Aquaculture in Zambia

Zhang, Lin; Maulu, Sahya; Hua, Fenglei; Chama, Majory K.H.; Xu, Pao

Published in:
Fishes

DOI:
10.3390/fishes9010014

Publication date:
2024

Document version:
Publisher's PDF, also known as Version of record

fishes

MDPI

Review

Aquaculture in Zambia: The Current Status, Challenges, Opportunities and Adaptable Lessons Learnt from China

Lin Zhang [1,2], Sahya Maulu [3,4], Fenglei Hua [1,2], Majory K. H. Chama [5] and Pao Xu [1,2,*]

1 Freshwater Fisheries Research Center, Chinese Academy of Fishery Sciences, Wuxi 214081, China; zhanglin@ffrc.cn (L.Z.); huafl@ffrc.cn (F.H.)
2 Wuxi Fisheries College, Nanjing Agricultural University, Wuxi 214081, China
3 School of Biological and Marine Sciences, Faculty of Science and Engineering, University of Plymouth, Plymouth PL4 8AA, UK; sahya.maulu@plymouth.ac.uk
4 Centre for Innovative Approach Zambia, Lusaka 10101, Zambia
5 Natural Resources Development College (NRDC), Ministry of Agriculture, P/Bag CH99, Lusaka 10101, Zambia; chamamajorykabwe@gmail.com
* Correspondence: xup@ffrc.cn; Tel.: +86-510-85557959

Abstract: As a land-locked country in Southern Africa, Zambia is rich in natural resources suitable for fish production. However, aquaculture is still in its infancy with enormous potential as most of Zambia's fish now comes from capture fisheries. The aim of this study was to review the recent progress, status, challenges, and opportunities in Zambia's aquaculture industry while drawing some lessons from China's aquaculture experience, focusing on policy instruments, external support, quality seeds, and the investment environment for possible adaptation. To achieve this, we reviewed the existing literature about aquaculture in Zambia. This paper starts by reviewing the overall fishery sector's developments based on the analysis of relevant statistics over decades before narrowing down to the aquaculture sub-sector. The review shows that aquaculture production has continued to expand significantly and will soon play a leading role in food and nutrition security in Zambia. However, the industry still faces major challenges relating to investments, science and technology, fish seed and feed, and an underdeveloped value chain besides the increasing demand for fish products. Nevertheless, great potential still exists to further develop the aquaculture sub-sector and meet the ever-growing demand for fish products caused mainly by the rapid population increase.

Keywords: Zambia; aquaculture; challenges; adaptable lessons

Key Contribution: This paper analyzes the development of the aquaculture sub-sector of the fisheries sector in Zambia and provides a certain novelty in exploring its future development directions by drawing and adapting lessons from the experience of China.

check for updates

Citation: Zhang, L.; Maulu, S.; Hua, F.; Chama, M.K.H.; Xu, P. Aquaculture in Zambia: The Current Status, Challenges, Opportunities and Adaptable Lessons Learnt from China. *Fishes* **2024**, *9*, 14. https://doi.org/10.3390/fishes9010014

Academic Editors: Laura Susana López-Greco and Albert Kjartan Dagbjartarson Imsland

Received: 24 October 2023
Revised: 25 December 2023
Accepted: 27 December 2023
Published: 29 December 2023

1. Introduction

Fisheries play a key role in ensuring global food and nutrition security by providing fish products for foods and diversified nutrients [1]. Fish consumption accounts for 17% of the animal protein intake of the global population and more than half in several countries such as Cambodia, Sierra Leone, Bangladesh, Indonesia, Ghana, Mozambique, and some small island developing States [2]. In 2020, the world's per capita fish supply was 20.2 kg, which is more than double the 9.9 kg in the 1960s [3]. Fish is relatively inexpensive when compared to other sources of animal protein, such as cattle, and it is an important source of food and nutrition, particularly for rural people [4]. Yet, due to factors such as climate change and overfishing, natural fishery resources have been dwindling, and the development of sustainable aquaculture has become an important way to meet the growing demand for aquatic products [5].

Zambia is a landlocked country situated in the Southern part of Africa with 10 provinces and 116 districts. It covers about 752,614 km^2 of land, making it the 39th and 17th largest nation in the world and Africa, respectively [6]. The country is estimated to contain 15 million hectares of water in the form of rivers, lakes, and swamps [7], accounting for 4.5% of the inland water in Africa [8]. Furthermore, Zambia enjoys favorable climatic conditions ideal for fish production, with average annual temperatures ranging between 10 °C and 30 °C [9]. The annual rainfall ranges from 700 mm in the extreme southwest to 1400 mm in the north [10]. The rivers and lakes have largely supported the country's capture fisheries, while the vast expanses of water and land grant great potential for aquaculture development with a diversified farming system, such as cage culture and pond culture [11,12].

As one of the largest aquaculture producers in sub-Saharan Africa and the largest producer of farmed fish in the Southern African Development Community (SADC), Zambia's fishery sector contributes about 3.2% of the Agricultural Gross Domestic Product (GDP) and provides the mainstay to over one million people [13]. Zambia's fisheries contribute greatly to rural development in terms of income production, employment, and poverty alleviation [14]. According to the Food and Agriculture Organization of the United Nations (FAO), Zambians consume over 30% of their animal protein from fish [15], making fish a more indispensable food and nutrition source for Zambians compared to many other nations. Most of the fish consumed comes from freshwater capture fisheries, not from aquaculture, and are eaten as dried and/or smoked products [16]. However, the gap between capture fisheries and aquaculture production has declined significantly in recent years, suggesting that aquaculture could soon outpace capture fisheries. Recent projections show that Zambia's population is expected to reach 24 million in 2030 from the current estimated 19 million people, and an additional 71,591 tons of fish will be required to meet the projected demand for aquatic products [3]. The demand for fish continues to increase with the increase in the population [17], while the country's fish productivity has not kept the desired growth rate to meet the rising demand. Because of this, the domestic per capita supply in Zambia once decreased from a peak of 12 kg to less than 7 kg per annum [18], and though rising again to about 8 kg in recent years mainly due to the increase in aquaculture outputs [19], is still far lower than the world average of 20 kg.

The Zambian government and various international agencies have considered fish production through aquaculture as a promising and feasible means to cover the domestic deficit [20], and interventions have been undertaken to promote this sector. For instance, in 2017, the government launched the Zambia Aquaculture Enterprise and Development Project (ZAEDP), seeking mainly to support small-scale aquaculture production through financial and capacity development. While the recent increase in production can be attributed to these interventions, fish demand remains high, and the way forward has not been clear due to the absence of a stand-alone policy to direct development until this year. Furthermore, the country's huge potential, as seen through abundant freshwater resources, land, and human resources, is still far from being fully utilized despite several government interventions [12].

The literature has been probed regarding Zambian aquaculture from different aspects. For example, Genschick et al. (2017) reviewed the sector with data mainly from 2004 to 2014 focusing on the responsiveness of aquaculture development to the poor along the value chain [21], Kaminski et al. (2018) examined the upgrading trend and evidence of commercialization in aquaculture in Zambia [22], and it was commonly observed that this sector had gained significant development in recent years, mainly driven by the high demand and lead by a few large-scale commercial firms, while the small-holders were much left out of the value chain upgrading. Even though a few of the latest studies attempted to tackle concrete issues such as culture species [23], culture models [16] and farming systems [11], etc., the most recent review of the industry by Maulu et al. (2019) did not consider the major developments that took place in the industry after 2018. With the new policy—National Fisheries and Aquaculture Policy (NFAP) issued in 2023—now in place, a new chapter of aquaculture in Zambia is expected, and for it to happen, there is a need to

review the most recent developments, especially following the introduction of the ZAEDP project to analyze the progress and trends in aquaculture in Zambia and better benchmark where to start.

With such a background, this study aims to provide an overview of the recent developments, status, challenges, and opportunities in Zambia's aquaculture industry by examining the overall fishery sector and the comparative role of aquaculture in contrast to capture fisheries. Furthermore, this study identifies the challenges and opportunities facing the sector and draws lessons from China's aquaculture development experience for possible adaptation into the Zambian aquaculture industry to expand its production. As a country developing its aquaculture from almost zero into the world's top, accounting for 70% of global production [3], China has accumulated rich experiences, and the lessons we draw in this study may inform the aquaculture development of Zambia and even other Sub-Saharan African countries towards a more productive, efficient, and sustainable industry.

