetoe au Bénin. À cet effet, des entretiens approfondis ont été menés auprès du personnel clé, complétés par des observations directes sur le terrain. Un questionnaire (questions descriptives et ouvertes) a été administré aux parties prenantes. Les résultats ont révélé que le Bénin possède un potentiel important pour le développement de l'aquaculture grâce à ses ressources en eau non exploitées. L'élevage en cages au Bénin peut stimuler la croissance du secteur, créer des emplois, renforcer la sécurité alimentaire et réduire la pauvreté. La seule espèce cultivée en cages sur ce lac est *Oreochromis niloticus*. Les cages installées présentaient des volumes compris entre 45 à 62,5 m^3. La densité d'élevage sur ce lac variait de 96 à 200 poissons/m^3 avec un poids moyen final de 500 g après six mois d'élevage. La productivité est entre 7 et 15 kg/m^3. Cette activité est relativement rentable. Le bénéfice peut atteindre 1.785.000 Fcfa par an avec 10 cages. Les défis majeurs rencontrés sont le conflit entre les pisciculteurs en cages et les pêcheurs, le manque d'alevins et d'aliments de qualité et les lacunes réglementaires. Les perspectives d'avenir de la pisciculture en cages au Bénin semblent prometteuses.

Mots clés : Développement de l'aquaculture, Elevage en cage, *Oreochromis niloticus*, Changement climatique, Perspectives, Durabilité.

Abstract

Aquaculture farmers need to develop new or improved strategies or systems to sustain production amidst numerous challenges such as rising production costs and climate change, for efficient and sustainable aquaculture. This study aims to assess the opportunities and challenges of floating cage aquaculture production on Lake Djetoe in Benin. For this purpose, in-depth interviews were conducted with key personnel, supplemented by personal field observations. Furthermore, a questionnaire (descriptive and open questions) was administered to stakeholders. The study revealed that Benin has significant potential for aquaculture development owing to its abundant, unused water bodies. Cage culture in Benin can stimulate the growth of aquaculture industry, create employment, enhance food security and reduce poverty. The only species cultivated (Nile Tilapia, *Oreochromis niloticus*) in cage culture on Lake Djetoe are established with sizes ranging from 45 to 62,5 m^3. The stocking density on this lake rangesfrom 96 to 200 fish.m^{-3} with a final average weight of 500 g after a six-month culture period, and the productivity ranges from 7 to 15 kg.m^{-3}. This business is relatively profitable, up to US$ 2,975 yearly for a farm operating 10 cages. The major challenges faced on lake Djetoe are the conflict between cage culture farmers and fishermen, and the lack of quality fish seed and feed, and policy gaps that must be remedied. Overall, the future trends for fish cage culture in Benin appear relatively bright.

Keywords: Aquaculture development, Cage culture, *Oreochromis niloticus*, Climate change, future trends, Sustainability.

Les auteurs conservent le copyright de leurs travaux et accordent à la revue Sciences and Technologies for Sustainable Agriculture (STSA) une licence non exclusive de publication et de diffusion. Sauf indication contraire, les articles sont publiés sous licence CC BY 4.0, permettant leur réutilisation avec attribution appropriée, les auteurs demeurant seuls responsables du contenu de leurs publications.

Corresponding author: *Elie Montchowui*

Received on 23 fev 2026 and accepted on 25 Jun 2026

E-mail address: *elie.montchowui@una.bj*

1. Introduction

The crucial role that aquatic foods play in food security and nutrition is increasingly recognized, not only as a source of protein, but also as a distinctive and extremely varied source of essential omega-3 fatty acids and bioavailable micronutrients (FAO, 2022). Fisheries and aquaculture are key factors in food security, which is crucial for sustainable development goals (Dagoudo et al., 2021; FAO, 2022). Despite the rapid growth in recent years, neither subsector can avoid the challenges posed by the global population, which is expected to reach 9.6 billion people by 2050 (Mustafa et al., 2018).

Benin has experienced continued growth in aquaculture in recent years. Fish production was estimated at 5114,66 tons in 2018 (Dagoudo et al., 2022).

Aquaculture activities in Benin predominantly focus on pond culture systems and the cultivation of two species: Nile Tilapia (*Oreochromis niloticus*) and Sharptooth catfish (*Clarias gariepinus*), which limits productivity. Over the past two decades, there has been a considerable decrease in fish harvests due to the adverse effects of climate change, such as prolonged droughts and floods. During this period, annual fish importation increased, exceeding national fisheries production (Elègbè et al., 2019; Latifou et al., 2020). This has become a major challenge for the Beninese government in its effort to reduce dependence on imports. To promote further growth, it is necessary to accelerate the implementation of transformations that establish sustainable, inclusive and equitable fishing and aquaculture (Dagoudo et al., 2024). This requires changes in policies, management, innovation and investment. Furthermore, inland artisanal fishing production decreased from 44 726 tons in 2020 to 36 631,2 tons in 2021, a decrease of 18,10% (DSA, 2021). Moreover, the decline and high pressure on natural water resources have accelerated the development of complementary technologies such as cage aquaculture farming and aquaculture parks. These are innovative or new fish production avenues that have been adopted internationally (Gentry et al., 2017; Mbowa et al., 2017).

Benin is characterized by extensive aquatic water resources including lakes, rivers, natural depressions, wetlands, large impoundments, and irrigation canals that are potential sites for commercial cage aquaculture. Cages are easy to manage, produce high-quality fish and utilize existing water bodies (Beveridge, 1996); therefore, cage aquaculture offers a viable alternative for landless farmers in resource-poor areas as Benin.

Cage aquaculture is a significant technology for intensifying fish production. In Asia, America and Europe, a widespread and profitable culture of prawns and fish in cages has been successfully developed (FAO, 2004). Cage aquaculture dates back to many centuries in China (Bao-Tong, 1994). Since then, many nations in this region have practiced cage culture in freshwater and marine environments, including lakes, rivers, open sea, estuaries, reservoirs and ponds (Eng and Tech, 2002; Balcazar et al., 2006). Cage aquaculture in open water bodies could offer an opportunity for mitigating protein demand in the country. Nowadays, this practice has extended throughout the world because of its advantages. Cage aquaculture offers numerous benefits, including high production per unit volume of water, relatively low investment per unit of production, high estimated profitability levels, utilization of existing water bodies thus reducing pressure on land, relatively low capital requirements, ease of movement and relocation, reduced effect of drought on production relative to water availability, and flexible management (EL-Sayed, 2006; De Silva & Phillips, 2007). In most African countries, cage farming appears to be a new technology (Aura et al., 2018).

