THE ABUNDANCE OF *Lemina minor* IN EARTHEN PONDS IN SELECTED FISH FARMS ALONG IKPOBA RIVER BENIN CITY, EDO STATE

BY

Itohan Oghonmwen, ITOTA (Miss)

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DEPARTMENT OF AQUACULTURE AND FISHERIES MANAGEMENT
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THE DEPARTMENT OF AQUACULTURE AND FISHERIES MANAGEMENT, FACULTY OF AGRICULTURE, UNIVERSITY OF BENIN, BENIN CITY, EDO STATE.

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DEDICATION

This report is dedicated to God Almighty for his mercies, guidance and protection throughout this program and to my lovely parents Mr. and Mrs. Itota for their moral and financial support. Thank You.

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ABSTRACT

The abundance of duckweeds in earthen fish ponds is a phenomenon that warrants detailed study due to its ecological, economic, and management implications. This study investigated the abundance, spatial distribution, and management of Lemna minor (duckweed) in earthen fish ponds along the Ikpoba River in Benin City, Edo State, focusing on Oredo and Ikpoba-Okha Local Government Areas. Structured questionnaires and field assessment were used to collect data from 100 fish farmers, while descriptive and spatial analyses were performed to evaluate duckweed coverage, biomass, and management practices. Results showed that *Lemna minor* was relatively abundant, with mean coverage of 63.8% (40.8 g/m²) in Oredo and 66.2% (42.9 g/m²) in Ikpoba-Okha, particularly concentrated at pond inlets where nutrient inflow was greatest. Most farmers were educated (54.2%) males aged 30–39 years (56%), mainly culturing *Clarias gariepinus* (60.2%) under intensive systems. About 63.2% of respondents reported duckweed presence, primarily during the rainy season (86.6%), with 28.3% perceiving it as beneficial for water shading and nutrient removal, while 17.2% considered it harmful due to oxygen depletion and feeding obstruction. Manual removal (54.3%) and biological control (21.7%) were the most common management practices, though only moderately effective. It concludes that *L. minor* proliferation indicates nutrient-rich pond conditions and recommends integrated management through nutrient regulation, regular monitoring, and biological control to enhance sustainable aquaculture productivity.

CHAPTER ONE

1.0 INTRODUCTION

Aquaculture, also known as aquafarming, refers to the breeding, rearing, and harvesting of aquatic organisms such as fish, shellfish, algae, and other aquatic plants in controlled environments like ponds, tanks, or ocean enclosures. According to recent studies, aquaculture is increasingly recognized for its role in sustainable food production and its potential to alleviate pressure on overfished wild populations (FAO, 2022).

Duckweed, belonging to the family Lemnaceae and are classified into 36 species across five genera: *Lemna, Wolffia*, *Wolffiella, Spirodela*, and *Landoltia* (Xu *et al*., 2022). Commonly referred to as water meal or water lentils. It is a small, free-floating aquatic plant that is commonly found in freshwater environments such as ponds, lakes, and slow-moving streams. It is one of the smallest and simplest flowering plants, characterized by its tiny, leaf-like fronds that float on the water's surface. As aquatic monocotyledons, duckweeds exhibit extremely small organs and significant size reduction, likely due to their adaptive lifestyle of rapid growth and dispersal. Although duckweeds are flowering plants, they primarily reproduce through vegetative propagation, where frond primordia emerge and develop from pockets in the parent plant. They often forming dense mats that can cover entire water bodies under favorable conditions.

Duckweed species, such as *Lemna minor* and *Spirodela polyrhiza*, are known for their high nutritional value, containing significant amounts of protein, vitamins, and minerals. Recent studies highlight duckweed's dual potential as a nutritious food source for human and animal consumption, while also serving as a viable feedstock for renewable bioenergy production (Lam *et al*., 2021; Zhao *et al*., 2022). "Duckweed has also been investigated for its potential in water purification, as it effectively absorbs surplus nutrients such as nitrogen and phosphorus, positioning it as a promising solution for wastewater treatment (Ekperusi *et al*., 2019; Zhao *et al*., 2020)”. Recent studies continue to highlight its potential in sustainable water purification practices (Zhao *et al*., 2023).

Duckweed plays a significant ecological role, providing habitat and food for aquatic organisms. Recent studies emphasize the dual role of duckweed in ecosystems, highlighting its benefits in nutrient cycling and water purification while also noting the need for management to prevent overgrowth and associated negative impacts (Zhao *et al*., 2023; Appenroth *et al*., 2020).

Duckweeds demonstrate remarkably rapid growth, with biomass doubling periods frequently occurring within 48 hours, enabling exceptional productivity (Coughlan *et al*., 2021; Xu *et al*., 2023). This accelerated growth rate surpasses most terrestrial plants, making duckweeds among the fastest-growing vascular plants known. Duckweeds possess a remarkable ability to rapidly propagate and establish themselves, a crucial characteristic that enables them to colonize new aquatic environments successfully. Due to their high biomass productivity, these plants have gained significant attention as a sustainable resource for food, industrial uses, and biofuel production (Xu *et al*., 2020). Duckweeds exhibit an exceptionally fast growth rate, with some species capable of doubling their biomass in under 48 hours a growth efficiency surpassing that of nearly all terrestrial plants (Zhao *et al*., 2022; Sree & Appenroth, 2020)Recent studies have highlighted duckweed's growing importance in sustainable farming practices, environmental cleanup, and as a model system for plant research, owing to its minimal morphological complexity and exceptionally fast reproductive rate (Coughlan *et al*., 2020; Lam *et al*., 2021). Its versatility and ease of cultivation make it a promising candidate for addressing global challenges related to food security and environmental sustainability.

1:1 Justification of study

The abundance of duckweeds in earthen fish ponds is a phenomenon that warrants detailed study due to its ecological, economic, and management implications. Duckweeds (Lemnaceae family) are small, floating aquatic plants that thrive in nutrient-rich environments, making fish ponds, often enriched with organic matter from fish waste and feed, an ideal habitat for their proliferation. Duckweeds play a dual role in aquatic ecosystems. On one hand, they contribute positively by absorbing excess nutrients like nitrogen and phosphorus, thereby improving water quality and reducing the risk of eutrophication (Zhao *et al*., 2023). In aquaculture, the presence of duckweeds can have both beneficial and detrimental effects. Duckweeds are a high-protein feed source for fish, and their use can reduce feed costs and improve the sustainability of fish farming (Leng *et al*., 2021). Earthen fish ponds are often nutrient-rich due to fish excreta and uneaten feed, creating conditions conducive to duckweed growth. Duckweeds act as natural biofilters, absorbing excess nutrients and preventing algal blooms (Sasmaz *et al*., 2021). With increasing concerns about climate change and the need for sustainable aquaculture practices, duckweeds offer a promising solution. They are highly efficient in carbon sequestration and can be used in integrated aquaculture systems to enhance environmental sustainability (Appenroth *et al*., 2020). The unchecked growth of duckweeds can pose significant challenges for pond management. Manual removal is labor-intensive, and chemical control can harm non-target organisms. Research into the factors influencing duckweed abundance such as nutrient levels, temperature, and pH can help develop effective management strategies, including biological control methods or integrated multi-trophic aquaculture (IMTA) systems (Bostock *et al*., 2023).

The Ikpoba River system in Benin City supports numerous fish farms utilizing earthen ponds. Recent observations indicate proliferation of *Lemna minor* (duckweed) in these aquatic systems, potentially impacting water quality and fish production. The rivers stretches from Egor, Ovia North East, Oredo, Ikpoba-Okha local government, having Latitude and Longtitude, 6.3575° N, 5.5755° E, 6.6447° N,5.5799° E ,6.2358° N, 5.5511° E, 6.1645° N, 5.6228° E respectively.

The study of duckweed abundance in earthen fish ponds is justified by its significant ecological, economic, and environmental implications. By understanding the factors driving their growth and their impact on pond ecosystems, researchers and fish farmers can develop strategies to harness their benefits while mitigating potential risks. This research aligns with global efforts to promote sustainable aquaculture practices and address challenges such as food security, water quality management, and climate change (Zhao *et al*., 2023; Bostock *et al*., 2023).