2. Methods Section

To develop this work, we searched for the relevant literature containing information about fisheries and/or aquaculture in Zambia in major search engines such as the Web of Science, Scopus, and Google Scholar. Additional information was obtained from the national fisheries and aquaculture-related documents such as the annual fisheries and aquaculture production reports produced by the Department of Fisheries (DoF), Ministry of Fisheries and Livestock, Zambia. Production statistics from fisheries and aquaculture in Zambia were mostly obtained from the (FAO) Fishery and Aquaculture Statistics. Priority was given in the literature used in this study to the most recent publications. Meanwhile, by examining the challenges facing Zambia and where China's experience comes in relevance, lessons were drawn, and opportunities identified based on the literature analysis, stakeholder feedback, and peer experience within the sector.

3. Results and Discussion

3.1. Overall Status of Fisheries in Zambia

Zambia's total fish production is dominated by capture fisheries, which account for approximately 70% of the country's total production [10]. Aquaculture in Zambia is still in its infancy, with huge potential to expand the country's fish production. Fish production has generally increased steadily over the past 40 years (Figure 1), and in 2021, the total production reached 168,480 tons [3]. The past decade (2012–2021) oversaw an ever faster-growing performance in Zambia's fish production, at an average growth rate of 6.7% annually. Nevertheless, a deficit of 74,000 tons in fish supply has recently been estimated by the government [19]. Because of this, the country has become a net fish importer to meet the demand [15].

According to the Zambia Statistical Agency (ZSA), Zambia's fish imports have been increasing over the past 40 years, reaching a peak of 126,886 tons in 2016; thereafter, a continued decline was observed to 79,941 tons in 2020. This decline is attributed to the growing aquaculture industry and the steady increase in the production from capture fisheries in the country. During this period, the major import sources were Namibia, China, South Africa, and Poland. On the other hand, Zambia also exported fish to other countries, although the quantity was maintained at less than 10,000 tons throughout the years, despite an increase from 532 tons in 2018 to 6725 tons in 2021 (Figure 2). The major export destinations were the Democratic Republic of Congo, Hong Kong of China, the United States of America, and Malawi.

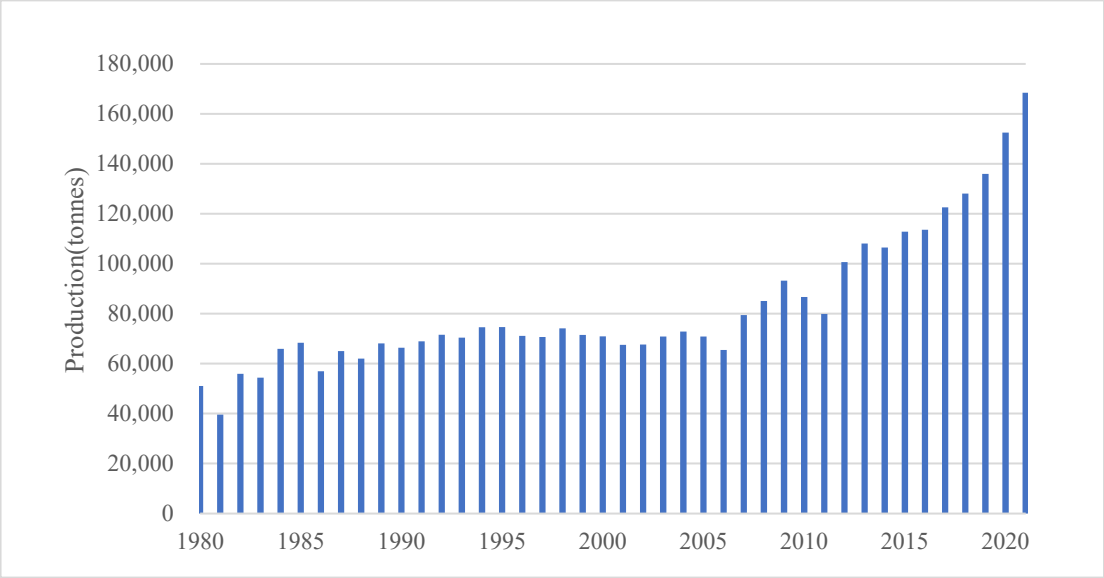

Figure 1. Total fish production in Zambia (1980–2021). (Source: FAO Fishery and Aquaculture Statistics).

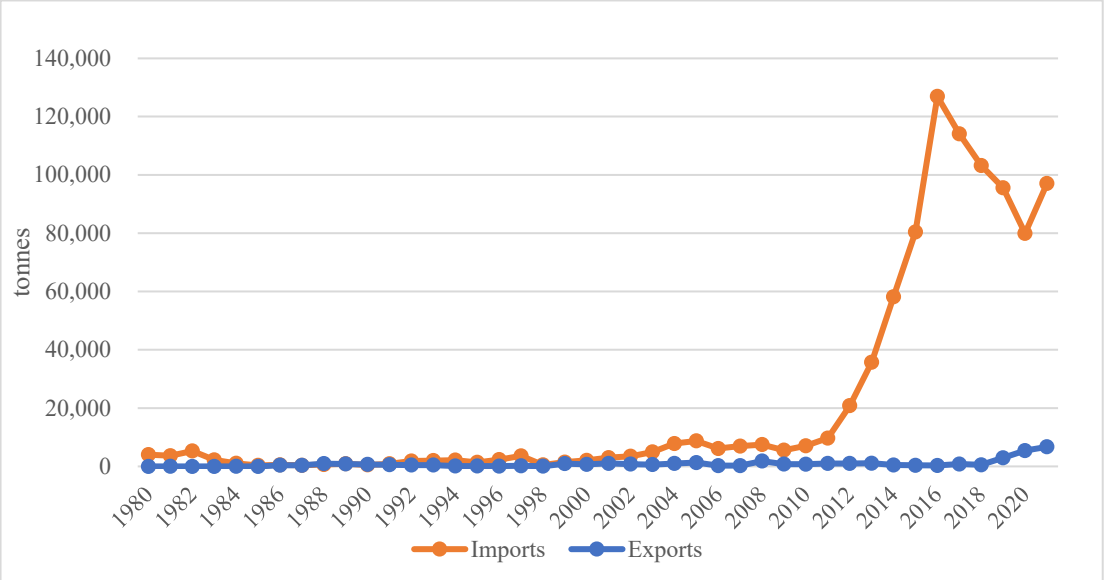

Figure 2. Total imports and exports of fish and fishery products in Zambia (1980–2021). (Source: DoF Zambia).

3.2. Capture Fisheries

Capture fisheries in Zambia are predominantly dominated by three major river basins, which are the Zambezi, Luapula, and Congo [14]. There are eleven main fisheries, four of which belong to the Congo River basin and seven to the Zambezi River basin, which is the largest. The fisheries in the Congo basin include Bangweulu, Mweru-Luapula, Mweru Wantipa, and Tanganyika. Kafue, Kariba, Lukanga, Upper Zambezi, Lower Zambezi, Itezhi-tezhi, and Lusiwashi belong to the Zambezi basin [24]. Over 400 indigenous fish species have been identified and documented from these water bodies [25]. Capture fisheries are dominated by artisanal fisher whose operations predominantly include gillnetting using craft made of planks or fiberglass [12]. Annual capture fisheries production increased from 50,988 tons in 1980 to 105,125 tons in 2021, and in recent years, it stabilized at a level of approximately 100,000 tons (Figure 3).