However, only 3.3% of fish farmers in Benin use floating cages, despite the method offering many opportunities given the availability of water resources (MAEP, 2015). Cage fish culture was recently adopted in Benin as a strategic objective to intensify aquaculture production and respond to the high demand for fishery resources (FAO, 2018). In 2019, the Toho-Todougba lagoon was the only site producing about 600 tons of fish through fish cage culture (Achoh et al., 2021). Nowadays, the government and other investors view cage fish culture as a means to increase fish production, potentially leading to higher incomes.

Despite the will of fish farmers and others, this method of culture faces challenges such as identifying suitable zones for cage aquaculture and determining the carrying capacity of the water resource for optimal production. Challenges include the discharge of organic particles into the environment, high concentrations of phosphorus and nitrogen, eutrophication, pollution, and disease management that hinder its development. However, to maximize production efficiency, adherence to best practices such as management level, quality of seed and feed, and adopting an ideal fish stocking density is required.

This paper assesses the production, opportunities and challenges of cage aquaculture, along with the limited information available on its sustainable management. This study aimsto evaluate the current state of cage aquaculture in Lake Djetoe, identify the opportunities and constraints affecting the sector, and provide evidence-based recommendations for its sustainable development.

2. Materials and methods

2.1. Study area

This study was conducted on lake Djetoe, located in the municipality of Lokossa, department of Mono, in the southwest part of Benin, situated at 6° 38′ N, 1° 43′ E. Lokossa City covers about 260 km^2 (Figure 1). The climate is sub-equatorial with two (2) dry seasons (December to March; mid-August to mid-September) and two (2) rainy seasons (April to July; mid-September to October), with a peak usually noted in June. The annual rainfall averaged 1264 mm with ambient temperatures fluctuating between 23°C and 35°C. Monthly evaporation rates varies from 59.2 to 145 mm. The municipality of Lokossa is blessed withnumerous waters bodies, including Mono river, lake Togbadji, lake Toho, lake Djetoe and many tributaries.

Lake Djetoe has become popular because of its expansive area (approximately 14 hectares), the abundance of fish species, ecological status, and the use of its water for surrounding agricultural activities.

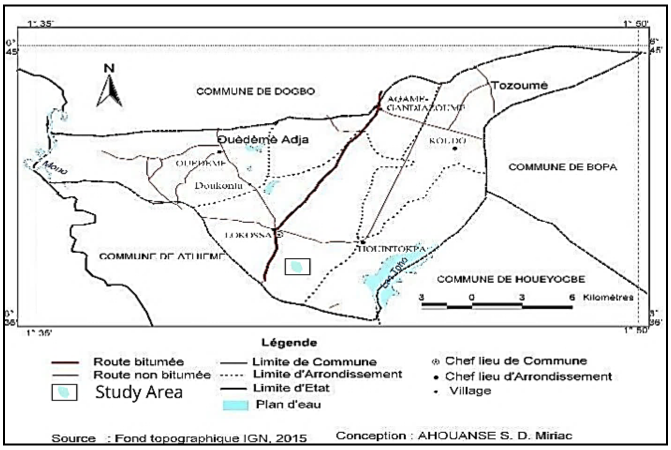

Figure 1. Map of the study area.
Source : Adapted from Miriac et al. (2020).

2.2. Study design

Information on management practices, fish cage culture operators and the socio-economic activities of the surrounding communities was collected as primary data. Additionally, the study investigated the challenges faced by farmers in cage aquaculture, including fish seed and fish feed availability, management quality. Two methods were used to collect information: Firstly, relevant and qualitative data were collected from in-depth interviews with key personnel and personal field observations. A draft questionnaire (descriptive and open questions) was then developed and pre-tested with three (03) cage aquaculture farmers before adjustments and improvements were made. Based on the responses from the pre-test, modifications, rearrangements and improvements were made to establish the final questionnaire. Specifically, the questionnaire covered respondents' socio-demographic characteristics, cage aquaculture production practices (cage size, stocking density, cultured species, feeding practices), sources and quality of fingerlings and feed, production performance, socio-economic benefits, and the main constraints and opportunities associated with cage aquaculture development in the study area. The perceived quality of fingerlings was assessed based on farmers' evaluations using observable production-related criteria, including survival after stocking, uniformity of size, apparent health status, vigor, and early growth performance. At least 90% of the cage aquaculture farmers, both active or inactive, especially in the locality with a direct impact on the lake in the municipality, were assessed. Fifty (50) people in the locality of Vivotin who had a direct impact on lake Djetoe, were interviewed (including aquaculturists, fishermen, agriculturists, fish traders, authorities and resource persons). There were six (06) permanent and active cage aquaculture farmers on Lake Djetoe in the Department of Mono, but onlyfour (04) operated seasonally. Secondly, scientific publications and reports on these aspects were mostly documented in English or French from different database like Agora, Google scholar and Scopus using key words like "Aquaculture", ''Fishing", "floating cage aquaculture", '' impact", ''challenge", or ''Benin" and'' culture species". No strict publication time restriction was applied. Prior to the selection, the duplicate publications and publications not relevant to the objectives of the study were excluded. The selected documents were those that specifically addressed floating cage aquaculture and/or its challenges, impacts, production systems, environmental implications, management practices and potentialities, covering all or part of Benin. Conference reports, projects, government publications and other non-peer-reviewed documents were obtained from the various actors involved, especially from Benin's Direction of Agricultural Statistics (DSA).

2.3. Data processing and analysis

The data, including fish species reared, stock density, cage size, fish feed/seed quality, were collected through structured questionnaires administered to cage aquaculture farmers. In addition, the fish species reared were identified through direct field observation, while cage dimensions were obtained through direct measurements conducted during the field survey to ensure data accuracy.

Cage productivity was estimated as the harvested fish biomass (kg) per unit cage volume (m^3). Harvested fish biomass was obtained from farmers' harvest records and survey responses, whereas cage volume was determined from the measured cage dimensions. Productivity was calculated by dividing harvested fish biomass by cage volume and expressed as kg m^{-3}.