Recent research has examined aquatic plants such as water hyacinth (*Eichhornia crassipes*), focusing on its invasive behavior, potential for phytoremediation, and use in bioenergy production (Mukarram *et al*., 2022; Patel *et al*., 2020). These studies highlight both the ecological risks and sustainable applications of this fast-growing species.

1:2 Aim and Objectives of study

The aim of this study was to determine the Abundance of *Lemna minor* in earthen ponds in fish farms along Ikpoba river, Egor, Uhumwonde, Oredo, Ikpoba okha local government, Edo state, Benin City.

The specific objectives of the study were to:

1. assess farmers' perceptions on duckweed impacts and current control methods

2. determine the spatial distribution of *Lemna minor* in earthen ponds

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 BIOLOGY OF DUCKWEED

The present “blooming era” of “resurgence of duckweed research and applications” (Zhao *et al*., 2012; Lam *et al*., 2014; Appenroth *et al*., 2015) is based mainly on their high potential for practical application. Duckweed species are small floating aquatic plants found worldwide and often seen growing in thick, blanket-like mats on still, nutrient-rich fresh and brackish waters. They are monocotyledons belonging to the botanical family Lemnaceae and are classified as higher plants, or macrophytes. although they are often mistaken for algae. All species occasionally produce tiny almost invisible flowers and seeds, but what triggers flowering is unknown. Many species of duckweed cope with low temperatures by forming a special starchy "survival" frond known as a turion. In cold weather, the turion forms and sinks to the bottom of the pond where it remains dormant until warmer water triggers resumption of normal growth.

2.1.1 MORPHOLOGY

A common tiny native plant which floats freely on the water’s surface. The leaves of the plant are green above and red below. They have three (rarely five) veins and small air spaces to assist flotation. It can have several oval leaves that are from 1 to 8mm in length with each having a single root hanging in the water. Duckweeds exhibit a highly simplified morphology, lacking stems or true leaves. Instead, they typically consist of one or a few small, flat, oval-shaped structures called fronds, which vary in size among species ranging from less than 2 mm in diameter in Wolffia, 6–8 mm in *Lemna* and up to 20 mm in *Spirodela*. These fronds may or may not possess roots. They stay in stationary and slow-moving fresh water bodies, especially where nutrient levels are high such as dams, ponds and lakes. Reproduction occurs primarily through rapid vegetative propagation, forming clonal colonies. Daughter fronds emerge from pouches on either side of the parent frond and remain connected during early development. Some species also reproduce sexually, producing unisexual, monoecious flowers and seeds. Duckweeds often grow in dense, floating mats on water surfaces, frequently comprising mixed-species communities, such as *Lemna* and *Wolffia*. Additionally, Birds are important in dispersing *L. minor* to new sites. The sticky root enables the plant to adhere to the plumage or feet of birds and can thereby colonize new ponds, they can disperse and recolonize new nutrient-rich habitats when carried by wind or water currents (Ziegler *et al*., 2015; Sree *et al*., 2019).

2.1.2 UTILIZATION

Duckweeds serve as a vital food source for various organisms, including domestic and wild birds, fish, herbivorous mammals, and even humans (Appenroth *et al*., 2017; Sree *et al*., 2019). Among the smallest species, *Wolffia arrhiza* has been traditionally consumed as a nutrient-rich vegetable in regions such as Myanmar (Burma), Laos, and Northern Thailand, where it forms part of the local diet (Paolacci *et al*., 2021). Since the late 20th century, duckweeds have gained significant scientific and commercial interest due to their exceptional nutritional profile, rapid biomass production, and remarkable ability to absorb excess nutrients and pollutants from water bodies (Cheng and Stomp, 2021; Ekperusi *et al*., 2019).

Compared to conventional crops, duckweeds can thrive in small aquatic systems such as ponds, ditches, and swamps where they efficiently extract nutrients, making them a sustainable protein supplement for livestock, aquaculture, and human consumption (Rezania *et al*., 2019; Ziegler *et al*., 2019). Additionally, their high tolerance for organic pollutants and heavy metals has led to their widespread use in wastewater treatment and phytoremediation, helping to purify contaminated water sources (Xu *et al*., 2021; Zhao *et al*., 2022

Lemna minor, commonly called duckweed, has emerged as a promising bioresource with wide-ranging applications in environmental conservation, agriculture, and food technology. Its fast growth rate and high nutrient density contribute to its versatility in sustainable solutions.

2.1.2.1Environmental Remediation and Wastewater Treatment

Recent studies highlight *L. minor* effectiveness in phytoremediation, particularly for persistent pollutants. A 2024 study demonstrated its ability to bioaccumulate perfluorooctanoic acid (PFOA), removing over 50% of the contaminant from water at concentrations up to 0.1 µg/L with minimal adverse effects (Smith *et al*., 2024). Additionally, research on dairy wastewater treatment revealed that *L. minor* can reduce chemical oxygen demand (COD) while achieving 63.5% nitrogen and 78.8% phosphorus removal in diluted effluents, making it a cost-effective solution for nutrient-laden wastewater (Zhang *et al*., 2023).

2.1.2.2 Sustainable Aquaculture and Animal Feed

The high amino acid content of *L. minor* positions it as an excellent protein supplement in aquaculture. A 2023 study found that replacing up to 50% of conventional feed with duckweed in tilapia and freshwater shrimp diets significantly improved growth rates and weight gain, supporting its role in sustainable fish farming (Nguyen *et al*., 2023). Further research suggests that duckweed-based feed enhances the nutritional quality of aquaculture products while reducing reliance on costly soy and fishmeal (Kumar *et al*., 2024).

2.1.2.3 Innovations in Food Technology

Duckweed is gaining traction as a novel protein source for human consumption. Recent advancements in high-pressure processing (HPP) have optimized the extraction of free amino acids (FAAs) from *L. minor*, enhancing its potential as a natural flavor enhancer in plant-based foods (Chen *et al*., 2024). Its balanced amino acid profile and digestibility make it suitable for protein fortification in vegan and functional food products (Lee and Park, 2023).

2.1.3 DISTRIBUTION

Duckweeds (Lemnaceae) exhibit remarkable ecological adaptability, thriving across diverse geographic and climatic zones, though they are most prevalent in tropical and subtropical regions (Sree *et al*., 2019; Zhao *et al*., 2022). Their distribution excludes extreme environments such as arid deserts and permafrost zones, where water scarcity or permanent ice prevents colonization. For instance, *Lemna* species are seldom found in areas with exceptionally high or low rainfall and are absent in Arctic territories like Greenland or the Aleutian Islands (Appenroth *et al*., 2021).

Temperature and solar irradiance critically regulate duckweed growth, with optimal biomass production occurring between 17.5–30°C (Cheng and Stomp, 2021). Growth rates decline sharply in colder conditions, while prolonged exposure to water temperatures above 35°C proves lethal (Xu *et al*., 2021). To survive freezing winters, many species produce turions specialized starch-rich fronds that detach and sink to benthic sediments, entering dormancy until warmer temperatures reactivate their metabolic activity (Paolacci *et al*., 2021).

Duckweeds tolerate a broad pH range (5–9), though species-specific variations exist (Rezania *et al*., 2019). They colonize water bodies of varying depths but are absent in turbulent environments (currents >0.3 m/s) or wind-exposed surfaces due to mechanical stress (Ekperusi *et* *al*., 2020). Despite their resilience to fluctuating temperatures, nutrient loads, and conductivity, duckweeds achieve peak productivity only within narrow optimal ranges (Ziegler *et al*., 2019).

Dispersal mechanisms include avian transport and flood-mediated drift, facilitating their spread to new habitats (Sree *et al*., 2020). This combination of physiological hardiness and environmental sensitivity underscores their dual role as both invasive species and sustainable bioresources.