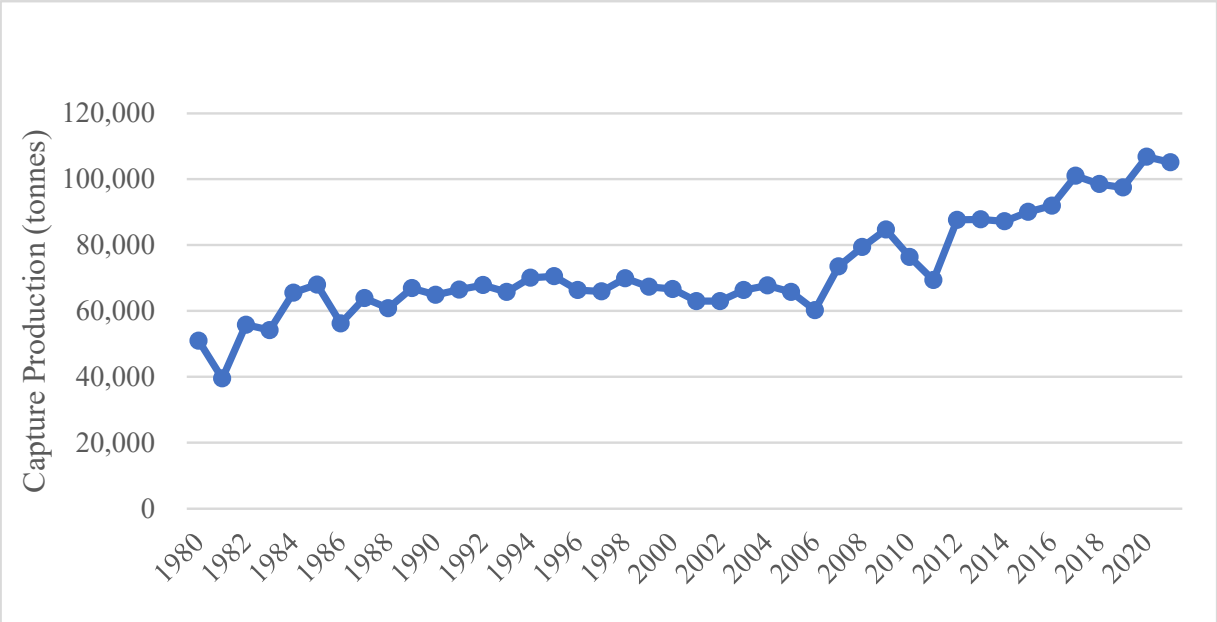

Figure 3. Total capture production in Zambia (1980–2021). (Source: FAO Fishery and Aquaculture Statistics).

The capture fishery sector in Zambia is facing various challenges to secure sustainable development, such as illegal, unregulated, and unreported (IUU), which is one of the major challenges globally, accounting for 11–26 million tons of fish annually [26]. The use of illegal fishing gear is particularly a major issue confronting the management of fisheries and sustainability in Zambia. According to a 2011 frame survey, 7273 gill nets were found to be illegal, accounting for 42.5% of recorded gill nets in the fishery in 2011 [27]. Another challenge comes from overfishing. In Zambia, overfishing and the use of unsustainable fishing methods leading to a decline in catches has continued in the presence of currently prescribed management possibilities [28]. Overfishing leads to the modification of fish biomass, size structure, and species composition that harms community structures and, hence, the productivity of a fishery [29,30]. Surveys and studies conducted by the Zambia government in 2021 showed an obvious reduction in the average size of fish at the catch and in their size at maturity for several capture species [19].

3.3. Aquaculture

Aquaculture in Zambia has experienced rapid growth in recent years, including a 5-fold increase within 10 years, and is expected to play a substantial role in food and nutrition security [31,32]. Figure 4 shows the trends in total aquaculture production in the past five years. Production in 2022 is estimated at 75,647 tons [33]. Zambia is now among the top ten aquaculture producers in Africa [34] and the largest producer of farmed fish in SADC [35]. Nile tilapia is the most produced fish in aquaculture in Zambia, accounting for about 60% of the total production [36]. A total of 12,019 employees in aquaculture were reported in 2016, increasing to almost 36,000 in 2019 [37]. The increase in aquaculture production is attributed to the rapid growth of the large commercial sector, especially the cage culture industry and large pond enterprises in Lake Kariba [11,21]. Efforts to promote production from small-scale production have also increased in recent years, as observed through the Zambia Aquaculture Development Project (ZAEDP), funded by the African Development Bank (AfDB) in collaboration with the Citizens Economic and Empowerment Commission (CEEC) in 2017.

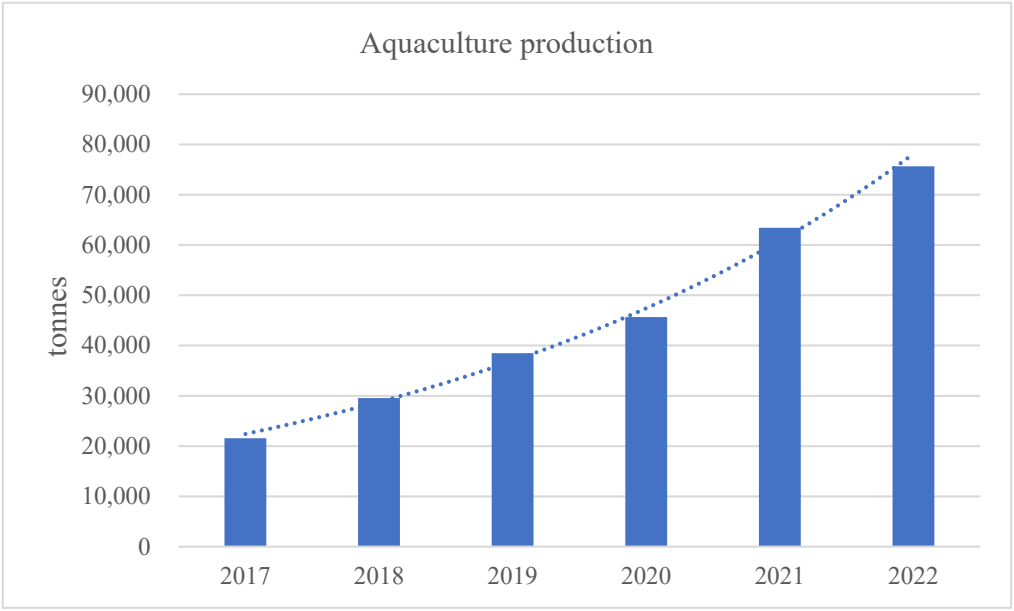

Figure 4. Trends in fish production from aquaculture in Zambia (2017–2022). (Source: DoF Zambia).

3.3.1. Cultured Species

In Zambia's aquaculture, the Cichlidae family leads the fish species used for aquaculture, with the common indigenous ones being the three-spotted Tilapia (*Oreochromis andersonii*), the green-headed Tilapia (*Oreochromis macrochir*), the red-breasted Tilapia (*Coptodon rendalli*), and Tanganyika Tilapia (*Oreochromis tanganicae*) [38]. Exotic species that are farmed in aquaculture include the Nile Tilapia (*Oreochromis niloticus*), common carp (*Cyprinus carpio*), and the red swamp crayfish (*Procambarus larkiai*) [12]. Amongst all these species, the exotic Nile Tilapia has been the main cultured species by commercial aquaculture producers in some parts of the country, and it is allowed by the government because of its faster growth and efficient feed utilization compared to the indigenous species [23], and it has even become the largest contributor to the total aquaculture output in the country. In 2021, Nile tilapia from aquaculture production was estimated at 39,365 tons, representing more than 62% of the total farmed fish production that year (Figure 5).