The collected data were organized into tables, charts, and graphs using Microsoft Excel to identify patterns from the responses obtained. The coded responses were transferred to the Statistical Package for the Social Sciences (SPSS) software version 23.0, which was used to obtain descriptive statistics (frequencies, percentages, modes, etc.) following standard procedures described by Field (2024).

3. Results

3.1. Cage Aquaculture industry on lake Djetoe in Mono department

First of all, water quality characteristics such as temperature, dissolved oxygen concentration, pH and transparency were monitored freely by the Territorial Agent Department of Agriculture (ATDA) of Benin for some farmers. However, the majority (90%) did not have access to this service. Fifty (50) people in the locality named Vivotin, a village that has a direct impact on lake Djetoe, were assessed. This group included aquaculturists, fishermen, agriculturists, fish traders, authorities, and resource persons. Additionally, there were six (06) permanent and active cage aquaculture farmers and four (04) seasonal cage aquaculture farmers on Lake Djetoe in the Department of Mono. Our investigation revealed that the limited numbers of fish farmers registered using cage technology is due to this farming technique being relatively new fishery innovation in Benin and still in its embryonic stage. Table 1 summarizes aquaculture production in Lake Djetoe including the active and permanent producers in the Mono department. The exotic Nile tilapia (*oreochromis niloticus*) is the only species cultured by these cage aquaculture farmers.

Based on interviews, it was discovered that the farmers had cages of various sizes ranging from 45 to 62,5 m^3. The study has revealed that all cage aquaculture enterprises surveyed on Lake Djetoe had less than 10 years of operational experience at the time of the survey in 2023. All the farmers on Lake Djetoe investigated were using square fish cages for their production and the production cycle ranged between six to eight months on average.

Concerning the typology, 10% of the farmers interviewed are cooperatives and the rest are individuals. Women accounted for 30% of those involved in ownership of the activity, but cage aquaculture producers on Lake Djetoe is dominated by males.

The stocking density by cage aquaculture farmers on Lake Djetoe rangesfrom 96 to 200 fish.m^{-3} (table 1) in the locality, with a final average weight of 500 g after six-month culture period, while the initial body weight was from 5 to 15g.

Cage culture productivity in this study (Lake Djetoe) ranges from 7 to 15 kg.m^{-3}, with productivity mostly influenced by cage management.

Constraints to cage culture development on lake Djetoe include the relative lack of investigation into key issues affecting freshwater cage farming. Foremost among these issues are the determination of suitable stocking densities for the lake, feed usage and related efficiencies, species suitability, identification of diseases and their management.

Table 1: Characteristics of cage aquaculture farms surveyed on Lake Djetoe (2023).

Company	Stocking density (fish.m^{-3})	Cage dimensions L × W × D (m)	Number of cage	Total cage volume (m^3)
Djêtoênousite/Rodrigue.	192	5*5*3	10	750
Pivot de Gloire.	200	6*3*2.5	6	270
Sergei agrofish.	153	5*5*2.5	10	625
Djêtoênou site/Issifou.	134	5*5*2.5	1	45
Djêtoênou site/Anne.	96	5*5*2.5	2	90
Djêtoênou site/victoire	150	5*5*2.5	1	45

Note: L = length; W = width; D = depth.

3.2. Fish seed sources and quality

Among the ten farmers interviewed on Lake Djetoe, eight farmers (80%) obtained their tilapia fingerlings from partners or private companies such as Wizard sibling consulting company and some private farms; one of the farmers (10%) collected fingerlings from the natural environment, like the Mono river, while another 10% was self-producers or obtained them from outside the country (Figure 2).

Concerning the quality of fingerlings used on lake Djetoe, five among the ten farmers interviewed (50%) rated the fingerlings as being of very good quality, four farmers (40%) rated them as good quality, while one farmer (10%) considered them not to be good enough (Figure 3).

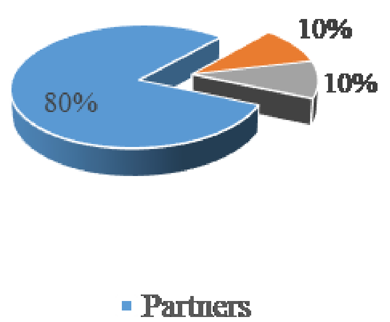

Figure 2: Sources of Nile tilapia fingerlings used by cage aquaculture farmers surveyed on Lake Djetoe (Mono Department, Benin).

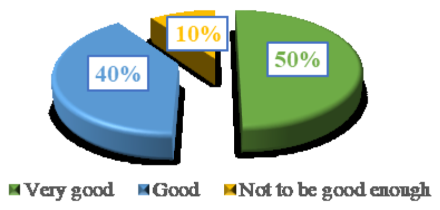

Figure 3: Farmers' assessment of fish fingerlings quality on Lake Djetoe

3.3. Fish feed sources and feeding frequency

Eight out of ten farmers interviewed (80%) on lake Djetoe use commercial feed, while two farmers (20%) use mixed feed (imported and local) (Table 2). The commercial feeds are either imported or manufactured by some key fishermen trained by the government. "Aller-Aqua" is the largest company importing feed in the Mono department. The local feed is bought from ''key fishers" and other farmers in the country.

Farmers on Lake Djetoe feed fish 3 to 5 times per day at 3 to 5% of live body weight (Figure 4). However, the challenge on the lake Djetoe lies in estimating the correct quantity of feed to be administered to the fish. Fish feeding frequency varies according to the fish´s stage of development. Consequently, more than 50% of the production cost is attributed to fish feed due to the lack of appropriate techniques for estimating current biomass during production.

Concerning the quality of the fish feeds obtained (Table 3), four out of ten farmers interviewed (40%) revealed that the quality was very good, other four farmers (40%) indicated that the feed was good while two farmers (20%) observed that the fish feed quality was rather inadequate at times.

This study has revealed the higher demand for feed from farmers and a scarcity of feed due to the high cost of raw materials, according to feed producers. This shortfall could lead to feed shortages, as reported by some farmers. Most farmers prefer using imported commercial feed, which may sometimes be inadequate for their fish´s stage, growth or environment conditions. Additionally, most feed producers have limited experience in producing floating feed production for cage aquaculture. Moreover, some aquaculture feed manufacturers have indicated that the high cost of raw materials, particularly micro-ingredients such as fish meal, vitamins and premixes, poses a major challenge in feed production.