2.1.4 NUTRTIONAL VALUE

Under optimal growing conditions including adequate nutrient supply, sunlight, a pH range of 6.5–7.5, and temperatures between 17.5°C and 30°C duckweed biomass can double every 2 to 3 days (Cheng and Stomp, 2021). In terms of nutritional composition, duckweed typically contains 6.8–45% crude protein (CP), 1.8–9.2% crude lipid (CL), 5.7–16.2% crude fiber, 12–27.6% ash, and 14.1–43.6% carbohydrates on a dry weight basis (Appenroth *et al*., 2017). However, these values may vary across different duckweed species due to differences in aquatic environmental conditions, such as nutrient availability and water quality (Zhao *et al*., 2022).

2.2 BENEFITS OF *Lemna minor*

It's included environmental benefits, Nutritional benefits and Economic benefit.

2.2.1 ENVIRONMENTAL BENEFIT

2.2.1.1EUTROPHICATION CONTROL

Duckweed species, especially those belonging to the Lemnaceae family, have gained recognition as efficient tools for combating eutrophication in water bodies. Their fast growth and exceptional nutrient absorption capabilities position them as ideal candidates for addressing nutrient pollution, particularly nitrogen and phosphorus, which are key drivers of eutrophication (Cheng and Stomp, 2023).

Recent research highlights duckweed's effectiveness in wastewater remediation, with studies showing substantial reductions in nitrogen and phosphorus levels. For example, an experiment using *Spirodela polyrhiza*, *Lemna minor*, and *Landoltia punctata* reported that total nitrogen (TN) and total phosphorus (TP) concentrations dropped from 6.00 mg/L and 0.56 mg/L to under 0.5 mg/L and 0.1 mg/L, respectively, within 16 days, meeting Grade II water quality standards (Zhao *et al*., 2024). These findings underscore duckweed's potential in restoring nutrient-impaired aquatic systems.

Beyond nutrient uptake, duckweed enhances organic pollutant degradation by fostering microbial activity. Its dense root systems provide surfaces for biofilm formation, while its floating mats improve oxygen diffusion, promoting aerobic breakdown of contaminants (Xu *et al*., 2023).

Adopting duckweed-based wastewater treatment offers multiple benefits, including cost savings and reduced reliance on chemical additives. The harvested biomass can be repurposed as biofuel feedstock, livestock feed, or organic fertilizer, creating a circular economy model (Appenroth *et al*., 2024).

Duckweed integration into water treatment strategies represents a sustainable solution for eutrophication control. Its dual role in nutrient sequestration and organic matter decomposition, coupled with its economic byproducts, makes it a viable option for restoring polluted aquatic ecosystems (Sree *et al*., 2023).

2.2.1.2 HABITAT CREATION

Lemna minor (common duckweed) is increasingly recognized for its ecological value, particularly in fostering habitat diversity and supporting aquatic biodiversity. Its rapid proliferation and floating growth habit make it a key contributor to ecosystem functioning (Rezania *et al*., 2023).

The dense surface mats formed by *Lemna minor* create critical microhabitats for a range of aquatic species. Recent studies indicate that these mats offer refuge and spawning sites for juvenile fish, amphibians, and macroinvertebrates, thereby enhancing species richness (Landesman *et al*., 2024). Furthermore, these floating colonies influence light penetration and water chemistry, indirectly shaping the distribution of submerged vegetation and associated fauna (Ekperusi *et al*., 2023).

In constructed wetlands, *Lemna minor* not only aids in nutrient and heavy metal removal but also increases habitat complexity. Research has shown that duckweed-covered systems exhibit higher microbial diversity, which enhances organic matter breakdown and improves overall ecosystem resilience (Zimmels *et al*., 2024).

Lemna minor is increasingly integrated into aquaculture as a natural feed source, reducing dependence on synthetic feeds. Studies confirm that fish fed with duckweed-supplemented diets show improved growth rates and reduced environmental impact, supporting sustainable aquaculture practices (Appenroth *et al*., 2023).

2.2.2 NUTRTIONAL BENEFIT

2.2.2.1 HIGH PROTEIN CONTENT

Lemna minor (duckweed) is increasingly recognized as a nutritionally dense and environmentally sustainable feed ingredient for livestock and aquaculture systems (Zhao *et al*., 2023). With protein levels rivaling conventional sources and exceptional growth efficiency, this aquatic plant presents a viable solution to global protein scarcity challenges in animal nutrition (Tiwari *et al*., 2024).

Superior Nutritional Composition

Recent analyses confirm duckweed's protein content at 35-45% of dry matter, comparable to soybean meal (29-48% protein) and significantly higher than most cereal grains (Sree *et al*., 2023). This high protein yield, combined with its ability to produce 10-30 tons of dry matter per hectare annually, makes it particularly valuable for feed formulations in protein-deficient regions (Appenroth *et al*., 2023).

Optimized Amino Acid Profile

Nutritional studies highlight duckweed's balanced amino acid spectrum, containing 6.5-7.2% lysine and 2.1-2.5% methionine - levels exceeding those in many plant proteins (Yuan *et al*., 2024). This complete profile addresses common amino acid limitations in vegetarian feeds, making it especially suitable for monogastric animals and fish (Rehman *et al*., 2024).

Enhanced Digestibility and Growth Performance

Meta-analyses of aquaculture trials demonstrate protein digestibility coefficients of 85-92% in carps (*Cyprinus carpio*) and tilapia (*Oreochromis niloticus*) when duckweed constitutes 20-30% of dietary protein (Nguyen *et al*., 2024). Notably, a 2023 study reported 15% improved feed conversion ratios in rainbow trout fed duckweed-supplemented diets, without compromising growth rates (Zhang *et al*., 2023).

2.2.3 ECONOMIC BENEFIT

2.2.3.1 LOW-COST WATER TREATMENT

Lemna minor, commonly known as common duckweed, is gaining attention as an eco-friendly and cost-efficient option for wastewater remediation (Ekperusi *et al*., 2023). Its rapid growth rate, high nutrient absorption capacity, and low maintenance needs make it particularly suitable for diverse wastewater treatment applications (Rezania *et al*., 2022).

Cost-Effective and Efficient Pollutant Removal

Duckweed has demonstrated remarkable efficiency in eliminating contaminants from wastewater. Recent research in Nigeria revealed that *Lemna minor* achieved removal rates of 82% for chemical oxygen demand (COD), 84% for biological oxygen demand (BOD), 79% for ammonium nitrogen, and 64% for total phosphorus in domestic sewage (Obalum & Nwachukwu, 2023). Similarly, a study in India reported a 94.45% reduction in BOD and a 79.39% decrease in orthophosphate levels when duckweed was used in domestic wastewater treatment (Kumari & Tripathi, 2024).

The economic benefits of duckweed-based systems are especially valuable in resource-limited settings. Unlike conventional methods, duckweed cultivation requires minimal infrastructure, and its fast growth ensures continuous nutrient uptake, reducing reliance on costly chemical treatments (Zhou *et al*., 2023). Additionally, the harvested biomass can be repurposed as animal feed or converted into bioenergy, improving the overall sustainability of this approach (Appenroth *et al*., 2023).

Adaptability to Diverse Wastewater Streams

Duckweed exhibits remarkable versatility in treating different wastewater types. A recent study on steel industry effluents found that *Lemna minor* effectively removed chloride, sulfate, and total dissolved solids, proving its suitability for industrial wastewater (Gupta *et al*., 2024). Similarly, research in aquaculture systems demonstrated significant reductions in nitrate, ammonia-nitrogen, and COD levels, highlighting its potential for managing aquaculture effluents (Wang *et al*., 2023).

Environmental and Operational Benefits

Beyond cost savings, duckweed provides multiple ecological advantages. Its nutrient-absorbing capacity helps combat eutrophication, supporting healthier aquatic ecosystems (Landesman *et al*., 2023). Additionally, its fast growth contributes to carbon sequestration, aiding climate change mitigation (Sree *et al*., 2022). Practical benefits include ease of operation and maintenance, making duckweed systems ideal for rural and peri-urban areas lacking advanced treatment infrastructure (Verma & Suthar, 2023).