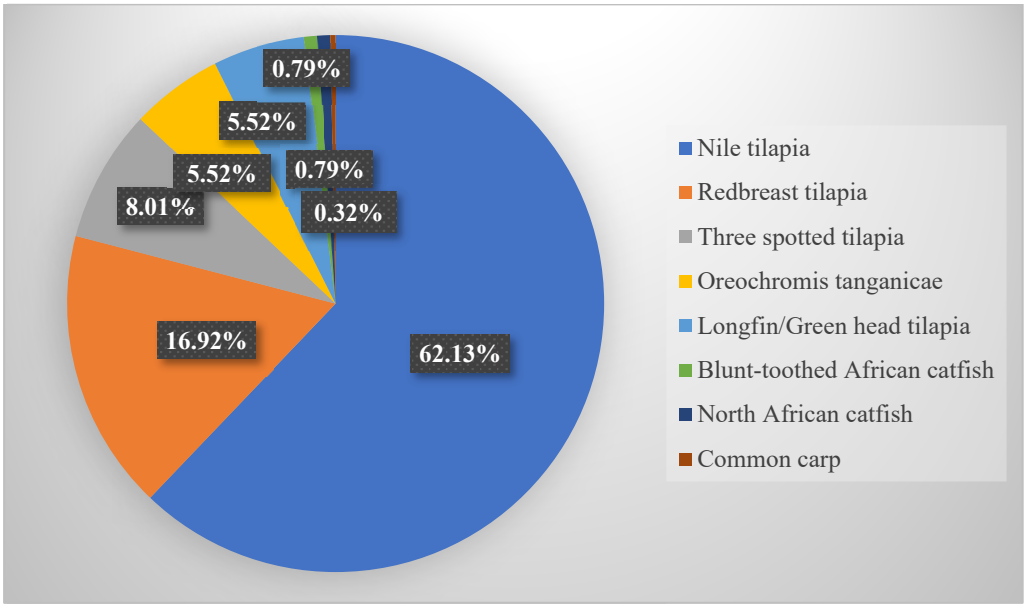

Figure 5. Zambia's main cultured species in 2021. (Source: FAO Fishery and Aquaculture Statistics).

3.3.2. Aquaculture Production Systems

Aquaculture production systems in Zambia can be categorized into extensive, semi-intensive, and intensive based on the level of production, capital investment, labor, and management practices employed [21].

In extensive production systems, cultured organisms depend entirely on the occurrence of natural foods, primarily plankton, which is usually enhanced through pond water fertilization [12]. There is no intentional supplementary feeding, and productivity is usually very low. The system is often characterized by the use of traditional earthen ponds or reservoirs and is commonly practiced in rural communities, probably because it is cheaper and does not require much technical knowledge [39]. The majority of the small-scale fish farmers under this system produce fish mainly for household consumption. Semi-intensive systems use fertilization or supplementary feeds to provide a farmer with fish for household consumption and income [21].

In intensive systems, the fish is fed with artificially prepared diets to enhance production within the shortest period of time possible. It is characterized by high investment costs and a high level of management, resulting in higher profits [12]. Large-scale commercial aquaculture producers in Zambia are represented by this system. The main cultural facilities in this system are land-based and cages. Tilapia and catfish are the main species of fish cultured in this system [40]. A land-based system of culturing can be defined as an intensive method of pond and or tank aquaculture, where stocking involves higher mono-sex seeds and relies on the use of artificial feeds as well as putting in higher capital and labor investments [21]. This entails the construction of complex earthen ponds, as well as concrete or plastic water storage facilities, with production systems ranging in different sizes. Commercial cage aquaculture in Zambia, situated mostly in the Southern Province around Lake Kariba, is growing rapidly [11,21]. Table 1 shows the aquaculture production systems and production against the different categories of aquaculture producers in Zambia in 2021.

Table 1. Production estimates based on aquaculture systems in 2021. ("/" means not available) (Source: DoF, 2022).

Systems	No. of Farmers	No. of Ponds/Dams	No. of Cages	Area (m^2)/Area (ha)	Volume (m^3)/Area (ha)	No. of Production Cycles	Total Fish Produced (MT)
Small scale Ponds	13,565	11,693.92	/	7016.35	/	1.5	32,977.36
Commercial Land-Based	33	3828.08	/	2945.95	/	1.5	10,718.06
Small scale Cages	636	/	190	/	82,987.96	1.5	5073.44
Commercial (cages)	13	/	263	/	294,230.04	2	14,586.14
Total	14,247	15,522	453	9962.30	377,218	/	63,418.00

3.4. Governance

The Department of Fisheries (DOF) is one of the Departments in the Ministry of Fisheries and Livestock (MFL), and it has two main branches (divisions), namely the Capture Fisheries Branch and the Aquaculture Branch; one is responsible for capture fisheries development and management and the other for aquaculture development, respectively. The main function of the Department of Fisheries is to oversee the implementation of the national fisheries programs in capture fisheries and aquaculture development. The Department is also responsible for the enforcement and regulation of the Fisheries Act, Chapter 22 of the Laws of Zambia 2011. It conducts research in fisheries and aquaculture for sustainable fisheries and economic efficiency. The units in the department include the Capture Fisheries Extension and Advisory Services; Aquaculture Extension and Advisory Services; Capture Fisheries Research and Development; and Aquaculture Research and Development (Figure 6).

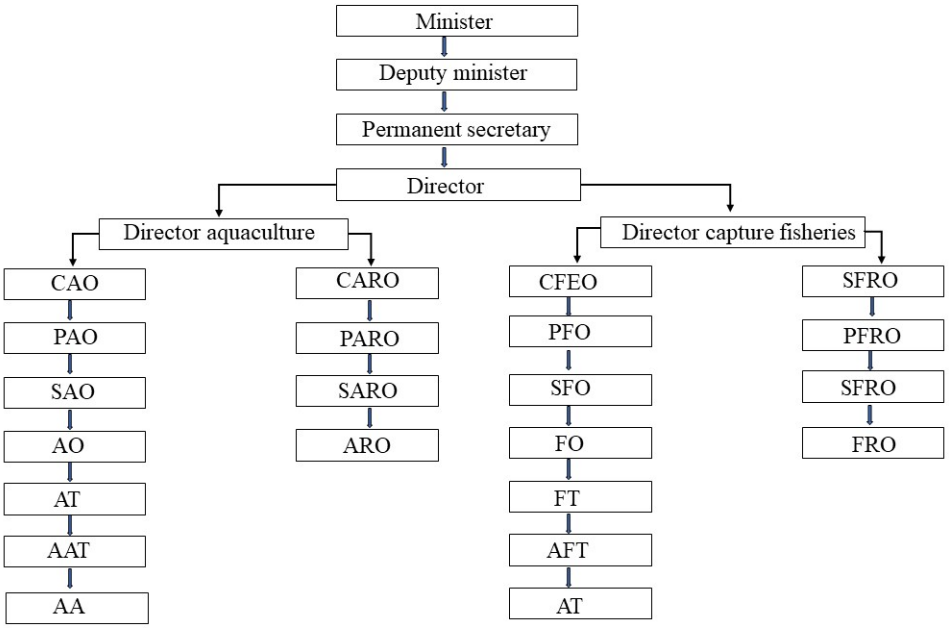

Figure 6. The Department of Fisheries' institutional structure (Source: DoF Zambia). Note: C–Chief, P–Principal, S–Senior, A–Aquaculture, O–Officer, A–Assistant, F–Fisheries, E–Extension, R–Research, T–Technician.

With the support of various stakeholders, major breakthroughs and advancements in fisheries and aquaculture have recently occurred. In 2023, the Government developed the National Fisheries and Aquaculture Policy (NFAP) to provide guidance on the implementation of fisheries and aquaculture programs. This policy is expected to lead to the transformation of the capture fisheries and aquaculture sub-sector, which are key to boosting production and productivity in the agricultural sector. Through this transformation, the sub-sector can contribute to accelerating economic growth, ending hunger and malnutrition, and improving household and national income.

3.5. Challenges Analysis of Aquaculture Development in Zambia

Although Zambia's aquaculture industry has comparative advantages and has made efforts, its potential has not yet been utilized due to several challenges such as a limited financial capacity to access quality fish feeds by most farmers, poor quality fish seed, low extension service delivery, and capital investment [11,12,21,38].

3.5.1. Fish Seed Diversity and Quality

Fish seed is one of the most important primary inputs in aquaculture and its quality can be a key determinant of the success or failure of a fish farming venture. The fish seed supply in Zambia can be categorized into the public (the government) and the private sector. Five major government hatcheries across the country provide mixed-sex native tilapia fingerlings to small-scale aquaculture farmers [22]. However, their hatcheries produce a limited capacity to meet farmers' demands. This has given an opportunity for the emergence of the private sector to close the gap in the fish seed demand. Unfortunately, this gives rise to serious challenges related to quality as farmers tend to focus on acquiring cheaper but low-quality fingerlings. For example, the most common and less expensive source of acquiring fingerlings is from fellow farmers. A study by Kaminski (2018) [22] revealed that farmers do not consistently purchase fingerlings every year but instead allow fish to breed for generations, thus recycling their stock year after year. This is more common among subsistence fish farmers who grow fish for food rather than business. Business-oriented fish farmers consider such practice a major problem due to clear problems with inbreeding and stunted fish growth. Inbreeding compromises the quality of fish seeds and

may increase production costs in aquaculture, particularly through feeding [12]. Furthermore, a limited number of cultivable species has resulted in limiting the diversification of the aquaculture industry.