Table 2: Sources of fish feed used by cage aquaculture farmers on Lake Djetoe (n = 10)

Source of fish feed	Percentage (%)
Imported feed	50%
Feed manufactured by key fishermen	30%
Mixed feed	20%

n = number of interviewed farmers

Table 3: Farmers' assessment of fish feed quality on Lake Djeto (n = 10)

Quality	Percentage (%)
Very good	40%
Good	40%
Inadequate	20%

n = number of interviewed farmers

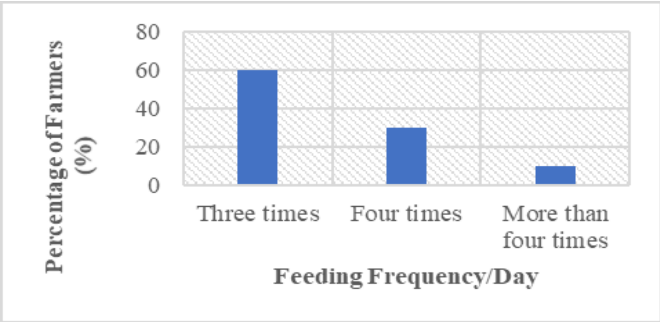

Figure 4: Feeding frequencies used by cage aquaculture farmers on Lake Djetoe

3.4. Socio-economic impacts of floating cage aquaculture

This study has revealed the socio-economic impact of floating cage aquaculture in the locality following our investigations. People have generally stated that fishing and aquaculture has significantly improved their income. For cage farmers, this activity is optimal regarding access to stress-free jobs, contribution to food security, conversion, and the easy involvement of women in the process. According to farmers' reports, this activity yields an annual income between $US 1,300 and $US 2,000 yearly depending on the diligence of the farmer, with fewer disease outbreaks (Table 4). Furthermore, women were significantly more involved in fish processing and marketing than culture in the locality. Farmers reportedly manage activities such as making nets. According to the farmers, cage aquaculture and related activities generate up to US$ 2,975 in annual profit for a farm operating 10 cages (750 m^3 total production volume). They had two production cycles per year. Income and profit values were estimated based on information provided by farmers regarding production volumes, sales prices, and operational costs during their most recent production cycle. For them, aquaculture can contribute greatly to poverty eradication in their locality. Consequently, inhabitants prepare to engage in these activities, and those already involved are looking for ways to improve or expand them. The socio-economic enhancement of aquaculture farmers has allowed for the improved education of their children up to university level. Farmers revealed that the cage aquaculture system is more productive compared to capture fisheries. Another challenge on Lake Djetoe was the conflict between traditional fishermen and cage culture farmers. The traditional fishermen, due to the ignorance of laws and regulations on cage aquaculture in the country, considered themselves owners of the lake and required returns from cage culture farmers. Additionally, due to a lack of financial investment in building floating houses, some traditional fishers would vandalize the cages at the night when the farmers were absent. Nowadays, a contract is made between traditional fishermen and cage culture farmers by the local authorities. It has beendiscovered that most farmers on Lake Djetoe lacksthe capacity to obtain appropriate equipments for fish grading and harvesting for their production. Investigations have revealed that eight of the ten (80%) cage aquaculture farmers interviewed faced additional constraints to cage culture on Lake Djetoe, including low prices and quality of wild-caught fish, lack of economies of scale, high investment costs, lack of training in cage culture, insufficient processing facilities, inexperience in disease identification and management, and lack of commitment from the government to aquaculture development in the locality as well as fishery extension. The proliferation of water hyacinth (*Eichhornia crassipes*) in Lake Djetoe may also represent a significant constraint to the development of cage aquaculture, as it can obstruct access to cages, interfere with farm operations, and affect water circulation.

Table 4: Socio-economic indicator of farmers on Lake Djetoe

Socio-economic indicator	Value
Production cycles per year	2
Annual income per farmer (USD)	1,300–2,000
Annual profit from cage aquaculture and related activities (USD)	Up to 2,975

4. Discussion

4.1. Cage Aquaculture industry on lake Djetoe in Mono department

This study has found that Nile tilapia is the only species cultured by cage aquaculture farmers on lake Djetoe in the Mono Department. This may be due to the limited species cultured in Africa in general (Dagoudo et al. 2025). Moreover, culture practices and management along with tilapia´s rapid growth, may be another reason for this fact. Furthermore, Tilapia has a strong worldwide market as it is widely cultured globally (FAO 2009). These findings are similar to research conducted by Mbowa et al. (2017), which stated that the predominant species cultured in cages in Uganda is Nile tilapia.

It was discovered that the farmers had different sizes of cages ranging from 45 to 62.5 m^3. All the farmers were using square fish cages for their production, and the production cycle ranged between six and eight months on average. The differences are due to individual financial capacities since larger companies had bigger cages on average and were benefiting from economies of scale, as well as knowledge concerning management and owner preferences. Opiyo et al. (2018) observed in their results that five riparian countries in Kenya had different cages sizes, ranging from 8 to 125 m^3. Mbowa et al. (2017) categorized them in Uganda in small cages of approximately 32 m^3 in size, while larger cages are about 600 m^3.

Cage aquaculture production on lake Djetoe is dominated by males because the peoplebelieve that managing these facilities requires intensive labor and working on water is an activity that most women may not find appealing. This very male dominance was reported by Njiru et al. (2018) and Aura et al. (2018) on Lake Victoria in Kenya.