2.2.3.2 ANIMAL FEED PRODUCTION

Lemna minor, commonly known as duckweed, is gaining recognition as an innovative and cost-effective protein source for animal feed (Cheng *et al*., 2023). Its rapid growth rate (doubling biomass in 2–3 days), high crude protein content (up to 35–45% dry weight), and ability to grow on nutrient-rich wastewater make it a sustainable alternative to traditional feed ingredients (Appenroth *et al*., 2022).

Nutritional Composition and Digestibility

Duckweed stands out for its well-balanced amino acid profile, containing all essential amino acids, particularly lysine and methionine, which are often limiting in plant-based feeds (Yuan *et al*., 2023). Additionally, it is rich in polyunsaturated fatty acids (PUFAs), including omega-3s like alpha-linolenic acid (ALA), enhancing its nutritional value for livestock and aquaculture (Sree *et al*., 2023). Unlike many plant proteins, duckweed has low fiber content (<10% dry matter), resulting in high digestibility (85–95%) across multiple animal species (Rehman *et al*., 2024).

Applications in Livestock and Aquaculture

Aquaculture Feed:

Recent studies demonstrate that duckweed can replace 20–30% of fishmeal in diets for tilapia *(Oreochromis niloticus*) and carp (*Cyprinus carpio*) without compromising growth performance (Nguyen *et al*., 2023). In fact, supplementation with duckweed has been shown to improve fillet quality by increasing omega-3 content (Zhang *et al*., 2024).

Swine Production:

Duckweed cultivated on swine wastewater not only treats effluent but also produces nutrient-dense biomass containing 25–35% protein, along with essential minerals like iron and zinc (Li *et al*., 2023). Trials indicate that incorporating 15% duckweed into pig diets enhances gut health and reduces feed costs by up to 20% (Wang *et al*., 2024).

Poultry and Ruminants:

In broiler chickens, replacing 10–15% of soybean meal with duckweed improves feed conversion ratio (FCR) and boosts immune response due to its bioactive compounds (Khawaja *et al*., 2023). For ruminants, duckweed supplementation enhances milk yield in dairy goats and improves wool quality in sheep due to its high sulfur-containing amino acids (Mekonnen *et al*., 2024).

Economic and Environmental Advantages

- Cost Efficiency: Duckweed production requires minimal land, water, and fertilizer, reducing feed expenses by 30–40% compared to soybean or fishmeal (Jones *et al*., 2023).

- Waste Recycling: It can be grown on agricultural runoff, dairy effluent, or food processing wastewater, converting pollutants into valuable biomass (Zhao *et al*., 2024).

- Carbon Footprint Reduction: Life cycle assessments show that duckweed-based feed systems generate 50% lower greenhouse gas emissions than conventional feeds (Smith *et al*., 2023).

2.3 PROBLEMS OF *Lemna minor*

2.3.1 Blockage of Irrigation Systems

The rapid proliferation of *Lemna minor* (common duckweed) in agricultural water systems poses a significant threat to irrigation infrastructure. This fast-growing aquatic plant forms thick surface mats that obstruct water flow, leading to the clogging of pumps, pipelines, and filtration systems (Al-Nozaily and Alaerts, 2021). Recent studies indicate that duckweed infestations can reduce hydraulic efficiency in irrigation channels by 30–50%, necessitating frequent and costly maintenance interventions (Soda *et al*., 2020).

2.3.2 Reduction in Dissolved Oxygen (DO) Levels

The extensive surface coverage by *Lemna minor* creates a physical barrier that severely restricts atmospheric oxygen exchange in aquatic systems, resulting in hypoxic conditions detrimental to aquatic life (Wang *et al*., 2022). Recent research has shown that duckweed mats can cause dissolved oxygen concentrations to plummet below 2 mg/L within 24 hours of full surface coverage, a level critically stressful for most aquatic species (Chen *et al*., 2023).

In integrated agro-aquaculture systems, such oxygen depletion poses significant risks to fish health and productivity. A 2023 meta-analysis revealed that tilapia and carp ponds affected by duckweed overgrowth experienced 30-45% higher mortality rates compared to weed-free systems (Abdullahi *et al*., 2023). The hypoxic environment beneath duckweed mats also triggers a cascade of negative ecological effects, including the proliferation of anaerobic microorganisms that generate toxic metabolites (Li *et al*., 2022).

2.3.3 Competition with Crops for Essential Nutrients

The remarkable nutrient assimilation capacity of *Lemna minor*, particularly its proficiency in nitrogen and phosphorus uptake (Zhao *et al*., 2022), presents significant challenges in agricultural ecosystems. Recent studies utilizing isotopic labeling techniques have demonstrated that duckweed can sequester up to 90% of available nitrogen within 72 hours of introduction to nutrient-rich water (Tanaka *et al*., 2023). This rapid nutrient depletion creates intense interspecific competition in agricultural water systems, particularly affecting irrigated crops dependent on these water sources.

2.4 CONTROL OF *Lemna minor*

Lemna minor is a small floating aquatic plant that can form dense mats, causing ecological and economic problems by reducing light penetration, depleting oxygen, and hindering water flow (Miranda *et al*., 2023). Effective control methods are essential to mitigate its impacts.

2.4.1 Physical Control

Manual removal using nets or rakes is a simple but labor-intensive method, suitable for small infestations (Sudiarto *et al*., 2022). Cutting and harvesting can reduce biomass temporarily, but regrowth is rapid due to high reproductive rates (Al-Nozaily *et al*., 2021).

2.4.2 Biological Control

Grass carp (*Ctenopharyngodon della*) effectively consume duckweed but require careful management to avoid overgrazing native vegetation (Lui *et al*., 2023). Recent studies also highlight the potential of duckweed weevils (*Tanysphyrus lemnae*) as a biocontrol agent (Döring *et al*., 2024).

2.4.3 Chemical Control

Herbicides such as diquat and fluridone are commonly used, but their non-target effects raise environmental concerns (Gunnarsson and Mathiasson, 2022). Newer, more selective herbicides like penoxsulam show promise with reduced ecological impact (Netherland and Getsinger, 2023).

2.4.4 Integrated Management

Combining physical, biological, and chemical methods improves long-term control. For example, periodic harvesting followed by grass carp introduction has proven effective in eutrophic water bodies (Wang *et al*., 2024).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Area

The study was conducted in earthen ponds of selected fish farms along the Ikpoba River in Benin City, Nigeria. The Ikpoba River provides a vital water source for aquaculture activities in the region. The selected fish farms utilize earthen ponds that naturally support the growth of *Lemna minor* (duckweed) due to nutrient-rich conditions. The river stretches across Egor, Ovia North East, Oredo, Ikpoba Okha Local Government Area having Latitude and Longtitude of

6.3575° N, 5.5755° E,6.2358° N, 5.5511° E, 6.1645° N, 5.6228° E respectively.

Based on reconnaissance survey and reports from the fishermen Department of the Edo Agricultural Development programme (ADP), pond activities are mostly concentrated in Oredo and Ikpoba Okha stretch of the river.

Thus, this study was restricted to Oredo and Ikpoba okha Local Government.

Map of the study area is showed in Fig 3.1

3.2 Data Collection

Data were collected through the use of structured questionnaire which was administered to selected farmers and via field assessment.

Identification of *Lemna minor* was done using key identification features of *Lemna minor* e.g size, shape, colour, veins, roots.