3.5.2. Fish Feed Accessibility and Affordability

Fish feed plays a significant role in aquaculture as it accounts for about 50–70% of the total fish production cost [41,42]. The rapid growth of large-scale commercial aquaculture producers recorded in recent years has stimulated the development of the fish feed manufacturing industry mostly from the private sector that produces four different categories: fry mash, juvenile crumble, starter pellets and grower pellets [11]. It is important not only to have sound knowledge of nutrient requirements but also to formulate feeds optimally using the appropriate ingredients. This has been a challenge for the aquatic feed industry mainly because macro-ingredients, including fishmeal and fish oil, and essential micro-ingredients, such as premixes and vitamins, are imported, which maintains the price of commercial feeds at a moderately high level [21]. In 2021, fish feed prices in Zambia increased by more than 100%, which is mainly attributed to the rising demand for feedstuffs, mainly proteins, and difficulties in sourcing raw materials [19]. In Zambia, like many developing countries, this has always been a constraint due to their high demand and pricing. Additionally, farmers lack access to training and quality inputs; they often use poor quality or old fish feed, resulting in low production. The investment is generally low among most small-scale farmers.

3.5.3. Post-Harvest Fish Losses

Fish are highly perishable, which is determined by their natures, leading to higher levels of post-harvest losses (PHLs) compared with many other food sectors. However, statistics on post-harvest fish losses in the fisheries sector of Zambia are generally unclear. According to FAO (2011), it was estimated that yearly global quantitative food losses in sub-Saharan Africa are around 33% for fish, which is much higher than 20% for cereals. A study by Maulu et al. (2020) showed that in Zambia, the lack of cold storage facilities and fluctuating weather conditions are the major challenges impacting the post-harvest fish industry. Processing reduces post-harvest losses and increases options for the storage, transport, and retailing of fish [43], yet the most common processing techniques among fish producers in Zambia are sun-drying, smoking, chilling, and freezing [44], with small-scale farmers being far less reachable to cold storage facilities and not to mention more sophisticated processing techniques. On the other hand, less access to favorable markets also reduces the profit margin of small farmers [45], and limited transportation also adds to the loss. PHLs have a heavy negative impact on the income and nutrition of the majority who depend on the fish, especially for small and medium-sized fisheries producers.

3.5.4. Fish Marketing Mechanism

Most of the fish produced in Zambia is sold through informal channels as fish is in high demand from fisheries and farms. Large-scale producers have established marketing arrangements in the country to sell their products. However, as the industry grows, there is a strong need to promote formal marketing mechanisms along the value chain to create more market opportunities for fish producers and processors. This also improves access to aquatic products by people of different economic statuses across communities. The current situation is that fish producers either sell to wholesalers or traders, who then sell to retailers, and the fish reaches consumers [22]. However, it is also common for fish caught from natural water bodies or aquaculture facilities to be sold directly to consumers. This is the most common practice among small-scale fish producers in this country. Often, fish is sold at relatively low prices compared with the fish sold through the formal market.

3.5.5. Fishery Management

Zambia first introduced co-management fisheries systems in the early 1990s [46]. Co-management has been endorsed and is actively promoted by the central government as a key management tool. However, most fishers move from one fishing region to another in pursuit of good catches, which contributes to their unwillingness to engage [47]. This is worsened by a lack of understanding of the benefits of community-based management systems as a common pool of resources, as well as an insufficient presence of extension and enforcement personnel. As a result, there is a poor level of compliance with fishery rules, which leads to the depletion of fishery resources. Although the government has developed the aquaculture strategic plan, which is enshrined with the description of best aquaculture management practices, the benefits of such management tools have not been translated into enhancing fish production. The capacity of the government to implement best aquaculture management practices is limited and, therefore, requires consolidated collaboration with relevant stakeholders.

4. Opportunities to Boost Aquaculture Production in Zambia through Adaptable Lessons from China

China is the largest producer of aquatic products in the world, accounting for around 35% of the global fish and seafood production volume in 2020 [3]. In 2022, China's total aquatic product output was 68 million tons [48], while this number was only 4.65 million in the year 1978 [49]. With multidimensional measures taken, especially since the mid-1980s, China's aquaculture gained great momentum and resulted in China becoming the first country in the world with aquaculture outputs exceeding its capture ones. In retrospect to the aquaculture development path of China, many similarities could be found with the conditions that Zambia is facing, and therefore, lessons could be gained from China's experience that could inform Zambia in enhancing its aquaculture production by taking advantage of existing opportunities, while also avoiding some detours that China has taken. Therefore, this section highlights key aspects of aquaculture development related to the challenges affecting Zambia's aquaculture industry. Using these experiences from China's approach to developing the aquaculture sector rather than comparing, we draw some lessons that may be easily adopted in Zambia to enhance national fish production.

4.1. Sound Policy Formulation and Appropriate Implementation

Political will and political agenda play a major role in aquaculture policy and regulation [50]. China has long set the "aquaculture-prioritized" principle for its fishery development, along with a series of goal-oriented policies and strategies to stimulate, guide, and support the sector's fast development. Furthermore, China employs a unique experimental approach to public policy development and sustainably develops the sector [51]. In this approach, provincial and municipal level pilot projects create an experience with novel approaches under small-scale and controlled settings [39,40]. Successful and effective approaches under different contexts are then scaled up into new national policies for replication and expansion [52]. In Zambia, the NFAP was newly introduced in 2023 as a response to existing and emerging challenges affecting fish production to drive economic growth, addressing hunger and malnutrition, and overcoming the national fish deficit, estimated at 74,000 tons annually. Furthermore, this policy is seen as a means to achieve the sustainable utilization of the country's abundant natural resources. Some of the measures outlined in the NFAP include promoting sustainable fish production and productivity, strengthening the delivery of extension services, research, and development, enhancing the market for fish products, improving and maintaining aquatic animal health, protecting the environment, and mainstreaming cross-cutting issues in fisheries and aquaculture. Nevertheless, what still requires more attention is, for example, the fact that policy implementation and enforcement shall be closely overseen to ensure that regulations are better observed and more scientifically implemented while promoting in-depth research in context-based aquaculture management theories. Additionally, there is a need to ensure a

better understanding of the aquaculture sector using government-initiated demonstrations, farmer-level training, and education. Meanwhile, more scientific but flexible licensing and regulatory frameworks, as well as tangible supporting measures, such as governmental subsidies, for access to production inputs, just like in agriculture, may be provided to enable easier access for existing and potential farmers to enlarge or start aquaculture businesses and accelerate development.

4.2. Government Support to S&T with Step-to-Step Goals

Government support through financial and technical services are key catalysts for enhancing aquaculture productivity. China's improvement in aquaculture is largely based on the development of key national research that is adequately funded by the government to develop new technology and improve existing ones. Zambia's NFAP measures to promote sustainable fish production and productivity may not be achieved without strong government support for the sector. In China, for example, the contribution rate of S&T to the fishery sector development was estimated at 63% during the 13th five-year plan (2016–2020) and is anticipated to reach 67% during the 14th five-year plan (2021–2025) [53,54], manifesting the country's high input into the fishery S&T. Chinese aquaculture/fisheries research institutes and universities are considered the architects of basic research and the development of novel technology to expand fish production [55]. The rapid development of China's fish production in recent decades could also be attributed to improved technical support through the extension of service delivery [10]. Some key deliberate efforts made by the government include the establishment of the comprehensive aquaculture extension service delivery, guidance on strengthening the promotion of aquatic technology under the rural revitalization strategy, as well as the development of the National Fisheries Science and Technology Collaboration Alliance [56,57]. These have played a key role in the expansion of fish production in China. As aquaculture in Zambia continues to draw interest from both the public and private sectors, there is a need to increase financial and technical support to boost this production. While recent support to small-scale aquaculture producers through input under the ZAEDP project has undoubtedly supported the recent expansion in production from this small-scale sector, technical support remains low due to the low delivery of extension services [12]. The lack of financial and technical support in aquaculture may be attributed to the fact that this sector was previously under the Ministry of Agriculture, and its role in food and nutrition security was not fully recognized. However, enormous potential can be anticipated from increasing the recognition of the importance of the sector and improved support by the Zambian government, especially in aspects such as fish breeding programs, promoting local feed formulations, and wider extension service delivery.