Stocking density is considered one of the vital factors affecting fish growth, gross fish yield and feed utilization (Chakraborty et al. 2010). In lake Djetoe, different stocking densities of Nile tilapia range from 96 to 200 fish.m^{-3}. The variation in stocking densities may be attributed to the initial size at which the fish are stocked and harvested, water depth, season and management-related reasons (feeding regime, pond maintenance, and harvesting frequency…). The stocking density by cage aquaculture farmers in this study is similar to the results of Opiyo et al. (2018) and Njiru et al. (2018) on Lake Victoria in Kenya, estimated at 60 to 350 fingerlings.m^{-3}; Hasimuna et al. (2019) found a stock density ranging from 53 to 160 fingerlings.m^{-3} in Lake Kariba (Zambia); Abaho et al. (2020) demonstrated a good growth with 200 fish.m^{-3} in Lake Albert (Uganda). Blow et al. (2007) and Ofori, (2010) found a stocking density for *O. niloticus* ranging from 63 to 188 fish.m^{-3} with an initial body weight of 10 g to 30 g on Lake Volta (Ghana). Pullin, et al. (1996) suggest that stocking density for *O. niloticus* should vary with the season, recommending an average of 100 fish.m^{-3} in the dry season and 85 fish.m^{-3} in the rainy season in the Niger River. A stocking density ranging from

40 to 60 fish.m^{-3} for *O. niloticus* was found on lake Toho-Todougba in Benin with feeding three times daily promoting the optimization of the production and profit (Aïzonou et al. 2023).

Cage culture productivity in this study (Lake Djetoe) ranges from 7 to 15 kg.m^{-3}. The productivity mostly depends on cage management. Blow et al. (2007) and Ofori, (2010) found a productivity of 9.6 kg.m^{-3} after six months of *O. niloticus* culture on Lake Volta (Ghana). Similarly, Mbowa et al. (2017) observed a range between 5 to 35 kilograms of fish per cubic meter in Uganda.

4.2. Fish feed and feeding frequency

Cage aquaculture management requires in-depth knowledge about feeding, environmental aspects, and the biology of the species being reared. In this study, farmers on lake Djetoe feed 3-5 times per day at 3–5% of live body weight, generally three times daily. The difference in feeding frequency on lake Djetoe is due to the financial capacity of the owners and the difference in stock density observed. Feeding frequency affects the zootechnical growth performance of farmed fish. According to Huchette and Beveridge (2003), although natural feeding is confirmed, special feeding, regardless of natural trophic accessibility, resulted in good productivity. Sakr et al. (2015) proved that in the presence of periphytons, one (01) distribution of protein-based feed per day is sufficient to enhance the productivity of *O. niloticus* in a floating cage. Moreover, Cuvin-Aralar et al. (2012) stated that a 24-hour interspersed feeding did not affect the growth of *O. niloticus* in floating cage culture. However, more research is required to determine the impact of 48-hour interspersed feeding on productivity. Further research is needed to determine the optimal feeding frequency for improved growth of *O. niloticus* in tropical regions, particularly in Benin's lake and rivers, including lake Djetoe, as it could significantly enhance farmer's income.

In 2021, the total quantity of aquaculture feed supplied generally in Benin was 4,503.55 tonnes, against a requirement of 33,610 tonnes, resulting in a coverage rate of 13.40% (DSA 2021). This shortfall could lead to a lack of feed as some farmers have observed. While 20% of the farmers were not satisfied with the feed used, 80% perceived the quality of their feed as good or very good. Therefore, it is possible that the quality of fish feed may not be the primary issue. Instead, the combination of fish feed with local/wild resources and husbandry practices might contribute to the productivity levels observed. Fish growth is a function of genetics and environment. The quality of both the broodstock and their offspring concerning their health, depends on genetic aspects.

4.3. Fish seed

Fish seed is the most vital aspect and constitutes the key challenge to the development of this industry in most African countries. This study has found that 80% of farmers interviewed in lake Djetoe obtained their tilapia fingerlings from partners or private companies, while 10% collected them from natural environments like the Mono river. The remaining 10% were self-producers or obtained fingerlings from outside the country. This may be due to factors such as the price of fingerlings, each farmer´s financial capacity, and their level of determination and understanding. Additionally, the high cost of transportation due to the distance from the source of supply, management strategies for transport, and the varying experiences of each farmer may be another factor. On the other hand, capturing wild fingerlings or juveniles for aquaculture is also a type of culture (Lovatelli and Holthus 2008). However, it is necessary to practice appropriate capture methods while assessing the risk of resource exhaustion (FAO 2011). Our investigation has revealed that at the national level in Benin, 72% of aquaculture farmers obtain their tilapia fingerlings from private partners, while the remaining 28% collect tilapia from natural environments or self-production (DSA 2020). Among those who acquired tilapia from partners, 86% purchased directly from private sectors; 1.85% from the government; 1.17% from Non-Governmental Organization, and 10.91% from foreign partners (DSA 2020).

In this study, 10% of participants who reported that the seeds were not too good were primarily those who collected from natural environments or were self-producers. It was also observed that for some farmers, the source of fingerlings procurement was distant, potentially causing stress and injuries to the fish, as well as incurring high transportation costs. At the national level in Benin, 87.2% were satisfied with their obtained fingerlings (DSA 2020). The farmer´s opinions about seed quality were based on their personal viewpoints and years of experience with the seeds used until harvest. In Benin, there were 85 operational hatcheries in 2021, with 93% located in the southern departments. A total of 22,664,708 fry was produced in 2021 compared to 19,860,782 in 2020, representing an increase of 14.12% (DSA 2021). This annual growth confirms the availability of fry in the country. A key barrier to the development of competitive cage culture in lake Djetoe is the lack of access to domestically produced high-quality extruded fish feeds and seeds at competitive prices. The high cost of seeds and feeds disrupts the farmers' plan. As it is well known, fish seed is the most vital aspect and remains a significant challenge to the development of the aquaculture industry in most African countries.

4.4. Socio-economic impacts of floating cage aquaculture

Fishing and aquaculture have considerably improved the income for the people and the locality around lake Djetoe. For cage farmers, it is their best activity regarding the access to stress-free jobs, contribution to food security, easy involvement of women in the process, and enhancement of their children´s education up to university level. The results of this study are similar to those found by Codjo et al. (2023 a, b), who found out that cage aquaculture improved food and nutritional security, farmer's living condition and contributed to job creation in Lac Toho, Benin. Hidayati et al. (2018) reported that cage aquaculture enhanced food security not only for the immediate population but also for neighboring nations or regions. Furthermore, Blow et al. (2007) demonstrated that cage aquaculture had reduced Ghana's unemployment rate through the multiple jobs it offers. Aquaculture in general and cage culture in particular, have bright prospects for the future in this department. Nevertheless, some people, especially fishermen, were against the installation of floating cage on the lake because it reduces their fishing area and can pollute the environment. These concerns are similar to the results found by Schénone et al. (2011), Gorlach-Lira et al. (2013) and Yoboue et al. (2018) who found that floating cage fish farming is associated with the release of organic matter into the ecosystem. Meanwhile, Beveridge (1984) showed that each ton of tilapia produced releases between 23 kg to 29 kg of total phosphorus into the environment.