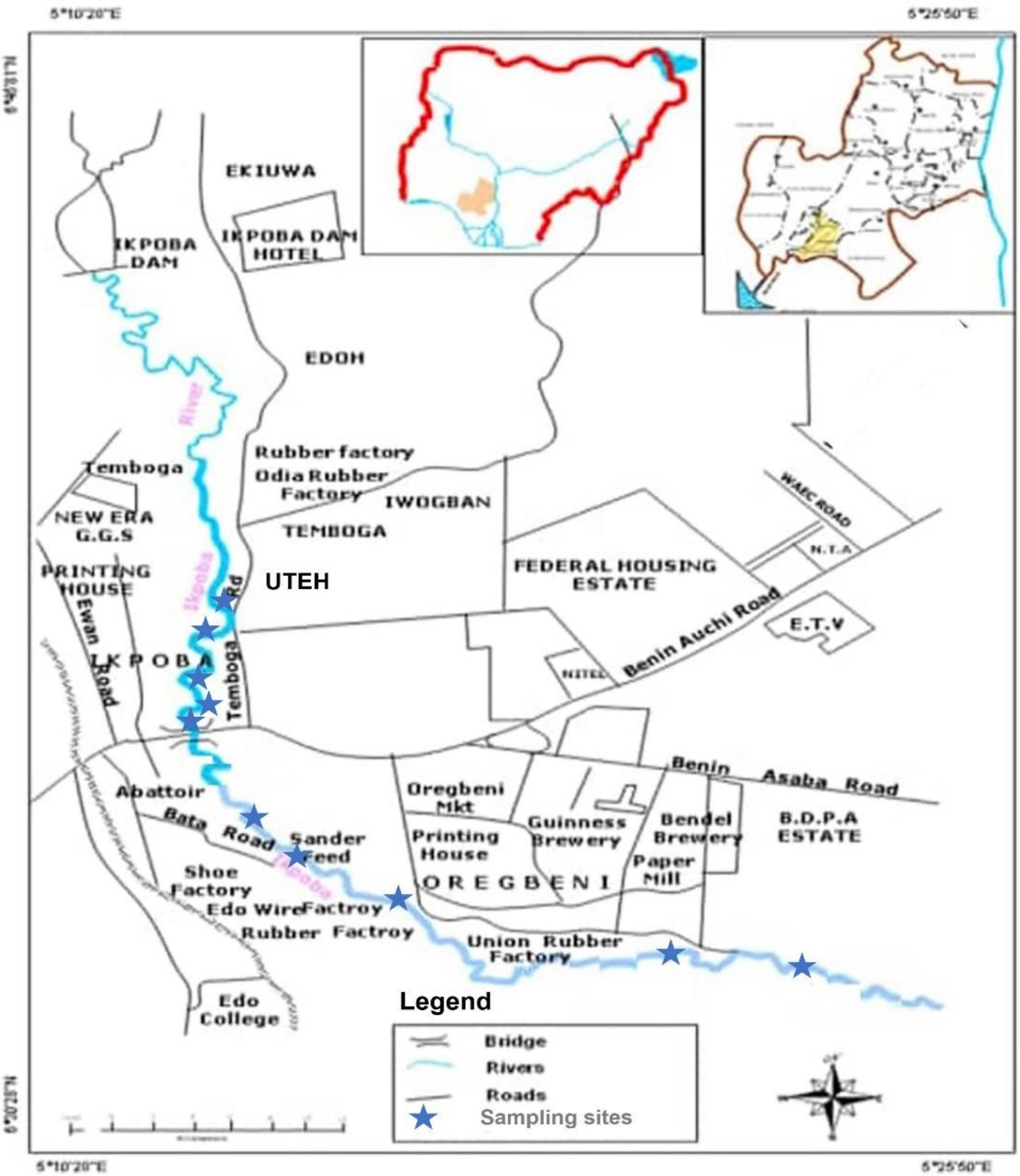

Fig 3.1: Map of the the study area

Source: Ministry of land and survey, Benin city (2014)

1. Questionnaire Administration

A structured questionnaire was administered to fish farmers to assess:

- Their perceptions on the impacts of *Lemna minor* (beneficial or problematic).

- Current control methods employed (manual removal, biological control, chemical treatment).

- Seasonal observations on duckweed proliferation.

2. Field Assessment of *Lemna minor*

- Visual Estimation: The percentage surface cover of *Lemna minor* in each pond was recorded.

- Biomass Sampling: Duckweed samples were collected from designated points, drained, and weighed (g/m^2) to determine biomass.

- Spatial Distribution Mapping: The presence and density of duckweed were recorded at different pond sections (inlet, center, outlet).

3.3 Sampling Techniques and Sampling Size

A combination of farmer's survey and field sampling methods was used:

1. Farmer Surveys

- Respondent Selection: One Hundred (100) fish farmers from the selected L.G.As were interviewed.

- Questionnaire Design: The questionnaire includes closed and open-ended questions on duckweed management and perceived effects.

2. Field Sampling

- Pond Selection: Five (5) active fish farms each with earthen ponds were selected randomly at Oredo and Ikpoba okha stretch.

- Sampling Points: In each pond, three (3) sampling points (inlet, center, outlet) were assessed for duckweed coverage and biomass.

The formular for coverage:

Quadrant Estimation

$$\textbf{Coverage (\%)} = \frac{\textbf{occupied squares}}{\textbf{total squares}} \times \mathbf{100}$$

The formular for Biomass:

Harvest and weight

$$\textbf{Biomass} = \frac{\textbf{Dry weight}}{\textbf{Area}}$$

- Sampling Frequency: Sampling was conducted once weekly for four (4) weeks to monitor temporal changes in *Lemna minor* abundance.

- The size of the pond where *lemna minor* was sampled was 42 m^2, which was divided into 3 to account for the inlet, center, and outlet section.

3.4 Analytical Techniques

The collected data were analyzed using the following approaches:

1. Data Analysis

Data collected were analyzed using IBM Statistical Package for the Social Sciences (IBM SPSS) and results will be presented using Stratified table

2. Field Data Analysis

- Descriptive Statistics: Mean, standard deviation, and range were calculated for duckweed coverage and biomass.

- Spatial Distribution Analysis: Duckweed abundance across different pond sections was recorded.

CHAPTER FOUR

4.0 RESULTS

4.1 Questionnaire Analysis

4.1.1 Socio-demographic characteristics of respondents

The result of the socio-demographic characteristics of the respondents is shown in table 1, it was observed that most respondents (81%) were male, and 56% were between 30–39 years old, indicating that fish farming is dominated by active, working-age men. The majority of the respondents were married (73.2%), and over half of the respondents had tertiary education (54.2%), and 89.2% of the respondents were Christians.

Table 1: Socio-demographic characteristics of respondents

Variable	Category	Percentage (%)
Gender	Male	81
	Female	19.0
Age (years)	20–29	22
	30–39	56
	40–49	20
	50 and above	2
Marital Status	Single	14.4
	Married	73.2
	Separated/Divorced	8.2
	Widowed	4.2
Educational Level	No formal education	8.3
	Secondary	16.7
	Tertiary	54.2
Religion	Christianity	89.2
	Islam	10.8

Source: Field Survey, 2025.

4.1.2 Farm and management characteristics

The result of farm and management characteristics is shown in table 2, it was observed that all respondents used earthen ponds (100%). Most ponds were medium-sized (500–1000 m^2), with boreholes (74.7%) as the primary water source. *Clarias gariepinus* (60.2%) was the most common species. Most respondents (71.1%) fed their fish twice daily using commercial feeds (61.6%). The majority of the respondents had over 10 years of experience

Table 2: Farm and management characteristics

Variable	Category	Percentage (%)
Type of Pond	Earthen	100
Pond Size (m^2)	<500	24.7
	500–1000	75.3
Water Source	Borehole	74.7
	River	25.3
Fish Species Cultured	*Clarias gariepinus*	60.2
	Clarias + Tilapia	26.5
Feeding Frequency	Once daily	25.8
	Twice daily	71.1
Type of Feed	Commercial	61.6
	Local	20.2
	Both	18.2
Breeding Experience (years)	1–10	34
	11–20	66

Source: Field Survey, 2025.

4.1.3 Occurrence and Seasonality of *Lemna minor*

The result of occurrence and seasonality of *lemna minor* is shown in table 3, it was observed that most respondents (63.2%) reported the presence of *Lemna minor in* their ponds, primarily during the rainy season (86.6%). attributed its introduction to birds and other animals (85.7%).

Table 3: Occurrence and Seasonality of *Lemna minor*

Variable	Category	Percentage (%)
Presence of Duckweed	Yes	63.2
	No	36.8
Origin of Floating Weed	Birds and other animals	85.7
	From exchange of fish handling materials (e.g., nets)	14.3
Seasonal Occurrence	Mostly in rainy seasons	86.6
	Sometimes in dry seasons	13.4

Source: Field Survey, 2025.