4.3. Improvements in Production Systems That Best Suit Local Conditions

China's fast development in aquaculture benefits a lot from its diversified production systems, which are set up based on different local conditions, including climate, topography, economic level, and consumer preferences. Production systems, such as pond farming, cage and pen culture, recirculating systems, and different aquaculture models, such as mono-culture, polyculture-like-integrated multi-trophic aquaculture (IMTA), and integrated farming systems, are widely used. While Zambia's aquaculture industry is still relatively new, opportunities to utilize different production systems and models exist [32]. For example, although tilapia is the most widely and abundantly cultured species countrywide, there are other species not utilized for aquaculture, such as the carp that have been reported in this country [12]. Different fish production systems and models could be tried to better utilize water and land resources and strive for better economic and environmental effects. However, while new production systems and models may be introduced to boost national fish production, the investments and operating costs of such technologies must be affordable for a large proportion of the farmers. For example, foreign aquaculture recirculatory systems (RAS) introduced in China in the 1980s were not adopted by the farmers

due to high startup and operating costs [58]. Furthermore, introduced technologies must have minimum impacts on the environment to attain sustainable development, such as the introduction of non-fed species into polyculture. In Zambia, ponds are the most used fish farming facility (18,582) at 83.5%, followed by tanks (2,567) at 11.5%, then dams (796) at 3.6% of the total number of fish farming facilities [13]. Opportunities exist to improve existing technologies and introduce new ones. As a matter of fact, cage aquaculture has become one of the major contributors to national aquaculture production in recent years [12,32]. Moreover, there are opportunities to leverage the potential of integrated farming systems to combine different species or different sectors (such as aquaponics and aquaculture plus agriculture, poultry, or even livestock) into one system.

4.4. Species Improvement and Diversification with Long-Term Breeding Programs

Quality seed is the key to the success of aquaculture practice. About 100 species were cultured in China's aquaculture in the 1980s [59]. Currently, however, over 800 species and 240 improved varieties are reportedly cultured in China, making it the most diverse industry worldwide [55]. Species improvement has been achieved through traditional selective breeding and molecular approaches. The increased aquaculture production in China has been largely attributed to its diverse aquaculture species [60]. Currently, in Zambia, only around eight fish species, mainly from the Tilapia genus, are reportedly used in aquaculture [47], with only one species still undergoing strain improvement. Great potential exists to introduce new species in aquaculture, given that over 450 fish species have been reported in the fisheries sector (FishBase), and at least three species outside the tilapia genus have shown potential for use in aquaculture [12]. Thus, increasing the variety of aquaculture species in Zambia is very crucial in achieving enhanced productivity and sustainability. To achieve this, research must be enhanced to improve existing culture species and explore the scientific and economic values of farming other potential species. This could also help in building the sector's resilience to climate change and emerging diseases [61]. Within the boundaries that the country's legislation allows, more scientific breeding plans and methods could be adopted, such as selective breeding and mono-sex breeding for local species, including, in particular, long-term breeding programs, which are set up considering the years needed for genetic improvements [23]. This has been one of the key successful factors for aquaculture production in China. However, such projects require adequate financial support and political alongside adequately trained experts in the field to actualize these benefits. Furthermore, several factors, such as ecological conditions, local consumer preferences, international market opportunities, and people's culture, should be considered when introducing new species or varieties.

4.5. Creation of Environment to Promote Private Investments and Better Involve Smallholders

Prolonging the fisheries sector value chain is necessary to create more income and employment, improve food and nutrition security, bring more economic and social benefits, and, therefore, sustain the sector's development. The private sector is usually a key contributor to fisheries and aquaculture development in many countries and has proved to be necessary in complementing government efforts to promote sustainable development. However, their level of contribution usually depends on whether there is a favorable environment for private investment and a clear roadmap or "a policy" to guide these efforts. For example, in China, private companies in feed manufacturing (such as the Tongwei group) and genome-sequencing companies (such as BGI in Shenzhen, China) were established to support government efforts in providing technical solutions to promote a sustainable and profitable aquaculture industry [55]. Although Zambia has managed to attract private investments in cage aquaculture (e.g., Yalelo Ltd., Lusaka, Zambia) and feed manufacturing companies (e.g., AllerAqua Ltd, Lusaka, Zambia), upgrading and commercialization in aquaculture chains are found to be taking place in various forms [22], there is still substantial potential to attract more private investments into the sector, such as offering tax preferences, simplifying registration procedures, improving

infrastructures, and helping to dock with farmers or state-owned bases. On the other hand, in commercialization processes, smallholders have been much left out and benefit less from the industry upgrading; therefore, synergies between larger enterprises and small-scale producers should be pursued to best benefit poor rural and urban households, such as through investing in the better organization of smaller producers and improved technical and financial services [62] in terms of employment or corporate leadership. The enhanced organization levels of small farmers could uplift their position and voices in the value chain with more power than one could exert as an individual. For example, as a farmer's cooperative, it could act as an entity more equally in negotiations with upstream or downstream players along the chain, such as input suppliers or the market, and therefore, better secure the profit margins of all its members. All in all, this sector's development should be roundly examined from an industry perspective and towards a whole-value-chain vision. All stakeholders, especially small-scale farmers and small and medium-sized enterprises (SMEs), should be fully accounted for and facilitated to become better involved in the value chain to ensure the sector's self-driven development in the long run.

5. Conclusions

With capture fishery output stagnating and the national population continuously growing, Zambia is facing a large gap between the demand and supply of fish products, resulting in a large number of fish imports every year while also threatening food and nutrition security. Located in Southern Africa, Zambia is, in fact, rather rich in inland water resources, which promises huge potential in aquaculture development and, thus, to improve livelihood. Even though aquaculture is far from new to Zambians, and it has made remarkable progress over the past few years, the development of the sector in general is still lagging behind in many aspects. Furthermore, the progress this sector has made has been largely driven by only a few larger commercial investments into the sector, and the much larger group of farmers involved in fish farming, mainly small and medium-scale farmers, are still struggling to carry this business forward, while being confronted with such constraints as poor-quality seeds, inaccessible or unaffordable feed, a lack of farming technology and management knowledge, etc. Viewing this from an industrial perspective, all the nodes along a value chain should be taken into account to sustain this sector's development, and such measures as the following are believed and tested (for example, by China) to be conducive to promoting and escorting the aquaculture development of Zambia: policies and regulations prioritizing aquaculture along with potent implementation wills and measures; government support and input into S&T alongside innovation and extension with a focus on fish seed and feed; a diversified farming system both in terms of facilities, intensifications, and models; and the involvement of private investments and organizations of farmers into the sector to secure an inner-driven impetus. With further efforts made regarding these aspects in accompanying the implementation of NFAP, aquaculture in Zambia can be expected to grow faster and more sustainably in all the economic, social, and environmental dimensions and better fulfill its roles in food and nutrition supply, poverty reduction, and rural development.

Author Contributions: Conceptualization, L.Z. and P.X.; methodology, L.Z.; software, F.H.; validation, S.M., M.K.H.C. and L.Z.; formal analysis, L.Z. and S.M.; investigation, L.Z. and F.H.; resources, M.K.H.C. and L.Z.; data curation, L.Z. and S.M.; writing—original draft preparation, L.Z., F.H. and M.K.H.C.; writing—review and editing, L.Z. and S.M.; visualization, L.Z.; supervision, P.X.; project administration, P.X. and L.Z.; funding acquisition, P.X. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Central Public Interest Scientific Institution Basal Research Fund, Freshwater Fisheries Research Center, CAFS, grant number 2023JBFM14 and the FAO triangular cooperation project, Up-scaling the FAO-China SSC Programme through triangular cooperation with the Netherlands (part 1), grant number GCP/GLO/971/MUL-TFAA11AA19388.