5. ***Conclusions and Prospect***

Currently, only a limited number of studies have investigated the production performance and challenges of cage aquaculture in Benin. This paper has examined the current status and potential for improving production efficiency and overcoming challenges in cage aquaculture on Lake Djetoe in the Mono department. The study has revealed an abundance of water resources and farmers interested in cage culture, indicating that cage culture has significant potential to spur the growth of the aquaculture industry and create employment opportunities.

Overall, the future prospects for fish cage culture in Benin look relatively bright. Despite challenges and constraints, cage aquaculture in Benin has significant opportunities to contribute to worldwide aquaculture production, given its abundant water resources and appropriate land. Several water bodies, such as lakes, lagoons, reservoirs and rivers, have not yet been utilized for cage aquaculture, although they may possess suitable ecological conditions for its development. Lake Djetoe, in particular, has great potential for cage aquaculture due to its suitable ecological conditions and large surface area. This potential can be improved by optimally using accessible resources and addressing the challenges highlighted in this study, which are largely surmountable.

In order to satisfy market demands, improve consumer's health, increase profits, and protect aquatic environments and the well-being of farmers, Benin needs sustainable development of cage culture. This section briefly outlines the objectives to reach and the directions to take.

Priority 1: Strengthening the regulatory and institutional framework

❖ Local policies development: laws and guidelines should be developed, including guidance on relaxing policies and accelerating the progress of the cage aquaculture industry to establish the core position of cage aquaculture and protect farmers' property rights.

❖ National policies development: guidelines and laws must be developed to preserve the environment and ecological priorities from harms caused by cage aquaculture farming.

Priority 2: Improving access to quality production inputs

❖ Promote the use of high-quality and nutritionally balanced feeds, while encouraging research on alternative and locally available feed ingredients. To reduce the nutrient load in effluents, high-energy feeds with high digestibility should be formulated. This can be achieved gradually by demonstrating to farmers methods for enhancing the efficiency of using insect ingredients, plants and oils to replace fish meal and fish oil, ultimately improving feeding management strategies;

❖ Improve access to quality fingerlings and nutritionally balanced feeds. Strengthening local hatchery production, improving fingerling transportation practices, and promoting the availability of quality feed would significantly enhance productivity and profitability.

Priority 3: Capacity building and technical support

❖ Establish a training program for farmers on cage aquaculture management, as its success requires in-depth knowledge of feeding, environmental aspects, and the biology of the species being reared.

❖ Develop imperatively better knowledge and management strategies concerning disease identification and prevention.

❖ Develop business strategies for cage enterprises to track actions, monitor progress and implement changes for improved performance.

Priority 4: Environmental management and production optimization

❖ Identify suitable zones, lakes, rivers for cage aquaculture and determination of the capacity for each lake or river to avoid challenges such as pollution, disease outbreaks, and overexploitation.

❖ Implement effective management strategies to control invasive aquatic plants, particularly water hyacinth (*Eichhornia crassipes*), in order to improve water circulation, facilitate cage operations, and maintain suitable environmental conditions for aquaculture development.

❖ Establish optimal stocking densities for tilapia and existing aquaculture systems in the country, while encouraging cage culture farmers to diversify the species they cultivate.

❖ Develop a system for a regular monitoring of water quality parameters.

Priority 5: Long-term sector development and innovation

❖ Promote selective breeding programs to enhance tilapia productivity.

❖ Promote research on species diversification, improved feed formulations, and innovative management practices to enhance the resilience and competitiveness of the cage aquaculture sector in Benin.

Addressing these priorities would contribute to increasing fish production, improving livelihoods, enhancing food security, and oiling the sustainable growth of cage aquaculture in Benin.

Conflict of interest

All the authors declare that no conflict of interest opposes them.

Data Availability

Data are available if needed.

Acknowledgments

The authors would like to sincerely thank all the institutions represented by the authors for working together toward a common goal. We also extend our gratitude to the aquaculture farmers and feed manufacturing companies within and outside the department for cooperating in information sharing during the research.

Author contributions

Author 1 and Author 2: conceptualized and designed the study, conducted the field data collection, and drafted the original manuscript. Author 3: contributed to methodology development, data validation and performed the statistical analysis. Author 4: contributed to critical revision of the manuscript, supervised the research work and provided overall guidance. All authors reviewed, edited, and approved the final manuscript.

6. References

Abaho, I., Zaabwe, T., Izaara, A., Kasigwa, H. N., Mushabe, N., Byenkya, S., Nkambo, M., Baguma, S. D., Hafashimana, D. L. N., & Efitre, J. (2020). Effect of stocking density on growth and survival of Nile tilapia (*Oreochromis niloticus*, Linnaeus 1758) under cage culture in Lake Albert, *International Journal of Fisheries and Aquaculture* 12: 26-35.

Achoh, M. E., Agadjihouèdé, H., Gangbè, L., Houssou, A., Aïzonou, R., Ahouansou Montcho, S., & Chikou, A. (2021). Ecological status of a West African lagoon complex under anthropogenic pressure, Toho-Todougba complex, Benin. *International Journal of Aquatic Biology* 9: 279-289. https://doi.org/10.22034/ijab.v9i5.1107

Aïzonou, R., Houssou, A. M., Koussovi, G., Dessouassi, C. E., Achoh, M. E., Hounhouedo, S. L., Hountchémè, C.I., & Agadjihouèdé, H. (2023). Effect of Stocking Density and Feeding Strategy on Zootechnical Parameters and Profitability of Nile Tilapia (*Oreochromis niloticus*) Reared in Floating Cages in Toho-Todougba Complex Lagoon in Benin Republic. *Fishes* 8: pp 192. https://doi.org/10.3390/fishes8040192

Aura, C. M., Musa, S., Yongo, E., Okechi, J. K., Njiru, J. M., Ogari, Z., Charo-Karisa, H., Mbugua, H., Kidera, S., Ombwa, V., & Oucho, J. A. (2018). Integration of mapping and socio-economic status of cage culture: towards balancing lake-use and culture fisheries in Lake Victoria, Kenya. *Aquaculture. Research* 49:532–545. https://doi.org/10.1111/are.13484

Balcazar, J., Aguirre, A., Gomez, G., & Paredes, W. (2006). Culture of Hybrid Red Tilapia (*Oreochromis mossambicus × Oreochromis* *niloticus*) in Marine Cages: Effects of Stocking Density on Survival and Growth. pp 1-5.