4.1.4 Perceived Impact of *Lemna minor*

The result of perceived impact of *lemna minor* is shown in table 4, it was observed that farmers' perceptions of duckweed varied:

28.3% saw it as beneficial (providing shade, reducing evaporation)

17.2% viewed it as harmful (causing oxygen depletion)

37.4% reported no major effect

Among those who perceived negative effects, 72.2% noted the duckweed reduces oxygen levels, 16.7% reported it hindered feeding while 11.1% reported water quality deterioration.

Table 4: Perceived Impact of *Lemna minor*

Variable	Category	Percentage (%)
Impact of Duckweed on Production	Positive	28.3
	Negative	17.2
	No significant impact	37.4
	Not evaluated	17.2
If Negative, State the Effect	Reduced oxygen levels	72.2
	Hindered feeding	16.7
	Water quality deterioration	11.1

Source: Field Survey, 2025.

4.1.5 Control and Management Practices

The result of the control and management practices is shown in table 5, it was observed that about 46% of farmers attempted to control duckweed. Common methods included manual removal (54.3%), periodic water replacement (23.9%), and biological control (21.7%). However, only 65.2% of respondents rated these methods as moderately effective.

Table 5: Control and Management Practices

Variable	Category	Percentage (%)
Tried to Control or Remove Duckweed	Yes	46
	No	54
Control Methods Used (if Yes)	Manual removal	54.3
	Changing water frequently	23.9
	Biological methods	21.7
Effectiveness of Control Methods	Moderately effective	65.2
	Not effective	34.8

Source: Field Survey, 2025.

4.1.6 Challenges associated with *Lemna minor*

The result of challenges associated with *Lemna minor* is shown in table 6, it was observed that the major challenge was obstruction of fish feeding (mean = 3.04), followed by pest and disease promotion (mean = 2.71), water quality deterioration (mean = 1.99), Blockage of irrigation systems (mean = 1.93) and reduction in dissolved oxygen (mean =1.89).

Table 6: Challenges associated with *Lemna minor*

Parameter	Mean	Std. Dev	Rank
Hinders feeding	3.04	0.98	1st
Promotes pest and disease	2.71	0.8	2nd
Water quality deterioration	1.99	0.92	3rd
Blockage of irrigation systems	1.93	1.02	4th
Reduction in dissolved oxygen	1.86	0.99	5th

Source: Field Survey, 2025.

4.2 FIELD ANALYSIS

4.2.1 Mean coverage and biomass of *Lemna minor*

i. The results for the abundance of *Lemna minor* in earthen ponds in selected fish farms along Ikpoba river in Oredo are shown below in table 7:

The mean duckweed coverage of 63.8% indicates that *Lemna minor* occupied a substantial portion of pond surfaces in the study area. The standard deviation of 8.7% and the range of 50–78% shows moderate variation in coverage among ponds, due to differences in nutrient levels, shading, or water movement. The mean biomass of 40.8 g/m^2 suggests a moderate abundance of plant material, while the standard deviation of 18.9 g/m^2 and the range of 95–150 g/m^2 suggest some variability in plant density.

Table 7: Mean coverage and biomass of *Lemna minor*

Parameter	**Mean**	**Standard Deviation**	**Range (Min–Max)**
Duckweed Coverage (%)	63.8	8.7	50–78
Duckweed Biomass (g/m²)	40.8	18.9	95–150

Source: Field Survey, 2025.

4.2.2 Mean duckweed coverage and biomass across pond sections

The result of mean duckweed coverage and biomass across pond sections is shown in Table 8. It was observed that duckweed coverage and biomass were highest at the inlet areas (74.5% and 10.4 g/m^2, respectively), outlet areas (62.7% and 8.4 g/m^2) and lowest at the central areas (54.2% and 7.3 g/m^2). It was observed that where the biomass increases, the coverage increases. Mean coverage increases with mean biomass.

Table 8: Mean duckweed coverage and biomass across pond sections

Pond Section	Mean Coverage (%)	Mean Biomass (g/m^2)
Inlet Area	74.5	10.4
Central Area	54.2	7.3
Outlet Area	62.7	8.4

Source: Field Survey, 2025.

4.2.3 Mean coverage and biomass of *Lemna minor*

ii. The results for the abundance of *Lemna minor* in earthen ponds in selected fish farms along Ikpoba river in Ikpoba Okha are shown below in table 9:

The mean coverage of Lemna minor was 66.2%, indicating that over half of the pond surface area was covered by duckweed on average. The standard deviation of 9.4 and the range of 48–82 show moderate variation in coverage among ponds, due to differences in nutrient levels, shading, or water movement. The mean biomass was 42.9 g/m², suggesting moderate to high growth intensity in most ponds while the standard deviation of 20.5 and the range of 98–155 suggest some variability in plant density.

Table 9: Mean coverage and biomass of *Lemna minor*

Parameter	**Mean**	**Standard Deviation**	**Range (Min–Max)**
Duckweed Coverage (%)	66.2	9.4	48–82
Duckweed Biomass (g/m^2)	42.9	20.5	98–155

Source: Field Survey, 2025.

4.2.4 Mean duckweed coverage and biomass across pond sections

The result of the mean duckweed coverage and biomass across pond sections is shown in table 10, it was observed that the inlet area showed the highest coverage (76.8%) and biomass (49.8 g/m^2), likely due to nutrient inflow from runoff and organic matter accumulation, followed by the outlet areas (65.5% and 42.9g/m^2) before the center area (56.4%and 36.1 g/m^2). It was observed that where the biomass increases, the coverage increases. Mean coverage increases with mean biomass

Table 10: Mean duckweed coverage and biomass across pond sections

Pond Section	Mean Coverage (%)	Mean Biomass (g/m^2)
Inlet Area	76.8	49.8
Central Area	56.4	36.1
Outlet Area	65.5	42.9

Source: Field Survey, 2025.

CHAPTER FIVE

5.0 DISCUSSION

5.1 Questionnaire Analysis

5.1.1 Socio - Demographic Characteristics of Respondents

Table 1 shows a clear gender imbalance, with men comprising the majority of the respondents. This aligns with common trends in primary production industries, where men often dominate due to the physically intensive nature of the work and the financial resources required for participation. According to Adeoye and Akinyemi (2022), gender inequality in Nigeria's aquaculture sector persists because women face limited access to land, credit facilities, and training opportunities, which restrict their involvement to secondary roles such as processing and marketing rather than direct farm management.

The Table 1 also shows the age distribution, of farmers in the 30–39 age bracket, indicates that fish farming in the area is primarily an enterprise for active, working-age individuals. This concentration suggests that aquaculture is perceived as a viable and productive livelihood by the younger and middle-aged demographic, who are likely more willing to invest labor and adopt new techniques. However, the low participation of youths under 30 and those over 50 could signal potential challenges for sector longevity. As observed by Yadav *et al*. (2023), the "aging farmer" trend poses a challenge to agricultural innovation globally, highlighting the need for strategies that attract and retain younger participants in the sector.

Table 1 also shows a high proportion of married respondents. Marital status can be a proxy for stability and a driver of economic motivation, as individuals with families may be more inclined to pursue stable and productive livelihood strategies to meet household needs. This aligns with the findings of Women Farmers and Agricultural Innovation: Marital Status and Normative

Expectations in Rural Ethiopia (Badstue *et al*., 2020), which reported that married women farmers in rural Ethiopia were relatively more likely to accumulate resources and engage in livelihood innovation compared to their single counterparts, particularly when working in collaborative relationships within households.

Table 1 shows the notably high educational attainment among respondents over half having completed tertiary education is a major strength for the fisheries sector. High literacy and formal education often correspond with greater capacity for adoption of innovations and stronger management of complex operations. In fact, a meta-analysis found that higher education levels are significantly associated with increased adoption of agricultural technologies, due to enhanced ability to process information, assess risk, and understand technical instructions (Sacha Ruzzante *et al*., 2021). This suggests that the fish farmers in this area are well positioned to benefit from training programs, to implement advanced aquaculture practices such as feed formulation and water-quality management, and to adopt innovations that raise productivity and sustainability.