Data Availability Statement: Data sharing not applicable. The data presented in this study are available within the article.

Acknowledgments: The authors are thankful to Brian Pelekelo Munganga and Peter Daka from the DOF of Zambia for their valuable suggestions on the manuscript.

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

References

1. Finegold, C. *The Importance of Fisheries and Aquaculture to Development*; The Royal Swedish Academy of Agriculture and Forestry: Stockholm, Sweden, 2009; pp. 353–364.
2. Scientists to Global Policymakers: Treat Fish as Food to Help Solve World Hunger. Available online: https://www.sciencedaily.com/releases/2021/01/210119122051.htm (accessed on 10 December 2023).
3. FAO. *The State of World Fisheries and Aquaculture 2022. Towards Blue Transformation*; FAO: Rome, Italy, 2022.
4. Ayoola, S.O. Sustainable fish production in Africa. *Afr. J. Food Agric. Nutr. Dev.* **2010**, *10*, 1–9.
5. Subasinghe, R.; Soto, D.; Jia, J.S. Global aquaculture and its role in sustainable development. *Rev. Aquac.* **2009**, *154*, 2–9. [CrossRef]
6. Mudenda, H.G. *Assessment of National Aquaculture Policies and Programmes in Zambia*; Institute of Policy Studies: Lusaka, Zambia, 2009.
7. Nsonga, A.; Simbotwe, M. Challenges and Emerging Opportunities for Aquaculture Development in Zambia. *Int. J. Fish. Aquat. Stud.* **2014**, *2*, 232–237.
8. Cai, J.N.; Galli, G.; Zhou, X.W. *Zambia—WAPI factsheet on Aquaculture Growth Potential*; FAO: Rome, Italy, 2022. [CrossRef]
9. Dinar, A.; Hassan, R.; Mendelsohn, R.; Benhin, J. *Climate Change and Agriculture in Africa: Impact Assessment and adaptation Strategies*; Routledge: London, UK, 2008.
10. Kasali, G. *Climate Change and Health in Zambia. Lusaka, Zambia: CLACC Working Paper*; IIED: London, UK, 2008.
11. Hasimuna, O.J.; Maulu, S.; Monde, C.; Mweemba, M. Cage Aquaculture Production in Zambia: Assessment of Opportunities and Challenges on Lake Kariba, Siavonga District. *Egypt. J. Aquat. Res.* **2019**, *45*, 281–285. [CrossRef]
12. Maulu, S.; Munganga, B.; Hasimuna, O.; Hambiya, L.; Seemani, B. A Review of the Science and Technology Developments in Zambia's Aquaculture Industry. *J. Aquac. Res. Dev.* **2019**, *10*, 2. [CrossRef]
13. Ministry of Fisheries and Livestock. *The 2017/2018 Livestock and Aquaculture Census Main Report*; Ministry of Fisheries and Livestock and Central Statistics Office: Lusaka, Zambia, 2021.
14. Musumali, M.M.; Heck, S.; Husken, S.M.C.; Wishart, M. *Fisheries in Zambia: An Undervalued Contributor to Poverty Reduction*; World Fish Center: Penang, Malaysia, 2009.
15. Fishery and Aquaculture Country Profiles. Zambia, 2021. Country Profile Fact Sheets. Fisheries and Aquaculture Division. Rome. Updated 7 February 2022. Available online: https://www.fao.org/fishery/en/knowledgebase/82 (accessed on 25 December 2023).
16. Kaminski, A.M.; Little, D.C.; Middleton, L.; Syapwaya, M.; Lundeba, M.; Johnson, J.; Huchzermeyer, C.; Thilsted, S.H. The Role of Aquaculture and Capture Fisheries in Meeting Food and Nutrition Security: Testing a Nutrition-Sensitive Pond Polyculture Intervention in Rural Zambia. *Foods* **2022**, *11*, 1334. [CrossRef] [PubMed]
17. Tran, N.; Chu, L.; Chan, C.Y.; Genschick, S.; Phillips, M.J.; Kefi, A.S. Fish Supply and Demand for Food Security in Sub-Saharan Africa: An Analysis of the Zambian Fish Sector. *Mar. Policy* **2019**, *99*, 343–350. [CrossRef]
18. Shula, A.K.; Mofya-Mukuka, R. *The Fisheries Sector in Zambia: Status, Management, and Challenges. Indaba Agricultural Policy Research Institute Technical Paper*; Department of Fisheries, Ministry of Agriculture and Livestock: Lusaka, Zambia, 2015; p. 3.
19. Department of Fisheries (DoF), Zambia. *Fisheries and Aquaculture Statistics: Annual Report*; Ministry of Fisheries and Livestock: Chilanga, Zambia, 2021.
20. Avadí, A.; Cole, S.M.; Kruijssen, F.; Dabat, M.H.; Mungule, C.M. How to Enhance the Sustainability and Inclusiveness of Smallholder Aquaculture Production Systems in Zambia? *Aquaculture* **2022**, *547*, 737494. [CrossRef]
21. Genschick, S.; Kaminski, A.M.; Kefi, A.S.; Cole, S.M. *Aquaculture in Zambia: An Overview and Evaluation of the Sector's Responsiveness to the Needs of the Poor. Penang, Malaysia: CGIAR Research Program on Fish Agri-Food Systems and Lusaka, Zambia*; Department of Fisheries: Lusaka, Zambia, 2017; Working Paper: FISH-2017-08.
22. Kaminski, A.M.; Genschick, S.; Kefi, A.S.; Kruijssen, F. Commercialization and Upgrading in the Aquaculture Value Chain in Zambia. *Aquaculture* **2018**, *493*, 355–364. [CrossRef]
23. Basiita, R.K.; Trinh, T.Q.; Sakala, M.E.; Chungu, P.; Malambo, T.; Hampuwo, B.; Mwema, C.; Benzie, J.A.H. Performance of *Oreochromis Niloticus* and *Oreochromis Andersonii* in Controlled Laboratory Conditions in Zambia. *Aquac. Rep.* **2022**, *27*, 101338. [CrossRef]
24. Sector Profile. Agriculture, Livestock and Fisheries. *Agric. Livest. Fish.* **2010**, *1*, 8.
25. Utsugi, K.; Mazingaliwa, K. *Field Guide to Zambian Fishes, Planktons and Aquaculture*; Japan International Co-operation Agency (JICA): Tokyo, Japan, 2002; p. 41.