Bao-Tong, H. U. (1994). Cage culture development and its role in aquaculture in China. *Aquaculture research*, 24: 305- 310. https://doi.org/10.1111/j.1365-2109.1994.tb00693.x

Beveridge, M. C. M. (1996). Cage Aquaculture. John Wiley & Sons.

Blow, P., & Leonard, S. (2007). A review of cage aquaculture: sub-Saharan Africa. In M. Halwart, D. Soto and J. R. Arthur (eds). Cage aquaculture – Regional reviews and global overview, pp. 188–207. FAO Fisheries Technical Paper. No. 498. Rome, FAO. 241 pp.

Chakraborty, S. B., Mazumdar, D., & Banerjee, S. (2010). Determination of ideal stocking density for cage culture of monosex Nile Tilapia (*Oreochromis niloticus*) in India. Proceedings of the Zoological Society 63:53-59. https://doi.org/10.1007/s12595-010-0007-3

Codjo, V., Ahouansou, M. S., Sossou, C. H., Hounkpatin, P., Honfoga, B., Biaou, G., & Moncthowui, H. E. (2023a). Perceptions of the attributes of fish farming in floating cages on Lake Toho: The case of fishermen in Southern Benin. *Agro-Science*, 22: 1-9. https://orcid.org/0000-0002-0790-2926.

Codjo, V., Sossou, C. H., Noukpozounkou, D., Ahouansou Montcho, S., Honfoga, B., Mensah, G.A., & Biaou, G. (2023b). Analyse socio-économique de la contribution des pêcheurs à la mise en œuvre de la pisciculture en cages flottantes sur le lac Toho au Sud-Bénin. *Bulletin de la Recherche Agronomique du Bénin*) 33: 76-84.

Cuvin-Aralar, M. L., Philip, G., Adelaida, P., Aida, A., & Lydia, N. (2012). Skip Feeding as an Alternative Strategy in the Production of Nile Tilapia *Oreochromis niloticus* (Linn.) in Cages in Selected Lakes in the Philippines. *Philippine Agricultural. Scientist* 95: 378–385.

Dagoudo, M., Qiang, J., Bao, J. W., Tao, Y. F., Zhu, H. J., Tumukunde, E. M., Ngoepe, T. K., & Xu, P. (2021). Effects of acute hypoxia stress on hemato-biochemical parameters, oxidative resistance ability, and immune responses of hybrid yellow catfish (*Pelteobagrus fulvidraco × P. vachelli*) juveniles. *Aquaculture International* 29: 2181–2196. https://doi.org/10.1007/s10499-021-00742-1

Dagoudo, M., Qiang, J., & Solevo, M. P. (2022). Current status in science and technology developments in Benin's aquaculture industry: a review. *Aquaculture International*, 30: 1155-1169. https://doi.org/10.1007/s10499-022-00853-3

Dagoudo, M., Adjahouinou, D. C., Tossavi, N. D., Amegnaglo, C. J., Nzau Matondo, B., Ovidio, M., & Montchowui, E. (2024). Traditional Fish Hole Aquaculture System in Benin: Status, Challenges, and Research Prospects for Sustainable Development in Climate Change Mitigation. Sustainability, 16(23), 10499. https://doi.org/10.3390/su162310499

Dagoudo, M., Benhaïm, D., & Montchowui, E. (2025). Current status and prospects for efficient aquaculture of the African bonytongue, *Heterotis niloticus* (Cuvier, 1829). *Journal of the World Aquaculture Society*, *56*(2), e70009.

De Silva, S. S., & Phillips, M. J. (2007). A review of cage aquaculture: Asia (excluding China). In M. Halwart, D. Soto & J. R. Arthur (Eds.), Cage aquaculture – Regional reviews and global overview (pp. 18 – 48). FAO *Fisheries Technical Paper*. Rome : FAO. pp 241.

DSA (Direction de la Statistique Agricole). (2021). *Rapport de Performances du Secteur Agricole*. pp 51-52.

DSA (Direction de la Statistique Agricole). (2020). *Enquête d'estimation de la production aquacole campagne agricole 2019-2020*. pp 1-72.

Elegbe, H. A., Tovignan, S. D., Vodouhe, F., Jimmy, P., Imourou Toko, I., Koussahoue, S., &

Egah, J. (2019). Comparative analysis of economic profitability of improved fish breeding systems in the valley of Ouémé, Benin. *Journal of Agriculture and Environmental Sciences*, 8(2), 121-131. https://doi.org/10.15640/jaes.v8n2a15

EL-Sayed, A. F. M. (2006). Intensive culture. In A. F. M. EL-Sayed (Ed.), Tilapia culture (62 pp.). Wellingford, Oxfordshire, UK: *CABI Publishing*.

Eng, C. T, & Tech, E. (2002). Introduction and history of cage culture. In: P. T. K ., Woo, D. W. Bruno, and L. H. S. Lim (eds.). Diseases and Disorders of Finfish in Cage Culture. *CAB International.* pp 1-39.

FAO (*Food and Agriculture Organization of the United Nations)*. (2022). Résumé de situation mondiale des pêches et de l'aquaculture. Vers une transformation bleue. Rome, FAO.

FAO (*Food and Agriculture Organization of the United Nations)*. 2018. The state of world fisheries and aquaculture: contributing to food security and nutrition for all, Rome.

FAO (*Food and Agriculture Organization of the United Nations)*. (2011). Aquaculture development. Use of wild fish as feed in aquaculture. FAO Technical guidelines for Responsible Fisheries. Rome. 5: 79.

FAO (*Food and Agriculture Organization of the United Nations).* (2009). "Climate Change Implications for Fisheries and Aquaculture." FAO Fisheries and Aquaculture Technical Paper 530, FAO, Rome.

FAO (*Food and Agriculture Organization of the United Nations)*. (2004). FAO regional technical expert workshop on cage culture in Africa. *Entebbe*. 6: 1-127

Field, A. (2024). *Discovering statistics using IBM SPSS statistics*. (6th ed.) Sage publications limited.