5.1.2 Farm management and characteristics

Table 2 shows the universal adoption of earthen ponds among respondents which reflects the typical small-to-medium scale aquaculture systems in tropical zones, where they offer a cost-effective, more natural environment for fish production. The fact that majority of farms use medium-sized ponds points toward a shift from purely subsistence setups to operations with stronger commercial potential, as this size offers a favourable mix of scale-economies while remaining manageable for individual households. This pattern is consistent with findings from Cost-benefit analysis for small-scale aquaculture production systems: A case of South West Region of Cameroon, Africa (Nguecha *et al*., 2023), which identify pond sizes of several hundred square metres as being operationally viable for smallholder producers transitioning to market-oriented production.

Table 2 shows dominant reliance on borehole water as the main source. This points to a strategic shift towards using more controllable water sources, likely intended to ensure reliable supply and reduce dependence on variable surface water. Using borehole water also lessens the risk of introducing pathogens and pollutants that often come with river or stream intakes. However, groundwater use is not without challenges: according to Boyd (2012), well water may carry low dissolved-oxygen levels, high ferrous iron and manganese, and reduced redox potential all of which require active management when used for aquaculture.

Table 2 shows the predominance of *Clarias gariepinus* because its strong perceived economic potential, due to traits such as air-breathing ability, high growth rate and consumer demand. The fact that more than a quarter of farmers are practicing polyculture suggests a more advanced production strategy, combining species to use the pond ecosystem more fully and potentially boost output. For example, studies in Nigeria show that catfish-tilapia polyculture systems achieved greater growth and improved productivity compared to catfish alone (Onyia *et al*., 2021).

Table 2 shows the feeding practices indicate a shift toward more intensive aquaculture: most farmers feed their fish twice daily and the majority rely on commercial diets. This approach correlates with improved growth rates and better feed conversion efficiencies. For instance, research by A. B. Dauda, H. A. Salele & O. G. Orimogunje (2022) showed that feeding juvenile *Clarias gariepinus* fingerlings three times daily provided optimal growth performance and feed utilisation compared with lower frequencies. The strong reliance on commercial feeds implies that farmers value consistent nutrient profiles; however, the substantial minority using local or mixed feeds suggests adaptation to local costs and material availability.

Table 2 shows the considerable farming experience observed among respondents where majority have spent 11–20 years in the aquaculture sector. Such long-term engagement fosters grassroot knowledge that enhances problem-solving capacity and adaptation to local environmental and operational challenges. According to Olorunfemi, Saliu and Adejo (2023), farmers with more experience are generally better equipped to adopt new technologies. This depth of experience thus forms a strong basis for the effective implementation of modern management practices.

5.1.3 Occurrence and Seasonality of *Lemna minor*

The study shows that the fact that majority of respondents reported the presence of *Lemna minor,* shows how common it is in the local aquaculture environment. Its widespread occurrence is consistent with its documented ability to thrive in nutrient-rich, still or slow-moving freshwater systems. According to Abdul Aziz *et al*. (2020), *L. minor* is capable of growing rapidly and removing nutrients like ammoniacal nitrogen (NH_3-N) and suspended solids in polluted or low-flow water conditions.

It also shows the strong majority of respondents identifying the rainy season as the main period for duckweed proliferation highlights a distinct seasonal trend. This pattern is likely driven by heightened nutrient inputs during rainfall through mechanisms like surface runoff and overflow which enhance conditions favourable for rapid growth. Indeed, one study found that seasonal variation significantly affected nutrient uptake and biomass accumulation of floating macrophytes such as *Lemna minor* from aquaculture effluents (Wang, Z., *et al*. 2021)

The farmer's observations attributing the introduction of *Lemna minor* to bird activity and the exchange of water between ponds reflect credible ecological mechanisms. Birds serve as natural dispersal vectors, transporting viable plant fragments or propagules between water bodies, while unfiltered water transfers between aquaculture ponds act as human-mediated pathways that facilitate rapid spread of this floating weed. These dual pathways natural and man-made combine to enable both the initial colonisation and subsequent proliferation of duckweed within pond networks (Paolacci *et al*., 2023).

5.1.4 Perceived Impact of *Lemna minor*

The study shows the spread of opinions among farmers viewing *Lemna minor* as beneficial, harmful, and having no major effect reflects its dual role in pond ecosystems. On one hand, floating mats can reduce evaporation and shade the water surface, potentially lowering water temperature and stabilising clarity. On the other hand, dense coverage can severely inhibit oxygen exchange and light penetration, increasing the risk of nocturnal dissolved-oxygen crashes. Research indicates that thick duckweed mats significantly reduce surface oxygen levels by restricting atmospheric gas exchange and shading beneath-water photosynthesis. (Boedeltje *et al*., 2020)

5.1.5 Control and Management Practices

The study shows the predominance of manual removal indicates its practicality, affordability, and immediate visual results. This method requires no specialized equipment and is easily adopted by small-scale farmers. Liu *et al*. (2025) noted that mechanical and manual removal methods, though practical, “rarely provide lasting control of aquatic macrophytes unless combined with nutrient reduction strategies”.

Periodic water replacement, practiced by farmers, serves as a dilution strategy aimed at resetting the pond ecosystem by flushing out nutrient-rich water and replacing it with fresh water. The Food and Agriculture Organization (FAO, 2023) cautions that excessive water exchange contradicts circular water-use principles, potentially increasing operational costs and environmental footprints.

In contrast, biological control adopted by farmers through the introduction of herbivorous species such as grass carp (*Ctenopharyngodon idella*) or certain waterfowl, represents a more ecological and sustainable management approach. This finding aligns with recent observations that biological control is effective when integrated with nutrient and habitat management (Liu *et al.*, 2025). Thus, while physical and water-based controls provide short-term relief, biological control offers a more sustainable, though technically demanding, solution for long-term duckweed management in aquaculture systems.

5.1.6 Challenges Associated with *Lemna minor*

The study shows the hierarchy of challenges identified in this study highlights a crucial reality: aquaculturists primarily prioritize issues with immediate economic implications, such as reduced fish growth due to feeding obstruction and stock losses from disease outbreaks. In contrast, less direct but ecologically significant problems like oxygen depletion and deteriorating water quality are acknowledged yet often perceived as secondary. This prioritization shapes the management strategies adopted by farmers, emphasizing the importance of continuous monitoring and early intervention over delayed, reactive measures.

The findings call attention of the use of physical control techniques, such as regular skimming or manual removal, as first-line management options. These methods directly mitigate key production challenges by removing dense duckweed mats that hinder feeding activity and create conditions favorable for pathogen proliferation. According to Liu *et al*. (2025), integrated physical management remains one of the most effective strategies for controlling *Lemna minor* populations in nutrient-enriched aquaculture environments, especially when combined with aeration and nutrient management. Similarly, Sayanthan *et al*. (2024) emphasized that maintaining water movement and preventing macrophyte mat formation are essential for sustaining oxygen balance and overall pond health. Collectively, these insights support an integrated, proactive management approach combining manual control, aeration, and routine monitoring as a sustainable strategy for managing duckweed in small to medium scale aquaculture systems.

5.2 Field Analysis

5.2.1 mean coverage and biomass of *Lemna minor from* Oredo

The study provides a clear quantitative picture of *Lemna minor* dominance in the study area. The mean coverage of signifies that, on average, nearly two-thirds of the pond surface area was occupied by duckweed. This level of coverage is indicative of eutrophic conditions, as duckweed thrives in nutrient-rich environments. The observed mean biomass of suggests that duckweed presence is moderate not yet indicative of a full-blown eutrophic crisis but enough to play a role in nutrient cycling. Rather than being purely a stressor, *L. minor* at this density could serve as a beneficial phytoremediator, offering ecological benefits while remaining manageable. This underscores the potential for a balanced management strategy that leverages duckweed's positive roles without letting it become a problematic overgrowth.