26. Widjaja, S.; Long, T.; Wirajuda, H. *Illegal, Unreported and Unregulated Fishing and Associated Drivers*; World Resources Institute: Washington, USA, 2020. Available online: www.oceanpanel.org/iuu-fishing-and-associated-drivers (accessed on 25 December 2023).
27. Petit, P.; Shipton, T. *IUU Fishing on Lake Tanganyika. Implementation of a Regional Fisheries Strategy for The Eastern-Southern Africa and India Ocean Region. REPORT/RAPPORT*; Indian Ocean Commission: Port Louis, Mauritius, 2012.
28. Haambiya, L.; Kaunda, E.; Likongwe, J.; Kambewa, D.; Muyangali, K. Local-Scale Governance: A Review of the Zambian Approach to Fisheries Management. *JAST-B* **2015**, *5*, 82–91. [CrossRef]
29. Bianchi, G.; Gislason, H.; Graham, K.; Hill, L.; Jin, X.; Koranteng, K.; Manickchand-Heileman, S.; Payá, I.; Sainsbury, K.; Sanchez, F.; et al. Impact of Fishing on Size Composition and Diversity of Demersal Fish Communities. *ICES J. Mar. Sci.* **2000**, *57*, 558–571. [CrossRef]
30. Jennings, S.; Blanchard, J.L. Fish Abundance with No Fishing: Predictions Based on Macroecological Theory. *J. Anim. Ecol.* **2004**, *73*, 632–642. [CrossRef]
31. Chan, C.Y.; Tran, N.; Pethiyagoda, S.; Crissman, C.C.; Sulser, T.B.; Phillips, M.J. Prospects and Challenges of Fish for Food Security in Africa. *Glob. Food Secur.* **2019**, *20*, 17–25. [CrossRef]
32. Hasimuna, O.J.; Maulu, S.; Nawanzi, K.; Lundu, B.; Mphande, J.; Phiri, C.J.; Kikamba, E.; Siankwilimba, E.; Siavwapa, S.; Chibesa, M. Integrated Agriculture-Aquaculture as an Alternative to Improving Small-Scale Fish Production in Zambia. *Front. Sustain. Food Syst.* **2023**, *7*, 1161121. [CrossRef]
33. FAO. *Fisheries and Aquaculture Statistics: Annual Report (Draft)*; Ministry of Fisheries and Livestock: Chilanga, Zambia, 2023.
34. Ministry of Fisheries and Livestock of the Republic of Zambia (MFL). *National Fisheries and Aquaculture Policy (NFAP)*; Ministry of Fisheries and Livestock: Lusaka, Zambia, 2023.
35. Department of Fisheries (DoF), Zambia. *Fisheries and Aquaculture Statistics: Annual Report*; Ministry of Fisheries and Livestock: Chilanga, Zambia, 2019.
36. Department of Fisheries (DoF), Zambia. *Fisheries and Aquaculture Statistics: Annual Report*; Ministry of Fisheries and Livestock: Chilanga, Zambia, 2018.
37. Department of Fisheries (DoF), Zambia. *Fisheries and Aquaculture Statistics: Annual Report*; Ministry of Fisheries and Livestock: Chilanga, Zambia, 2020.
38. Mphande, J.; Hasimuna, O.J.; Kikamba, E.; Maulu, S.; Nawanzi, K.; Phiri, D.; Siavwapa, S. Application of anaesthetics in fish hatcheries to promote broodstock and fish seed welfare in Zambia. *Cogent Food Agric.* **2023**, *9*, 2211845. [CrossRef]
39. Musuka, C.; Mainza, R. Extent of Small-Scale Fish Farming in Three Districts of Lusaka Province. *Int. J. Aquac.* **2016**, *5*, 1–12. [CrossRef]
40. Namonje-Kapembwa, T.; Samboko, P. *Assessing the Profitability of Small-Scale Aquaculture Fish Production in Zambia*; Indaba Agricultural Policy Research Institute (IAPRI): Lusaka, Zambia, 2017.
41. Rana, K.J.; Siriwardena, S.; Hasan, M.R. *Impact of Rising Feed Ingredient Prices on Aquafeeds and Aquaculture Production*; FAO Fisheries and Aquaculture Technical Paper; FAO: Rome, Italy, 2009; p. 541.
42. Kord, M.I.; Srour, T.M.; Omar, E.A.; Farag, A.A.; Nour, A.A.M.; Khalil, H.S. The immunostimulatory effects of commercial feed additives on growth performance, non-specific immune response, antioxidants assay, and intestinal morphometry of Nile tilapia, Oreochromis niloticus. *Front. Physiol.* **2021**, *12*, 627499. [CrossRef]
43. Nölle, N.; Genschick, S.; Schwadorf, K.; Hrenn, H.; Brandner, S.; Biesalski, H.K. Fish as a Source of (Micro)Nutrients to Combat Hidden Hunger in Zambia. *Food. Sec.* **2020**, *12*, 1385–1406. [CrossRef]
44. Maulu, S.; Hasimuna, O.J.; Monde, C.; Mweemba, M. An Assessment of Post-Harvest Fish Losses and Preservation Practices in Siavonga District, Southern Zambia. *Fish. Aquat. Sci.* **2020**, *23*, 25. [CrossRef]
45. Naylor, R.; Fang, S.; Fanzo, J. A Global View of Aquaculture Policy. *Food Policy* **2023**, *116*, 102422. [CrossRef]
46. West, K. *Lake Tanganyika: Results and Experiences of the UNDP/GEF Conservation Initiative (RAF/92/G32) in Burundi, D.R. Congo, Tanzania, and Zambia*; Lake Tanganyika Biodiversity Project: Burundi, South Africa, 2001; p. 138.
47. Maulu, S.; Musuka, C. Assessing the Abundance and Distribution of Tilapia Species in Lake Kariba. *Int. J. Fish. Aquac. Sci. (IJFAS) IRPH* **2018**, *8*, 1–11.
48. Ministry of Agriculture and Rural Affairs of the People's Republic of China. *China Fishery Economic Statistical Bulletin 2022 (CFESB)*; Fisheries and Fisheries Administration Bureau: Beijing, China, 2023.
49. Li, X.; Li, J.; Wang, Y.; Fu, L.; Fu, Y.; Li, B.; Jiao, B. Aquaculture Industry in China: Current State, Challenges, and Outlook. *Rev. Fish. Sci.* **2011**, *19*, 187–200. [CrossRef]
50. Cavallo, M.; Raux, P.; Massa, F.; Fezzardi, D.; Pérez Agúndez, J.A. Why Not? Decrypting Social Attitudes toward European Aquaculture: An Updated Policy Perspective for an Old Problem. *Integr. Environ. Assess. Manag.* **2023**, *19*, 896–909. [CrossRef]
51. Kritzer, J.P.; Tang, Y.; Chen, Y.; Costello, C.; Gaichas, S.; Nies, T.; Peñas, E.; Sainsbury, K.; Shen, C.; Szuwalski, C.; et al. Advancing Multispecies Fishery Management in China: Lessons from International Experience. *Aquac. Fish.* **2023**, *8*, 351–362. [CrossRef]
52. Battista, W.; Tourgee, A.; Wu, C.; Fujita, R. How to Achieve Conservation Outcomes at Scale: An Evaluation of Scaling Principles. *Front. Mar. Sci.* **2017**, *3*, 278. [CrossRef]
53. Ministry of Agriculture of the People's Republic of China.. *The Thirteenth Five-Year Plan for National Fisheries Development (2016–2020)*; Ministry of Agriculture of the People's Republic of China: Beijing, China, 2017.

54. Ministry of Agriculture and Rural Affairs of the People's Republic of China. *The 14th Five-Year Plan for National Fisheries Development*; Ministry of Agriculture and Rural Affairs of the People's Republic of China: Beijing, China, 2022.
55. Wang, P.; Ji, J.; Zhang, Y. Aquaculture extension system in China: Development, challenges, and prospects. *Aquac. Rep.* **2020**, *17*, 100339. [CrossRef]
56. Yue, D.D.; Han, G.; Kong, W.L.; Li, M.L.; Fang, H. Research on the development strategy for fisheries science and technology innovation alliance in China. *J. Ocean. Univ. China (Soc. Sci.)* **2016**, *3*, 20–25.
57. Yang, J.W. New features and new countermeasures of current fishery technology extension. *Shandong Ind. Tech.* **2019**, *1*, 233.
58. Jing, Q.; Wang, Z.; Huang, B.; Guan, C.; Jia, Y. Development of the different aquaculture models for marine fishes. *Open J. Fish. Res.* **2018**, *5*, 37–44. [CrossRef]
59. Gui, J.F.; Tang, Q.; Li, Z.; Liu, J.; De Silva, S.S. (Eds.) *Aquaculture in China: Success Stories and Modern Trends*; John Wiley & Sons: Hoboken, NJ, USA, 2018.
60. Han, D.; Shan, X.; Zhang, W.; Chen, Y.; Wang, Q.; Li, Z.; Zhang, G.; Xu, P.; Li, J.; Xie, S.; et al. A Revisit to Fishmeal Usage and Associated Consequences in Chinese Aquaculture. *Rev. Aquac.* **2018**, *10*, 493–507. [CrossRef]
61. Maulu, S.; Hasimuna, O.J.; Haambiya, L.H.; Monde, C.; Musuka, C.G.; Makorwa, T.H.; Munganga, B.P.; Phiri, K.J.; Nsekanabo, J.D. Climate Change Effects on Aquaculture Production: Sustainability Implications, Mitigation, and Adaptations. *Front. Sustain. Food Syst.* **2021**, *5*, 609097. [CrossRef]
62. Subasinghe, R.P.; Phillips, M.J. Small-scale aquaculture: Organization, clusters and business. *FAO Aquac. Newsl.* **2010**, *45*, 37–39.