Gbaguidi, H. M. A. G., Adite, A., & Sossoukpe, E. (2016). Ecology and Fish Biodiversity of Man-Made Lakes of Southern Benin (West Africa): Implications for Species Conservation and Fisheries Management. *Journal of Environmental Protection* 7: 874-894. http://dx.doi.org/10.4236/jep.2016.76079

Gorlach-Lira, K., Pacheco, C., Carvalho, L. C. T., Melo Júnior, H. N., & Crispim, M. C. (2013). The influence of fish culture in floating net cages on microbial indicators of water quality. *Brazilian Journal of Biology*, 73, 457 - 463. https://doi.org/10.1590/S1519-69842013000300001

Gentry, R. R., Froehlich, H. E., Grimm, D., Kareiva, P., Parke, M., Rust, M., Gaines, S, D., & Halpern, B. S. (2017). Mapping the global potential for marine aquaculture. *Natural Ecology and Evolution* 1(9): 1317-1324. https://doi.org/10.1038/s41559-017-0257-9

Hasimuna, O. J., Maulu, S., Monde, C., & Mweemba, M. (2019). Cage aquaculture production in Zambia: Assessment of opportunities and challenges on Lake Kariba, Siavonga district. *Egyptian Journal of Aquatic Research* 45(3):281–285. https://doi.org/10.1016/j.ejar.2019.06.007

Hidayati, D., Dalimunthe, S. A., & Putri, I. A. P. (2018). Socio-economic vulnerability and benefits to the community associated with floating fish cages in the Jatiluhur reservoir. *The Water-Energy-Food Nexus* pp 245–260. https://doi.org/10.1007/978-981-10-7383-0_17

Huchette, S., & Beveridge, M. (2003). Technical and economical evaluation of periphyton-based cage culture of tilapia (*Oreochromis niloticus*) in tropical freshwater cages. *Aquaculture* 218 : 219–234. https://doi.org/10.1016/S0044-8486(02)00414-3

Latifou, A. B., Toko, I. I., Elegbe, H. A., Pelebe, R. O. E., Tougan, P. U., Boni, A. R., Ahyi, V., Hossou, E. S., Vissiennon, Z., & Chikou, A. (2020). Les Produits Halieutiques au Bénin : Sources d'Approvisionnement et Statistiques. *International Journal of Progressive Sciences and Technologies 21(1):*152-167.

Lovatelli, A., & Holthus, P. F. (2008). Capture-based aquaculture. Global overview. FAO Fisheries Technical Paper No. 508. Rome, FAO. pp 298. https://openknowledge.fao.org/handle/20.500.14283/i0254e

MAEP. (2015). Recensement des pisciculteurs du Benin. pp 1-38.

Mbowa, S., Odokonyero, T., & Munyaho, A. T. (2017). Harnessing floating cage technology to increase fish production in Uganda, *Economic Policy Research Centre (EPRC*), *Research Series pp 1-44*. https://doi.org/10.22004/ag.econ.262886

Miriac, A. S. D., Noukpo, A., & Christophe, H. S. (2020). Eau de consommation et maladies hydriques dans la commune de Lokossa au sud-ouest de la République du Bénin (Afrique de l'Ouest). *ESJ*, *16*(15). https://doi.org/10.19044/esj.2020.v16n15p393

Mustafa, S., Abentin, E., Raehanah, S. S. M., and Shapawi, R., Estim, A., & Shaleh, M. (2018). Positioning of Aquaculture in Blue Growth and Sustainable Development Goals Through New Knowledge, Ecological Perspectives and Analytical Solutions. *Aquacultura Indonesiana*. 19: 1-9*. https://doi.org/10.21534/ai.v19i1.107*

Njiru, J. M., Aura, C. M., & Okechi, J. K. (2018). Cage fish culture in Lake Victoria: a boon or a disaster in waiting? *Fisheries Management and Ecology*. 26(5):1–9. https://doi.org/10.1111/fme.12283

Obiero, K. O., Waidbacher, H., Nyawanda, B. O., Munguti, J. M., Manyala, J. O., & Kaunda-Arara, B. (2019). Predicting uptake of aquaculture technologies among smallholder fish farmers in Kenya. *Aquaculture International*, 27(6) : 1689-1707. https://doi.org/10.1007/s10499-019-00423-0

Ofori, J. K., Abban, E. K., Karikari, A. Y., & Brummett, R. E. (2010). Production parameters and economics of small-scale tilapia cage aquaculture in the Volta Lake, Ghana. *Journal of Applied Aquaculture* 22: 337–351.

Opiyo, M. A., Marijani, E., Muendo, P., Odede, R., Leschen, W., & Charo-Karisa, H. (2018). A review of aquaculture production and health management practices of farmed fish in Kenya. *International Journal and Veterinary Science and Medical* 6(2): 141–148. https://doi.org/10.1016/j.ijvsm.2018.07.001

Pullin, R.S.V., Lazarp, J., Legendre, M., Amon Kothias, J. B., & Pauly, D. (1996). Third International Symposium on tilapia in aquaculture. *In International Center for Living Aquatic Resources Management (ICLARM)* 41: 630.

Sakr, E. M., Shalaby, S. M., Wassef, E. A., El-Sayed, A. F. M., & Moneim, A. I. A. (2015). Evaluation of periphyton as a food source for Nile Tilapia (*Oreochromis niloticus*) juveniles fed reduced protein levels in cages. *Journal of Applied Aquaculture* 27(1): 50–60. https://doi.org/10.1080/10454438.2014.967073

Schenone, N. F., Vackova, L., & Cirelli, A. F. (2011). Fish-farming water quality and environmental concerns in Argentina: a regional approach. *Aquaculture International* 19(5): 855-863. https://doi.org/10.1007/s10499-010-9404-x

Yoboue, K. P., Aboua, B. R. D., Berte, S., Coulibaly, J. K., Ouattara, N. I., & Kouamelan, E. P. (2018). Impacts des exploitations piscicoles en cages flottantes sur la structure des macro-invertébrés benthiques de la lagune Ebrié (Côte d'Ivoire). *International Journal of Biological and Chemical Sciences* 12(2): 769-780. https://dx.doi.org/10.4314/ijbcs.v12i2.12.