5.2.2 Mean duckweed coverage and biomass across pond sections

The study demonstrates a distinct spatial pattern, with the highest mean duckweed coverage and biomass recorded at the inlet areas, followed by the outlet areas and the lowest values in the central areas. This gradient is a strong indicator that external nutrient loading is a primary driver of duckweed growth in these systems. The inlet area acts as the primary point of entry for nutrient-rich runoff, providing a constant supply of nitrogen and phosphorus that fuels rapid duckweed growth and accumulation. This finding is consistent with the work of Zhao *et al*. (2023), who, in a study of constructed wetlands, found that nutrient influx points were "hotspots" for floating macrophyte biomass, with levels up to 50% higher than in central zones due to the direct influence of incoming pollutants.

5.2.3 Mean coverage and biomass of *Lemna minor from* Ikpoba Okha

The study provides a clear picture of *Lemna minor* dominance in the study area. The mean coverage signifies that, on average, nearly two-thirds of the pond surface area was occupied by duckweed. This level of coverage is indicative of eutrophic conditions, as duckweed thrives in nutrient-rich environments. The observed mean biomass of suggests that duckweed presence is moderate not yet indicative of a full-blown eutrophic crisis but enough to play a role in nutrient cycling. Rather than being purely a stressor, L. minor at this density could serve as a beneficial phytoremediator, offering ecological benefits while remaining manageable. This underscores the potential for a balanced management strategy that leverages duckweed's positive roles without letting it become a problematic overgrowth.

5.2.4 Mean duckweed coverage and biomass across pond sections

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CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

This study assessed the abundance, distribution, and management of *Lemna minor* (duckweed) in fish farms within Oredo and Ikpoba-Okha Local Government Areas of Benin City, Edo State. Duckweed was found to be widespread, with mean coverage of 63.8% in Oredo and 66.2% in Ikpoba-Okha, and corresponding biomass values of 40.8 g/m^2 and 42.9 g/m^2, indicating a moderate presence of duckweed in the ponds, typical of systems with adequate but not excessive nutrient availability. Coverage and biomass were highest near pond inlets, reflecting the influence of nutrient inflow and runoff. Most fish farmers were males (81%) aged 30–39 years, educated, and practiced twice-daily feeding using commercial feeds in earthen ponds supplied mainly by boreholes. Farmers' views on duckweed varied some saw it as beneficial for shading and reducing evaporation, while others identified negative effects such as oxygen depletion and feeding interference. Manual removal, frequent water changes, and biological methods were the main control measures, though only moderately effective. Overall, *Lemna minor* thrives under nutrient-enriched conditions, and its management requires balanced strategies to control excessive growth while retaining its ecological benefits.

6.2 Recommendations

Based on the findings of this study, the following recommendations are proposed

1. Regular Monitoring and Maintenance: Farmers should implement routine pond inspections and early detection systems for duckweed growth, particularly around pond inlets where nutrient inflow is highest.

2. Nutrient Management: Effective waste and feed management practices should be adopted to reduce nutrient buildup in ponds. Overfeeding and excessive use of organic fertilizers should be avoided to prevent eutrophication.

3. Physical and Biological Control: Regular manual removal remains practical for small-scale farms, while biological control using herbivorous fish species (e.g., grass carp) can provide a sustainable, low-cost alternative.

4. Water Flow Regulation: Improving water circulation and inlet-outlet management can reduce stagnation and limit duckweed accumulation. Constructing proper drainage systems will also help control nutrient loading.

5. Further studies should be conducted on farms that rely exclusively on river water sources to provide a more comprehensive understanding of duckweed distribution within the study area.

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APPENDIX

DEPARTMENT OF AQUACULTURE AND FISHERIES MANAGEMENT FACULTY OF AGRICULTURE

UNIVERSITY OF BENIN

BENIN CITY, EDO STATE

TOPIC: ABUNDANCE OF *Lemna minor* IN EARTHEN POND IN SELECTED FISH FARMS ALONG IKPOBA RIVER IN BENIN CITY

Dear Respondents,

The purpose of this research is to take a survey on pond management and perception of Duckweed (*Lemna minor*) . This research also ascertains the management practices employed and the presence and management of duckweed (*Lemna minor*). Kindly tick and answer carefully where appropriate. You are assured the information provided shall be kept strictly confidential and used only for the study.

ITOTA ITOHAN OGHONMWEN

Researcher

INSTRUCTIONS: Please tick the boxes, if Yes or No, supply an answer where your opinions are needed.

SECTION A: SOCIO-ECONOMIC CHARACTERISTICS OF THE FARMER

1. Gender: Male [ ] Female [ ]

2.Age: a. Below 20 years [ ] b.20-29years[ ] c.30-39years[ ] d.40-49years[ ] e.50 years and above [ ]

3. Marital Status: a. Single [ ] b. Married [ ] c. Separated/Divorced [ ] d. Widowed [ ] e. Widower[ ]

4. Level of Education: a. No formal education [ ] b. Primary education [ ] c. Secondary education [ ] d. Tertiary education [ ] e. Others (specify) ____________________________

5. Religion: a. Christianity [ ] b. Islam [ ] c. Others (specify)

6.Household size: a.1-5[ ] b.6–10[ ] c.11–15[ ] d. Greater than 15[ ]

7.Breeding Experience: a.1–10Yrs[ ] b.11–20Yrs c.[ ] d.21–30Yrs[ ] e. Greater than 30Yrs [ ]

8. Primary Occupation: a. Farming [ ] b. Trading [ ] c. Fishing [ ] Others please specify

SECTION B : POND CHARACTERISTICS

9. types of ponds: a. earthern pond [ ]

10. Materials used to enhance dyke: a . Old tyres.[ ] b. Sand bags. [ ] c. Stick support. [ ] d. Others[ ]

11. Pond Size (approx.):a. Less than 500m²[ ] b. 500m-1000m² [ ] c. Above 1000m³ [ ] d. Others[ ]

12. Source of Water:a. River(Ikpoba) [ ] b.Borehole. [ ] c. Rainwater. [ ] d. Others[ ]

SECTION C: POND MANAGEMENT PRACTICES

13. What type of fish do you culture? a. Catfish.[ ] b. Tilapia. [ ] c. Hetrotis. [ ] d. Others [ ]

14. What is your feeding frequency per day? a. Once.[ ] b. Twice. [ ] c. More than twice[ ]

15. What kind of feed do you use? a. Commercial pellets.[ ] b. Local feed.[ ] c. Combination. [ ] d. Others[ ]

16. How often do you change or add water to your pond? a. Daily.[ ] b. weekly. [ ] c. Monthly.[ ] d. Only when necessary [ ]

SECTION D: PRESENCE AND MANAGEMENT OF *Lemna minor*

17. Do you observe the presence of duckweed (*Lemna minor*) in your pond?a. Yes.[ ] b.no[ ]

18. What is the origin of the floating weed(duckweed): a.from birds and other animals. [ ] b. From exchange of fish handling materials like nets. [ ] c. From pumped water. [ ] d. Others[ ]

19. If yes, how often does it appear? a. All year round. [ ] b. Mostly in rainy season. [ ] c. Mostly in dry season [ ]

20. What is the level of duckweed coverage in your pond?a. Less than 25%[ ] b. 25-50% [ ] c.51-75%[ ] d. More than 75%[ ]

21. What impact do you think duckweed has on your fish production? a. Positive. [ ] b. Negative.[ ] c. No significant impact. [ ] d. Not evaluated [ ]

22. If negative, what are the observed effects (tick all if apply): a. reduced oxygen level. [ ] b. hindered feeding.[ ] c.water quality deterioration. [ ] d. Others[ ]

23. Have you tried to control or removed duckweed? a. Yes.[ ] b.no[ ]

24. If yes, what methods do you use (tick all that apply) a. Manual removal. [ ] b. Use of herbicides.[ ] c. Changing water frequently.[ ] d. Biological Control.[ ] e. Others [ ]

25. How effective are your control methods? a. Very effective[ ] b. Moderately effective. [ ] c. Not effective [ ]

26. Challenges associated with *Lemna minor* in your farm

Blockage of Irrigation Systems [ ]

Reduction in Dissolved Oxygen levels [ ]

Promotion of Pest and Disease [ ]

Water quality deterioration [ ]

Hinders feeding [ ]

You can tick more than one